Introduction to the Special Issue on Humanitarian Applications: Doing Good with Good OR

Özlem Ergun, Pinar Keskinocak, Julie Swann
Georgia Institute of Technology, Atlanta, Georgia 30332
{oergun@isye.gatech.edu, pinar@isye.gatech.edu, jswann@isye.gatech.edu}

Keywords: humanitarian; disaster preparedness; societal impact; public sector.

Humanitarian applications include research that is primarily directed toward promoting human welfare. For example, humanity’s top 10 problems over the next 50 years have been outlined as the following: energy, water, food, environment, poverty, terrorism, disease, education, democracy, and population. Likewise, research focused on planning and responding to disasters can have an immediate impact on reducing loss of life, easing suffering, and advancing human dignity, all of which are goals of humanitarian applications.

When we look back to 2010, we see that millions of people were affected by devastating disasters; the earthquakes in Haiti and Chile, the floods in Pakistan, and the volcano eruption and tsunami in Indonesia are just a few examples. Unfortunately 2011 was not kinder to our planet and its people; the devastating triple disaster (earthquake, followed by tsunami, followed by a nuclear emergency) that occurred in Japan in early March affected thousands of people and significantly damaged the infrastructure. Although we wish that these disasters were rare events, looking at history unfortunately indicates otherwise. Thousands of disasters occurred over the past couple of decades, affecting millions of people, claiming lives, damaging infrastructure, and changing social and economic conditions. The impact of disasters on the economy is also significant, as we have seen with the Kobe earthquake, Hurricane Katrina, and many other catastrophes. Our planet is likely to face even more and stronger natural disasters as we move into the future. They will impact more and more people, in part because of the increasing presence of high-density population centers in vulnerable areas. Research to improve response to disasters thus can have a real and immediate impact.

The ongoing humanitarian crises in many parts of the world contribute to the loss of lives or prolonged suffering, because of a lack of basic resources in vital areas, including food, water, shelter, health, sanitation, and education. Hunger and malnutrition are the greatest risks to health worldwide—greater than AIDS, malaria, and tuberculosis combined (World Food Programme 2011). One in nearly six people does not get enough food to be healthy and lead an active life; these include people living in both developing and developed countries. In 2007, 36.2 million Americans (23.8 million adults and 12.4 million children) lived in food-insecure households (Food Research and Action Center 2008). Access to basic resources is significantly more limited in the developing world. In 2007, 9.2 million children died before age five, and 92 percent of these deaths occurred in Africa and Asia (UNICEF 2008). Every year over half a million women (99 percent of them in developing countries) die of complications during pregnancy or childbirth, and basic health care remains a difficult service to obtain in many parts of the world.

The public and civic sectors have many responsibilities that require the analysis of complex situations in which the use of operations research (OR) and management science (MS) in decision making can have a positive societal impact. Public sector activities that can benefit from a systematic decision-making process
include governmental decisions at the legislative and strategic levels, designing and delivering public programs (e.g., for safety and education), and establishing programs that support community development. These activities cover a wide range of issues from effective health care and education delivery to developing livable cities and ensuring homeland security, issues that impact the entire society.

Disaster preparedness and mitigation, response, recovery, long-term humanitarian problems related to the basic needs for life, and public sector applications all share some common characteristics. They often involve multiple players (e.g., governments, nongovernmental organizations [NGOs], industry, and sometimes military who must work together), multiple perspectives, and multiple or conflicting objectives, and they require and present challenges for collaboration and coordination. It is difficult but essential to assess the potential impact and consequences of both short-term and long-term actions. Furthermore, long-term humanitarian problems and disaster-related situations are complex with high uncertainty, and they take place in dynamically changing and severely resource-constrained environments in which information might not be available or reliable. Timing is key for decisions and actions. Although it is important to approach these problems from a scientific and engineering perspective, it is equally important to consider the human, social, and behavioral components. Finally, most of these problems are interdisciplinary in nature. For example, to develop an effective evacuation plan for hurricanes, one needs to understand issues such as the type of technology or information that is available about weather patterns, communication, road conditions, and how people behave when given recommendations or instructions under those conditions. These topics span multiple fields, including earth and atmospheric sciences, social psychology, and information technology. Similarly, work in the public or civic sectors may require a knowledge of not only the management sciences, but also government, politics, and human decision making.

