Inside Story

O.R.'s Do-Gooders

— Peter Horner, editor
horner@lionhrtpub.com

Last fall, I interviewed then-INFORMS President-Elect Cynthia Barnhart at the INFORMS Annual Meeting in Seattle where she indicated her theme for her presidency would be "doing good with good O.R." (see December 2007 *OR/MS Today*). Barnhart, however, was concerned that the next potential generation of operations researchers — young people now in college, high school or grade school — wanted to "do something good for the world," yet they couldn't connect their dream with the quintessential tool of the O.R. profession: mathematical modeling.

"It's amazing how much exciting O.R. work is going on," Barnhart said in the interview, referring to the "doing good" theme. This issue of *OR/MS Today* offers several cases in point.

During that same Seattle conference, I attended a tutorial entitled "Community-Based Operations Research" in which Michael Johnson and Karen Smilowitz outlined an emerging subfield of O.R. that focuses on community problems such as poverty and homelessness; they made a convincing argument why the O.R. community should get involved. As Johnson and Smilowitz point out, when 36.5 million Americans live in poverty and 12.6 million don't have enough food, something needs to be done. Enter O.R.

Ah ha, I thought, that sounds a lot like "doing good with good O.R." I asked Smilowitz if she and Johnson would contribute an article to *O.R. Today* based on their Seattle presentation. "We believe that O.R. models and analytic methods, especially those associated with community-based operations research, can significantly improve the quality of life of families and communities facing a wide variety of challenging and localized social problems," Johnson and Smilowitz write in "Community-Based Operations Research" (page 22). And so begins the first in a series of "doing good" stories in this issue.

When it comes to "doing good with good O.R.," does anyone do a better job than Eva Lee, the Georgia Tech dynamo who seemingly produces more positive energy than Georgia Power? Beginning on page 28, Lee gives readers a peek at some of her work in conjunction with the Centers for Disease Control and Prevention and the Center of Operations Research in Medicine and HealthCare at Georgia Tech in developing a decision support system that aids in large-scale dispensing of critical medical countermeasures (vaccines, drugs and therapeutics) in the event of biological or infectious disease outbreaks. Lee, a key member of the Sloan-Kettering Cancer Center team that won last year's Franz Edelman Competition might just be the poster person for "doing good with good O.R."

Next, Doug Samuelson sheds some light on the largely overlooked role O.R. analysts have played over the past 30 years by using statistical and data analysis to help monitor and prevent human rights abuse around the world. The topic serves as the subject of a new book, "Statistical Methods for Human Rights," which Samuelson reviews. "These analysts have quite literally affected the entire human race on a global scale," Samuelson writes in "Analysts Promote Human Rights" (page 36).

It is perhaps fitting that this "do-good" issue marks the 20th anniversary of the first issue of *OR/MS Today* published under the auspices of Lionheart Publishing. All of us at Lionheart, starting with President John Llewellyn, look forward to "doing more good" with *OR/MS Today* — today, tomorrow and well into the future.

A range of potential calamities – from a bioterrorist attack to a naturally occurring pandemic –

demands fast, efficient, large-scale dispensing of critical medical countermeasures.

In Case of Emergency

A Catastrophic health event, such as a terrorist attack with a biological agent, a naturally occurring pandemic, or a calamitous meteorological or geological event, could cause tens or hundreds of thousands of casualties, weaken the economy, damage public morale and confidence, and threaten national security. It is therefore important to establish a strategic vision that will enable a level of public health and medical preparedness sufficient to address a range of possible disasters. Although present public health and medical preparedness plans incorporate the concept of "surging" existing medical and public health capabilities in response to an event that threatens a large number of lives, the assumption that conventional public health and medical systems can function effectively in catastrophic health events has, however, proven to be incorrect in real-world situations. Therefore, it is necessary to transform the national approach to health care in the context of a catastrophic health event in order to enable public health and medical systems to respond effectively to a broad range of incidents.

By Eva K. Lee

Public Health

In the context of a catastrophic health event, several layers of medical capabilities become critical. These include the distribution of prophylactic medication to protect the general population; the capabilities to quickly identify and treat infected individuals over a potentially prolonged period of time; and the ability to monitor population health as the region recovers from the health catastrophe.

