Optimising decision support

The optimisation of emergency responses is fundamental when time and resources are limited. Here, **Professor Eva Lee** explains how her career in mathematics has given her the tools and knowhow to develop decision support systems that respond rapidly in times of disaster

Could you outline your principle motivations for the pursuit of industrial and systems engineering R&D?

I think it is in my blood. All my degrees are in mathematics. I have a strong theoretical background, and I have always been drawn to the application of theory. For my undergraduate degree I did a thesis on inventory control for power plants; and for my PhD thesis, I focused on the mathematics related to routing and transportation for an oil company. There is always motivation to apply the mathematics to real problems. For emergency response, it is definitely interesting to analyse and model all the inherent complexities, but it is most important that the work can be used on the ground in real situations.

What is the overarching goal of your project?

The principle aim is to be able to develop a knowledge-based information decision support software tool that can be used by emergency response planners to optimise overall system performance so that they can quickly and efficiently manage scarce resources during an emergency. The time to respond and the decisions made as an event unfolds can make the difference between life and death, so having a tool that can guide you to make smart decisions quickly is a huge asset.

How do you obtain quantitative data and which variables do you consider?

We have humans as one variable, decisions as another. Time is a dimension that we have to consider in terms of its constraints. These are all critical variables and parameters in the system base, which can influence decision and policy makers regarding the best use of resources. We also have to understand the risk/benefit trade-off. Understanding the limitations, whilst maximising the results and benefits is a critical objective.

Could you briefly comment on the global impact of your technology?

Our system was used in Haiti for planning the distribution of medical supplies and food. It was also used in Tanzania, where healthcare workers used the system to optimise the clinical operation and to more efficiently use scarce resources to meet healthcare needs. People would wait 7 hours before they were registered or able to see a doctor, now they wait for an hour. Using our technology, the entire workflow of the hospital team was optimised. And the doctors loved the technology. These local users help to make the system known to a much broader audience, which makes me really happy.

Is the technology affordable to those that need it most?

I negotiated with the university to give out the system for free for public health, emergency response usage. If one were to charge market value, it would be too expensive for cash-strapped public health and emergency departments. This is important to me because I want it to be used by the people who need it and for the benefit of society.

What has been your greatest challenge so far?

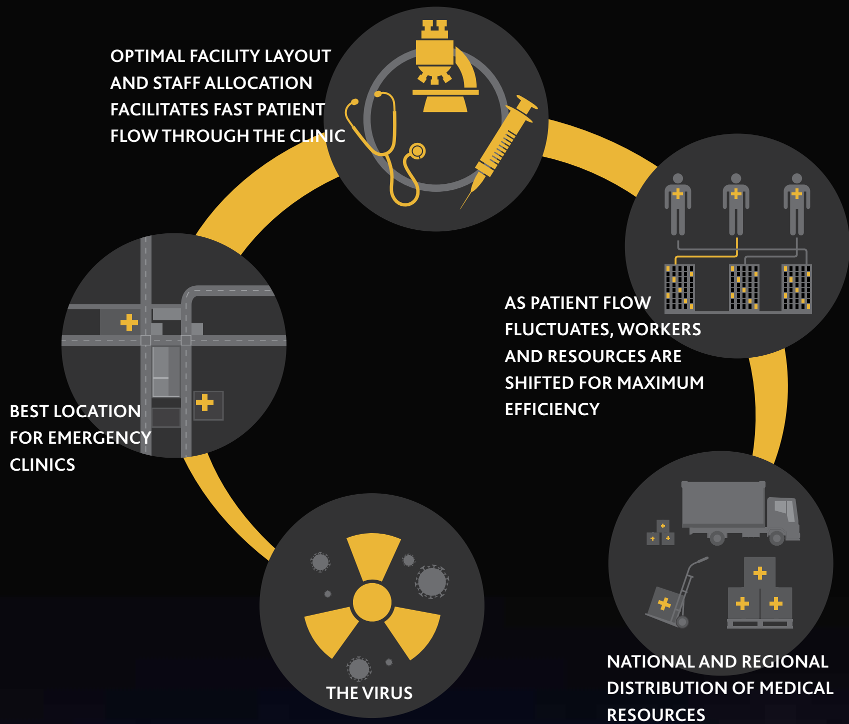
There was so much we had to learn about the limitations on the ground. Additionally, now that we have a system, the challenge is making others willing to use it. It is sometimes difficult

to convey to people that we are not trying to replace them, but trying to make operations more efficient and enable them to make better decisions. We design and provide technology that can optimise complex decisions.