Papers in This Issue

This special issue presents seven papers that address some of the key problems from the humanitarian and public sectors and suggest potential solution approaches.

A typical disaster timeline has three stages: mitigation and preparedness, response, and recovery. Mitigation focuses on preventing or reducing impact by, for example, requiring strict building codes in earthquake-prone areas, establishing zoning and land-use control against flooding, and installing tsunami warning systems. Preparedness focuses on building physical and human capacity that can be mobilized when a disaster hits and educating the public. The response stage begins immediately after a disaster hits and includes activities such as assessment of needs, procurement of needed goods (e.g., food, water, medical kits, shelter), mobilization of resources including human capacity, long-haul transportation, storage, debris collection, last-mile delivery, and distribution. Finally, the recovery phase focuses on debris clearance and disposal, rebuilding infrastructure, reestablishing communities, and incorporating lessons learned in future mitigation and preparedness activities.

During the response stage, timing is key for delivering relief items and services to the population in need. In “Pre-Positioning of Emergency Items for CARE International,” Duran, Gutierrez, and Keskinocak develop a mathematical model to evaluate the effect of pre-positioning relief items in a network of warehouses on CARE’s average emergency response time to disaster-affected regions worldwide. By considering the cost-benefit trade-off between different numbers of pre-positioning warehouses and response-time improvements, they suggest three locations: Dubai, Panama, and Hong Kong. CARE implemented the three-warehouse structure as suggested with a slight change (the third warehouse was opened in Cambodia instead of Hong Kong) and benefited from it recently; water purification tablets in the Panama warehouse were used during CARE’s response to the 2010 Haiti earthquake.

In responding to natural and man-made disasters, governments and NGOs sometimes request support from the military, especially in large-scale disasters where heavy and expensive equipment may be needed. For example, the US military played a key role during the Haiti earthquake in 2010 and in many other disasters including the relief effort following

In “Optimizing Schedules for Maritime Humanitarian Cooperative Engagements from a United States Navy Sea Base,” authors Salmerón, Kline, and Den-sham explain the development of a decision support tool to aid the US Navy in planning for humanitarian assistance missions. In recent years, the US Navy has elevated humanitarian engagement and disaster relief to core capabilities. These relatively new competencies encourage forward maritime forces to engage in humanitarian assistance and crisis response, also sending an important strategic communications message to foreign nations. Currently, the planning for these missions is being carried out without the support of any formal OR analysis. The decision support tool, Global Fleet Station Mission Planner (GFSMP), is a prototypic planning tool that helps the US Navy to schedule humanitarian assistance missions and allows fleet staffs to examine the feasibility of future deployments and activities. GFSMP identifies how one naval ship with embarked teams can best meet the logistical requirements and mission goals, and suggests deployment schedules and combinations of teams required to perform the missions. GFSMP was tested in the Trident Warrior 2009 exercise conducted by the Commander of the US Second Fleet, Mel Williams Jr., Vice Admiral, who stated that GFSMP “greatly enhanced the ability of the Seabasing Logistics team to develop initial deployments plans and quickly produce optimized varying courses of action for consideration as situations changed during the experiment” and that “these decision aids proved to be valuable assets that could be of use in the fleet today.”

NGOs play a key role both in disaster response and in long-term development. Most of these organizations rely heavily on volunteers to deliver their services. For example, volunteers constitute 96 percent of the total workforce of the American Red Cross (ARC) in carrying on its humanitarian work (American Red Cross 2011). ARC mobilized more than 200,000 volunteers during the Hurricane Katrina response.