Rapid distribution of medical countermeasures (vaccines, drugs and therapeutics) to a large population requires significant resources within individual communities. Few, if any, cities are presently able to meet the objective of dispensing countermeasures to their entire population within 48 hours after the decision to do so. State and local government authorities must create the appropriate framework and policies to distribute and share information on best practices and mechanisms to address the logistical challenges associated with this requirement. Further, the federal government must create effective templates for countermeasure distribution and dispensing that state and local government authorities can use to build their own capabilities.

The Strategic National Stockpile (SNS) is available to help agencies respond to public health threats that can be mitigated or eliminated by treating the affected population with antibiotics or vaccines contained in the SNS. It is critical that distribution of countermeasures from the federal government to the states be done effectively and efficiently. Further, public health agencies must develop plans to ensure that they can quickly receive the countermeasures, and dispense SNS prophylaxis and vaccines to the broad regional population.

Mass Dispensing

O.R. EXPERTS Arnold Barnett, Margaret Brandeau, Richard Larson, Ed Kaplan, Larry Wein and others have investigated various preparedness issues and emergency strategies. In mass dispensing, Kaplan et al. [1] argued that immediate mass vaccination after a smallpox bioterrorist attack would result in fewer deaths and faster eradication of the potential epidemic; and Wein et al. [2] concluded that immediate and aggressive dispersion of oral antibiotics and the full use of available resources (local non-emergency care workers, federal and military resources, nationwide medical volunteers) are extremely important.

Working with researchers at the Centers for Disease Control and Prevention (CDC) and state public health agencies since 2002, Georgia Tech (GT) researchers from the Center of Operations Research in Medicine and HealthCare have developed a decision support system that aids in large-scale dispensing and emergency response strategic and operational planning in the event of biological and infectious disease outbreaks. Through the design and integration of efficient optimization technology and large-scale simulation, their system, known as RealOpt©, allows public-health administrators to investigate the distribution of countermeasures from the federal agency to the affected states; and to investigate locations for dispensing facility setup, clinic design and optimal staffing. The system has been used successfully in planning for biodefense (e.g., anthrax, smallpox) and pandemic response drills in various locations in the United States since 2005. Because of its rapid speed, it facilitates analysis of "what-if" scenarios, and serves not only as a decision tool for operational planning, but also allows for dynamic, on-the-fly reconfigurations as an emergency event unfolds. In addition, it supports performing "virtual field exercises," offering insight into operations flow and bottlenecks when mass dispensing is required [3, 4, 5, 6].

Point-of-Dispensing

CDC and public health administrators work closely with one another to prepare for and document the steps required to administer medication in the event that mass dispensing is needed. The goal and objectives of a dispensing facility, point-of-dispensing (POD), are to deliver appropriate emergency services (e.g. vaccine, medical service, and education/training) to high-risk populations in an orderly, expeditious and safe manner. Within the POD facility, the tasks and objectives include:

1) assess health status of clients,
2) assess eligibility of clients to receive service,
3) assess implications of each case and refer case for further investigation if necessary,
4) counsel clients regarding service and associated risks,
5) administer service,
6) educate regarding adverse events,
7) document services,
8) monitor vaccine/medical prophylaxis take rates,
9) monitor adverse reactions, and
10) monitor development of disease.

The key to mass dispensing is to service the at-risk general population efficiently and effectively under time pressure. In an anthrax attack, citizens must receive antibiotic prophylaxis within 48 hours of the determination that an attack has occurred, as the mortality rate for persons demonstrating symptoms of inhalation anthrax is extremely high. Thus, it is recognized that multiple dispensing modalities must be employed in order to serve the entire regional population. In some instances, it is unreasonable to expect residents to travel to a designated POD facility. For example, nursing homes, assisted living facilities, homeless shelters, hospitals and prisons house many residents. In such cases, it would be more efficient to set up a closed POD inside these locations for dispensing, or to have medication dispensed by a mobile POD facility near the site. Airports and hotels, where a large number of non-resident travelers can be found, are also candidates for setting up on-site PODs to service specific vulnerable populations. Universities can use their own health facilities (and if necessary, additional mobile on-campus PODs provided by the state) to prophylax on-campus students, staff and faculty.