When we first started in 2004 the system was tested locally; there was a full-scale anthrax prophylactic dispensing event intended to gain an understanding of the challenges for giving out antibiotics to all citizens in an affected area. Eight counties participated and each made their own plans about how to satisfy local demands. One site's emergency response director used our system to help him make key resource and operations decisions. It took seconds for the system to come back with all the requirements. This site ended up being the only one that succeeded in satisfying the expectations set forth by the CDC, plus their throughput was 50 per cent higher than the second-placed system and they used the least number of personnel, with best operations.

Mitigating disaster

Scientists from the **Georgia Institute of Technology** have developed a world class real-time optimisation decision support system for emergency scenarios, an innovation that could revolutionise the way communities respond and services react in time of disaster



EMERGENCY RESPONSE CAPABILITY and medical preparedness are necessary features of any community or nation. In a world with an ever expanding populous, the number of those affected by natural disasters, terrorist attacks, as well as biological or chemical incidents continues to rise. Easing pressure on resources, optimisation of response capability and preparedness are features of paramount importance.

Recent times have seen favourable adoption of nuclear power as an alternative energy source. However, as past nuclear accidents such as Chernobyl, Three Mile Island and, more recently, the Fukushima Daiichi nuclear plant in Japan have shown, the consequences of nuclear disasters can be devastating. Indeed, limited human and material resources, as well as inevitable time limitations are significant challenges when responding to such an emergency. However, its emergency response planning is a highly complex task. In addition to the difficult shorter-term concerns of treating the injured, providing temporary shelters and distributing essential supplies, such events also necessitate the long-term assessment of the population's health, local radiation levels and tracking displaced citizens. More problematically, such disasters invariably involve large populations. It is for these reasons that a team from Georgia Institute of Technology, led by Professor Eva Lee, focuses its research efforts into developing a system for the optimisation of public health emergency and response infrastructure.

THE PROJECT

The group's focus over the past two years has been on the aftermath of the Fukushima Daiichi nuclear disaster. Following the Tohoku earthquake and tsunami on 11 March 2011, the Fukushima nuclear power plant suffered a series of failures which resulted in the greatest nuclear disaster since Chernobyl in 1986. The enormity and singularity of the emergency operations which took place have offered the team a prime opportunity for data collection and analysis. First-hand accounts and in-depth analysis in Fukushima's wake have provided a wealth of knowledge and real-life data pertaining to radiological emergency response.

Using the information it has accrued through collaborative research in Japan, the team's next step is to leverage this knowledge on to a large-scale, prophylactic system. More specifically, Lee's team aims to establish a knowledge data bank for radiological response, which will include emergency data collection and resource assessment. Having completed time-motion studies and analysis of the Japanese operations and communication strategies following the disaster, the team will produce a detailed first-hand understanding of successful strategies.

THE 2011 TOHOKU DISASTER resulted in 15,880 deaths, 6,142 injured and 2,694 missing, with an estimated recovery cost of ¥ 19-25 trillion (US $200-270 billion). For the first two months, the US provided 12,400 service members, 189 aircraft and 24 naval ships at a total cost of nearly $90 million. Fukushima Daiichi directly affected hundreds of thousands of residents. Teams of scientists from around the world converged to the area and offered multi-faceted rescue and recovery missions, and research. As evidence, a degree of urgency prevailed and many scientific projects involving international collaborations were launched to gain an understanding of the chain of events and how to better prepare and recover from future disasters.

Furthermore, subsequent data from the impressively extensive screening and registration process of the entire affected population will throw light upon the more long-term effects of the Fukushima disaster.