In “Helping a Small Development Organization Manage Volunteers More Efficiently,” authors Falasca, Zobel, and Ragsdale address the question of how to efficiently manage a volunteer workforce that has limited time availability within an NGO with scarce resources. The authors develop a spreadsheet-based multicriteria volunteer-scheduling model for a small development organization in a country in South America. The model was able to reduce the number of unfilled shifts and decrease total scheduling costs. The model also helped better satisfy the volunteers’ scheduling preferences, thus supporting the long-term retention of the volunteer workforce. This work also highlights the importance of spreadsheets in making decision models accessible to all types of organizations. Given the modeling power they offer, the familiarity of decision makers with their use, and the relatively low cost of using them, spreadsheets offer a convenient platform for delivering OR/MS solutions to small nonprofit organizations that promote human welfare.

Many public sector operations and policies at the tactical and strategic levels require the analysis of complex systems with many interactions and trade-offs. For example, in many centralized services, the public sector may provide resources to ensure equity among the population groups that receive the services, even if this increases the total cost of service delivery.

In “Quantitative Methods for a New Configuration of Territorial Units in a Chilean Government Agency Tender Process,” authors Durán, Epstein, Martinez, and Zamorano apply OR methodologies to determine new configurations of Chilean territorial units based on requirements for school meal services. The Junta Nacional de Auxilio Escolar y Becas (JUNAEB) is an agency of the Chilean government with responsibility for promoting the integration and retention of socially vulnerable children in the country’s school system. Its services include a school meals program under which private firms bid on supply contracts for territorial units within Chile. Before 2007, these units were defined manually, and their attractiveness to potential suppliers varied. This led to a series of problems for the government both in the contract tender process and the services provided. The authors determine new configurations of the territorial units to ensure that their attractiveness is similar and that schools in each region of the country receive meal services of similar and good quality. Since 2007, JUNAEB has used the configurations proposed by the authors, and
the homogenization of the territorial units has helped reduce the overall costs of the tender process to the Chilean government. Furthermore, the authors report that 25 percent more suppliers participated in the 2008 tender compared to 2005, when contracts for the same regions were tendered, and both the quantity and quality of the bids have gone up.

OR and mathematical programming can also contribute to social policy issues. For example, these techniques can be quite useful in identifying candidates for affirmative action who best fit the desired profile in terms of equity criteria.

In “A Mathematical Programming Approach to Applicant Selection for a Degree Program Based on Affirmative Action,” authors Durán and Wolf-Yadlin describe the use of OR tools in identifying candidates in a transparent and equitable way for a newly developed master’s program. In 2007, the Department of Industrial Engineering at the University of Chile allied with a major Chilean mining company to inaugurate a master’s degree program in globalization management. The program’s objective is to address the challenges Chile faces in its development of human and social capital by training young professionals. This paper describes the use of mathematical programming models in the program’s applicant selection procedure for the first three entering classes, subject to equity criteria on gender, regional origin, and socioeconomic background. The models generated robust solutions in minutes. The mathematical tools developed for this task were used during 2007–2009 and had the added advantage of bringing transparency to the selection process. The study demonstrates the potential of OR to contribute to affirmative action social policies, and more particularly to strengthen equality of opportunity in graduate-level education. Although it might still be too early to determine the long-term impact of the tools, the first graduating class has completed the program, and all 53 students enrolled did extremely well. For some of the disadvantaged students who were chosen because of affirmative action, the completion of the program will be a life-changing achievement. The directors of the program state that they cannot imagine decision making for future admission processes without the support of these tools.

Infectious diseases are now the world’s biggest killer of children and young adults worldwide, accounting for approximately one of every two deaths in developing countries (World Health Organization 2011). Primary contributors worldwide include pneumonia, tuberculosis, diarrheal diseases, malaria, measles, HIV/AIDS, and tuberculosis. The developed world is also not immune to the costs of infectious diseases to society, with significant impact from lethal variants of influenza, the impacts of hepatitis C on livers, and even hospital-acquired infections (Centers for Disease Control 2011, National Intelligence Council 2011, World Health Organization 2011). Although the threat of new diseases is real and not to be underestimated, the spread of infectious diseases results as much from human lifestyles and inappropriate use of antibiotic drugs as it does from mutations. In many cases, preventions or treatments for infectious diseases are available. However, when resources are limited, it is important to understand the relative costs and benefits of intervention strategies such as screening, vaccination, and treatment.