Clearly, if large employers and medical facilities prophylax their own employees, families, and patients, it will eliminate a high percentage of the population (may be as high as 40 percent in some large cities) from visiting public PODs, thus reducing the burden on those facilities. The federal/state/local resources required for a successful mass dispensing response can overwhelm the existing capacity of public health and medical sectors; thus business engagement and participation in this process is of paramount importance.

Public PODs are open facilities that are setup to serve the general public.

In the literature [3, 4, 5, 6], public PODs have generally been described as being setup inside existing facilities, with areas set aside for various activities in the dispensing process, including assembly/intake, triage, orientation, registration, screening, service, education and discharge. Public PODs can be mobile or stationary, and in the latter case, they can be set up as facility-based or drive-through.

A facility-based POD operates within a physical location, such as a building, warehouse, open field or large parking lot. Citizens are asked to arrive at the POD location and then walk through the POD to receive their medication or other treatment. Facility-based PODs may be scaled to operate within a setting as large as a professional sports stadium or as small as a volunteer firehouse within a rural community.

Due to the density of patients that would exist within a facility-based POD, this configuration will likely be utilized for events where further transmission of the disease will not occur through personal interaction (e.g., an anthrax attack). In cases where dispensing strategies intend to counteract the spread of infections diseases and where the infectious rate can be high — such as influenza or viral hemorrhagic fevers — facility-based PODs would likely not be utilized in favor of other configurations that limit personal interaction.

In a drive-through dispensing format, citizens are asked to drive to POD sites and remain in their vehicles throughout the dispensing process. Similar to a facility-based format, the scale of drive-through PODs can vary based upon operational scope and the physical locations available for dispensing. Locations utilized for this configuration may include freeways and arterial highways, large parking areas, tollbooths, large fields and fairgrounds. Drive-through PODs are preferred for events involving highly communicable diseases and, in some cases, for operations requiring medication injections.

The scale and complexity of dispensing varies depending on the medical prophylaxis to be distributed. While the U.S. federal government has stockpiled smallpox vaccines for the entire population, and antibiotics for anthrax prophylaxis is available to every citizen, countermeasures for certain events, such as pandemic influenza, may be available on a limited basis due to the constraints associated with manufacturing the vaccines specific to the disease itself. Mass dispensing, therefore, would likely occur in "waves" over a multiple week or month timeframe as vaccine can be cultivated and made available to public health officials. In this case, rationing of vaccines would likely be made based upon community need and clinical risk factors. For example, healthcare workers and public safety officials may receive initial doses of vaccines. This would then be followed by the communities/populations most likely to receive the greatest harm from the disease (e.g., young children, the elderly, the infirmed, indigent persons). A strategy for designing a cost-effective and efficient (with minimal casualty) rationing scheme that is socially acceptable is challenging, yet very critical.

Working with CDC, Georgia Tech researchers (Lee and her research team) developed a decision-support that aids in emergency response planning in the event of biological or infectious disease outbreaks. *Photo courtesy of the Centers for Disease Control and Prevention*

RealOpt

Mass dispensing requires the rapid establishment of a network of PODs and health facilities that are flexible, scalable and sustainable for medical prophylaxis and treatment of the general population. Optimizing throughput under limited resources remains a daunting task for efficient POD operations. The benchmark and analysis performed by CDC researchers [7] proved that a computerized planning system is invaluable as it offers insight into the practicality of POD operations during emergency situations. Further, the system must be fast enough to allow for analysis of "what-if" scenarios to facilitate strategic and operational planning, as well as dynamic analysis and reconfiguration as the event unfolds.

The design of RealOpt, a tool for emergency operational and strategic planning, addresses directly some of the computational bottlenecks of commercial software. RealOpt offers public health emergency coordinators the capability to:

- design customized and efficient POD floor plans for regional needs via an automatic graph-drawing tool. Users can design and compare various floor plans to determine the tradeoffs in personnel usage as well as operations efficiency.

- determine optimal labor resources required and provide the most-efficient placement of staff at individual stations within the POD. The resulting staffing plans maximize the number of individuals who can be treated, minimize the average time patients spend in the clinic, and equalize utilization across clinic stations.