The plans do not stop there. Further to the initial data compilation and publication, the information will be incorporated into a real-time simulator and decision support system. This system is designed to facilitate the planning and assessment of future operations performance, against pre-disaster preparedness.

WORKING WITH JAPAN

Importantly, the team travelled to Japan to begin observation soon after the disaster. In addition to the basic data collection and observation work, they conducted a number of intimate interviews at local Fukushima sites. This exemplary work ethic was made possible through collaboration with local Japanese academics, most notably Dr Atsuo Suzuki from Nanzan University. The partnership was hugely successful due to the organisation and speed with which both parties worked. Better still, the researchers had better access to several otherwise inaccessible sites and were able to conduct coherent studies through close interaction with local people.

Lee was able to communicate with individuals directly on a wealth of subject matter, from medical conditions to the types of emergency response they had experienced. In some instances, fundamental lapses in local knowledge were identified; one person, who had worked in the nuclear plant, explained that she had no knowledge of how to respond in the disaster scenario. Some had suffered radiation burns and rashes from unwittingly touching contaminated items, while others were far better equipped to deal with emergency responses. By adopting this human-centred approach the team became highly successful in certain aspects of data collection, from first-hand evidence to a profile of individuals' mental and personal response.

PRE-DISASTER PREPAREDNESS

The system allows provisions to be put in place for pre-disaster preparedness and on-the-ground response in many different scenarios. Indeed, the system currently has more than 7,000 user sites in the sphere of US public health to allocate resources.

By contrast, groups that do not have such a system for optimisation can run at as little as 10 per cent efficiency, compared to those that have access to the technology. Without it even decisions that seem simple are not often well made; knowing, for example, how many people to assign to each task is a difficult problem, mathematically speaking. Furthermore, each person in a team has different skills, so how to most efficiently and successfully assign people to certain tasks is made more complex still. Fortunately, all these considerations are taken into account by the new automated preplanning system. It allows people within the emergency site to plan more efficiently for any pandemic, attack or disaster; and helps smaller-scale hospital environments maximise their potential and efficiency. The system can also assist training, through facilitating understanding in a wealth of different scenarios in a short space of time. This represents the first system to work with people first hand and the first specifically designed for use in emergencies.

HUGE RELEVANCE

The technology has the ability to benefit a hugely varied range of sectors and fields. One excellent example of such technological success has been in the treatment of prostate cancer. Lee designed a complex planning system that helped change the way of operating on patients, while assisting the planning in real-time and improving overall results.

Another scenario in which the system could prove effective is in pandemic situations, where it can optimise responses – particularly in dispensing vaccinations, to ensure that fewer people become infected. In the same vein, the system could prove invaluable in terms of security. Consider military personnel overseas, who could be exposed to various kinds of pandemics in foreign territories; here, a similarly swift emergency response would be necessary. The same principle and technology applies to the potential for a biological attack. Thus, the team has used the system for planning responses to anthrax and biological events, and H1N1 mass vaccination where the consequences could be catastrophically widespread.

While it is certainly the case that many of the decision variables for several emergency scenarios are widely interrelated, this technology for optimising responses is certainly applicable not only to one purpose. As Lee concludes: "It has multi-purpose applicability for pandemics, natural disasters, healthcare resources and operations, homeland security and industry". The list is endless.

INTELLIGENCE

POPULATION PROTECTION AND MONITORING IN RESPONSE TO RADIOLOGICAL INCIDENTS

OBJECTIVES

To design and advance information – decision support system for population protection and emergency response; Establish a national knowledge databank for radiological response

To collect on-the-ground response and health monitoring data via time-motion study, process observation, and direct interviews; Provide advice and technology for effective and efficient screening and decontamination

KEY COLLABORATORS

Ferdinand H Pietz, Strategic National Stockpile, Centers for Disease Control and Prevention

Greg Burel, Strategic National Stockpile, Centers for Disease Control and Prevention

Bernard Benecke, Global Disease Detection and Emergency Response, Centers for Disease Control and Prevention

Atsuo Suzuki, PhD, Nanzan University

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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 a Professor at the School of Industrial and Systems Engineering at 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.

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