In “Doing Good with Good OR: Supporting Cost-Effective Hepatitis B Interventions,” authors Hutton, Brandeau, and So focus on hepatitis B, which is a vaccine-preventable viral disease that can lead to death from liver disease if left untreated. It is a major public health problem, especially in Asian populations, approximately 10 percent of which it infects. The authors use new combinations of decision analysis and Markov models to analyze the cost effectiveness of screening, treatment, and vaccination interventions to combat the disease in the United States and China. The analyses show that screening and treatment in the United States provide a good value for money and that catch-up vaccinations for children in China can save costs over the long run. The results of these OR-based analyses have been valuable in persuading policy makers to change the US public health policy on hepatitis B screening for millions of people, and have helped encourage policy makers in China to enact legislation to provide free catch-up vaccinations for hundreds of millions of children. This paper is an excellent example of how OR-based and MS-based analyses can be useful tools to identify cost-effective programs and support policy makers in making informed decisions.
Among infectious diseases, pandemic flu has received much attention from governments and health organizations in recent years. Many experts have been forecasting that a significant influenza pandemic is inevitable and likely imminent, given recent incidents of avian flu (H5N1), swine flu (H1N1), and influenza pandemic cases in history (1918, 1957, and 1968). The novel H1N1 virus emerged in 2009–2010, and influenza (and other) pandemics continue to be a threat globally.

In “A Nonhomogeneous Agent-Based Simulation Approach to Modeling the Spread of Disease in a Pandemic Outbreak,” authors Aleman, Wibisono, and Schwartz focus on intervention strategies for pandemic flu in Canada. During the recent pH1N1 “swine flu” outbreak, public health agencies were faced with the difficult task of designing mitigation strategies to limit the severity of the virus’s impact on the population. Further complications included delayed availability of limited vaccination supplies; in addition, the observed disease spread in rural Mexico was a poor predictor of disease spread in large urban centers in the United States and an even worse predictor in large Canadian cities, because of Canada’s low barriers to receiving medical care. To provide public health authorities in Ontario with a useful tool to plan mitigation strategies, the authors developed an agent-based simulation model based on transmission rates per unit time of contact, which are the same regardless of rural or urban settings, and incorporated high usage of public transportation and medical treatment facilities to more accurately represent Canadian cities than existing agent-based models, which are primarily based on US cities. The authors additionally incorporated the ability to test vaccine and social-distancing scenarios, which indicated that the rate at which the population is vaccinated significantly impacts disease spread and provides significant reductions in illnesses and deaths.

**Involvement**

The interest of the OR/MS researchers in humanitarian and public sector applications has been steadily increasing over the past decade. Below we summarize the different ways some of the authors in this special issue started working on humanitarian and public applications, such as those presented. The Department of Industrial Engineering at the University of Chile, which is home to the authors of two of the papers, has a long tradition of applying OR techniques in real-world problems in public and private sectors. The work presented in this issue on territorial units is a new chapter in a long-term project, which began between JUNAEB and the University of Chile in 1997, for designing and implementing combinatorial auctions for the procurement of school meals.

The interest of Drs. Falasca, Zobel, and Ragsdale in humanitarian applications grew out of their participation in an initiative sponsored by the Worldwide Disaster Risk Management Institute at Virginia Tech on public-private partnerships for building sustainable community resilience. This experience led to an ongoing interest in examining operational issues facing organizations that are outside the private sector. In general, the authors enjoy helping organizations that face unique and important problems and for whom improvements in operational effectiveness can make a significant and long-lasting difference, both to the organizations and the people that they serve.

Former US Navy Lieutenant Greta Spitz Densham envisioned relevant work on schedules of maritime humanitarian engagements for the US Navy for the Gulf of Guinea region during her time at the Chief of Naval Operations’ Strategic Studies Group. The paper began originally as the master’s thesis work of LT Spitz Densham, while she was a graduate student at the Naval Postgraduate School in 2007. Drs. Salmerón and Kline advised the study.