- perform disease propagation analysis, understand and monitor the intra-POD disease dilemma, and help to derive dynamic response strategies to mitigate casualties.

- assess current resources and determine minimum needs to prepare for readiness in emergency situations for their regional population.

- carry out large-scale virtual drills and performance analysis, and investigate alternative strategies.

- train personnel, design emergency exercises with a variety of dispensing scenarios. Such training exercises could be used to quickly get new emergency preparedness planners up to speed and to keep existing planners sharp.

Figure 1: Infrastructure of RealOpt, a tool for emergency operational and strategic planning.
Diagram courtesy of the Georgia Tech Center of Operations Research in Medicine and HealthCare

RealOpt allows users to input stochastic service distributions. This input can be obtained via role-play, measurements taken from clinical operations or estimates from time-motion studies during emergency drills. Further, RealOpt-netPOD© extends the operational planning capabilities of RealOpt to include regional dispensing design, allowing users to determine optimal dispensing locations and the optimal combination of dispensing modalities. It also provides features to perform economic model analysis on multi-modality variations for optimal and cost-effective regional response strategies.

Other issues we are investigating include:

1) Efficient and secure medication supply and re-supply processes. Following the initial delivery of medication from the federal level to the state Receive, Stage, Store sites, and eventual distribution to PODs for dispensing, it is critical for the POD staff and leadership to closely and accurately monitor supply levels in conjunction with burn rates to determine optimal re-supply levels. POD leadership will notify district leadership of the need for additional supplies and that request will escalate through appropriate channels for fulfillment.

2) Large-scale transportation and logistics issues. This involves the routing of personnel and volunteers to the respective working sites, routing of individuals to various dispensing sites, and the associated security analysis and personnel resources needed.

3) Mass casualty care. Treatment and medical care of individuals already infected poses another challenge. It is conceivable that the structure and operating principles of our day-to-day public health and medical systems cannot meet the needs created by a catastrophic health event. RealOpt can allow for re-staffing and re-orientation of existing health resources to adapt to medical needs during the catastrophic events. Further, intra-clinic disease propagation is a potential problem, and has to be tackled. In addition to the potential infection due to the biological agents or infectious disease, secondary infection, which commonly occurs in medical facilities, also needs to be addressed. Strategic and operational changes for monitoring and mitigating disease propagation and mass casualties are imperative.

Establishment of a robust, flexible and dynamic public health emergency capability requires careful strategic and operational systems design and planning. Moreover, it is important to coordinate collaborative planning and response efforts across the public health and private sectors, and federal/state/local government agencies. Issues involving security, sociology, psychology and public policy should also be investigated.

Emergency Drills, Time-Motion Studies, Post-Event Analyses

RealOpt was first disseminated in 2004, and currently has several hundred users among emergency preparedness planners. In 2005, the planning and resource estimation capability of RealOpt was tested and validated through an eight-county anthrax emergency drill in Georgia. Each county was responsible for its own planning and execution of the drill, with only one county, DeKalb, allowed to use RealOpt to determine POD layout and staffing needs. All together, this exercise involved between 600 and 700 public-health workers.

There was an immediate debriefing after the exercise at each site, and a follow-up meeting among all participating counties via teleconference. Debriefing was a mandated process involving discussion of POD layout, and analysis of processes, which external evaluators (independent of each county) observed and recorded. DeKalb achieved the highest throughput among all counties. Specifically, DeKalb was the only county that achieved above target throughput; it processed 50 percent more individuals compared to the second-place county (which processed about 71 percent of the targeted throughput). The external evaluators commented that DeKalb produced the most efficient floor plan (with no path crossing), the most cost-effective dispensing (lowest labor/throughput ratio) and the smoothest operations (shortest average wait time, average queue length, equalized utilization rate). The study proves that even without historical data, using our system, one can plan wisely and obtain good estimates of required labor resources.

In 2006 and 2007, working with multiple counties, districts, state and local public health emergency coordinators, we analyzed in detail the design of a cost-effective mass dispensing network for a metropolitan region comprised of multiple districts and with several million citizens. The study, reported in Lee et al. 2008 [6], illustrates the tradeoffs in the number of facilities needed versus the ease of accessibility to the PODs by the citizens. It demonstrates the importance of multi-modality dispensing to serve the entire regional population (both for operational efficiency and for optimal staff utilization). Further the study reveals that: 1) the sharing of labor resources across counties and districts is important; 2) the most cost-effective dispensing plan across a region consists of a combination of drive-through, walk-through and on-the-site PODs, each operating at a throughput rate depending on the population density, facility type and labor availability, and the optimal modality combination changes accordingly to the various facility capacity restrictions; 3) an increase in the number of PODs in operation does not necessarily increase the number of core public health personnel needed. Further, reduction in capacity (thus hourly throughput) eases the crowd control tasks of law enforcement personnel and helps to minimize potential problems inside POD operations.

This multiple-site analysis was followed by an associated anthrax drill in Atlanta in October 2007. This latter drill marked the first time that business volunteers were involved in the mass dispensing activities. Their involvement will prove to be a critical step in an actual emergency as regional large-scale dispensing requires manpower and collaborative assistance that is beyond the sole execution of the public health sector. In the two sites evaluated by the GT team, we observed promising business assistance with the POD operations.

The GT team has also participated in time-motion studies in anthrax and pandemic drills around the nation. Over the years, we observed a more consistent trend in the POD layout design, indicating perhaps a sharing of strategies among planners from different locales. Nevertheless, some operations (e.g., express lanes, pediatric lanes, complicated lanes) are still being tested and evaluated for potential gain in efficiency and staff usage. The design of POD layouts continues to evolve towards the more condensed and efficient form, where emergency managers look for various tasks in which volunteers can be used to supplement the scarcity of critical public health personnel. For each drill site, the POD floor plan, the resulting time-motion study measurements and the associated probability distribution estimates are input into RealOpt and distributed nationwide as a national knowledge databank and repository for emergency planning.

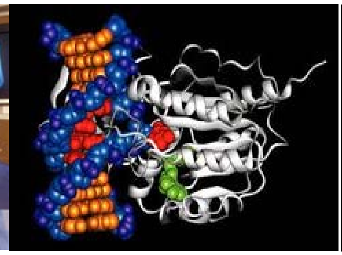
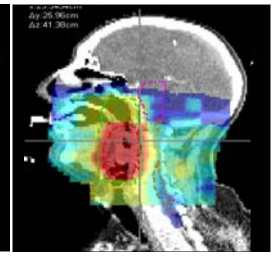
Besides anthrax and smallpox drills, RealOpt was also used by New Orleans for their October 2007 mass vaccination drill in which the community received free flu shots as their emergency team tested their capabilities of running a POD. The local team used RealOpt in the clinic design and in determination of optimal staffing. RealOpt was able to correctly predict bottlenecks for the planners, and the throughput numbers returned by the system were fairly close to the actual numbers (these individuals actually received flu shots). This further validates the importance of such a planning system.

The type of disaster being confronted (e.g., biological attack, infectious-disease outbreak or natural disaster) will influence the choice of dispensing strategy, clinic types, locations and dispensing modalities. Depending on the strategy selected, backup plans will be different, and the level of security and military personnel, as well as the number of health-care workers required, will vary. The key point is that flexibility — both of staff to be able to perform a number of different duties, and of facility to be readily reconfigured on-the-fly — is needed to respond to dynamic changes.

We expect that a feasible approach would be to set up a dispensing center based on the best estimates and analysis available, and then be prepared to reconfigure it while it operates.

A catastrophic man-made or natural disaster can destabilize critical infrastructure, impede sanitation services, and cripple healthcare delivery systems. While it is not possible to prevent all casualties in catastrophic events, strategic and operational improvements in our federal, state and local planning can prepare our nation to deliver appropriate care to the largest possible number of people, lessen the impact on limited health care resources, and support the continuity of society and government. This would include collaborative responses in all levels of business and government to pandemic disease, catastrophic natural disasters and other large-scale public health emergencies. **IORMS**

Center for Operations Research in Medicine and HealthCare



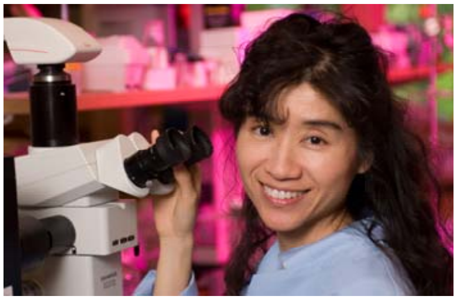
The Center for Operations Research in Medicine and HealthCare, founded in 1999 with partial support from the National Science Foundation and the Whitaker Foundation, is a collaborative education and research center established between the School of Industrial and Systems Engineering at Georgia Institute of Technology and medical and healthcare researchers in different disciplines. The Center's mission is to foster interdisciplinary education and research efforts involving the development and application of sophisticated techniques from the field of operations research to problems in medicine and healthcare.

The collaborative research program of operations research in medicine and healthcare at Georgia Tech is the first-of-its-kind among the operations research community. Students and faculty in the center work closely with medical researchers and healthcare practitioners on each research project. The Center is also part of the Health Systems Institute at Georgia Institute of Technology.

Focusing on health systems and biomedicine, researchers in the center tackle challenges through systems modeling, algorithms and software design, and decision theory analysis to advance various domains within healthcare. Specific research areas include disease diagnosis and prediction, optimal treatment strategies and drug delivery, healthcare outcome analysis and treatment prediction, public health and medical preparedness, large-scale healthcare/medical decision analysis, quality improvement and logistics operations management.

More information regarding the research and educational program of this center can be found at http://www.isye.gatech.edu/medicalor.

About the Author



Eva K. Lee is an associate professor in the H. Milton Stewart School of Industrial and Systems Engineering at Georgia Institute of Technology and director of the Center for Operations Research in Medicine and HealthCare. She is also a senior research professor at the Atlanta VA Medical Center. Since she was a child, she has had intense love and fascination towards mathematics and medicine. Upon graduation from the Department of Computational and Applied Mathematics at Rice University in 1993, she began venturing into biomedicine and healthcare areas. She has since received seven patents on innovative medical systems and devices, and was the first and only OR/IE recipient for the prestigious Whitaker Foundation Biomedical Grant for Young Investigators, awarded for her work on a novel approach for combining biological imaging and optimal treatment design for prostate cancer. In 2005, she received the INFORMS Pierskalla Award for research excellence in HealthCare and Management Science for her work on emergency response and planning, large-scale prophylaxis dispensing, and resource allocation for bioterrorism and infectious disease outbreaks. Together with Dr. Marco Zaider from Memorial Sloan-Kettering Cancer Center, they were named winners of the 2007 Franz Edelman award for their work on cancer therapeutics.

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References

1. Kaplan, E. H., D. L. Craft, L. M. Wein, 2002, "Emergency response to a smallpox attack: The case for mass vaccination," *Proc. National Acad. Sci.,* Vol. 99, No. 16, pp. 10935-10940.
2. Wein, L. M., D. L. Craft, E. H. Kaplan, 2003, "Emergency response to an anthrax attack," *Proc. National Acad. Sci.,* Vol. 100, No. 7, pp. 4346-4351.
3. Lee, E. K., S. Maheshwary, J. Mason, 2005, "Real-time staff allocation for emergency treatment response of biologic threats and infectious disease outbreak," 2005 INFORMS William Pierskalla Best Paper Award on research excellence in HealthCare and Management Science, Nov 2005.
4. Lee, E. K., S. Maheshwary, J. Mason, W. Glisson, 2006a, "Large-scale dispensing for emergency response to bioterrorism and infectious disease outbreak," *Interfaces,* Vol. 36, No. 6, pp. 591-607.
5. Lee, E. K., S. Maheshwary, J. Mason, W. Glisson, 2006b, "Decision support system for mass dispensing of medications for infectious disease outbreaks and bioterrorist attacks," *Ann. Oper. Res, Computing and Optimization in Medicine and Life Sciences,* 148 25-53.
6. Lee, E.K., H.K. Smalley, Y. Zhang, F. Pietz, B. Benecke, 2008, "Facility location and multi-modality mass dispensing strategies and emergency response for biodefense and infectious disease outbreaks," *International Journal on Risk Assessment and Management.* To appear.
7. Mason, J., M. Washington, 2003, "Optimizing staff allocation in large-scale dispensing centers," CDC report.