Dr. Aleman of the University of Toronto has been involved in medical applications of OR beginning with her dissertation; therefore, an expansion to public health sector problems was natural for her. Dr. Aleman’s work in pandemic modeling and planning began when a graduate student, a native of Indonesia who was inspired by his experiences providing aid after tsunamis, approached her about OR in emergency response. Marrying this idea with her other work in medical applications led to the pandemic research work that is presented in this issue. As with any interdisciplinary work, the hardest part of starting the research for Dr. Aleman was to find a collaborator in the “other” field, especially when the
collaborator was required to be a medical expert with an appreciation of mathematical modeling. After discussions with other colleagues, Dr. Aleman became connected to Brian Schwartz, an emergency medicine doctor now working in public health, who is enthusiastic about the power of industrial engineering in health care and in public health. Once the collaboration was established, determining the features that public health officials wanted that were lacking in current disease-spread models was easy; those determinations have since guided the research.

Dr. Brandeau began her research in health care with ambulance-location problems and has branched out into using models to help with clinical decision making and national and international policy. When David Hutton started his Ph.D studies, he chose to work with Dr. Brandeau because of her nontraditional area of research, which has impacted policy. Dr. Brandeau and David Hutton connected with Sam So, a liver transplant surgeon and founder of the Asian Liver Center at Stanford University, an organization that combats hepatitis B with outreach, education, advocacy, and research. Dr. So provided valuable background on the problems related to hepatitis B, clinical and policy expertise, and connections with policy makers. He was also an invaluable expert, ensuring that the models accurately reflected the real world. Drs. Brandeau and Hutton reviewed medical literature to obtain data for the models, implemented the models, and interpreted the results for interested policy makers. The multidisciplinary team was able to accomplish research and policy changes that none of its members could have effected individually. Drs. Brandeau and Hutton feel strongly that it is important to work closely with practitioners (like Dr. So) to make the models “believable” to other practitioners and to also make connections with policy makers.

The work on emergency items pre-positioning with CARE started as part of a project in a graduate class offered by Dr. Keskinocak, in which Duran and Gutierrez were Ph.D. students participating in the class. Gutierrez has also worked as an intern at CARE, and the authors continued their collaboration with CARE after completing the class.

**Future Directions**

We hope that you will enjoy the papers selected for this special issue. They represent just the tip of the iceberg of some excellent work that is being done in health (e.g., see Brandeau et al. 2004), humanitarian, and public sectors. We also hope that this issue serves as a catalyst for readers to think about ways that they can work on research that has societal impact; to that end, we discuss some directions for future research. Although we cite some articles below as representative examples of previous work, a variety of OR/MS research has been published on these topics; hence, the short list of references we provide in this introduction only provides a small sample; it is by no means exhaustive.

In the area of disasters and emergency management (Altay and Green 2006), much work has thus far focused on the planning stage in the time line; less has focused on the recovery phase (Ergun et al. 2011c). Recent events, such as Hurricane Katrina and the Haiti earthquake, have shown that managing debris after a disaster is a critical need, and effective management can improve or reduce response, recovery, and long-term effects (Stilp et al. 2011). The tragedies unfolding in Japan have also demonstrated the significance not only of the original disaster, but also the cascading effects that can occur when one event (e.g., an earthquake) triggers other disasters and effects (e.g., a tsunami, power outages, reduction in water supply, and ultimately a nuclear emergency). Although agencies such as the US Department of Homeland Security have brought some attention to cascading effects of disasters and the effect a disaster can have on critical infrastructure, many officials have commented that Japan has truly demonstrated that it can actually happen, even in a developed part of the world that focuses greatly on preparedness and mitigation. This is a critical area in which OR and MS researchers can use modeling to contribute to the understanding of cascading effects and to the corresponding measures that can be taken. Another fruitful research area for disasters is collaboration and coordination, which continues to be a challenge for the sector as a whole. In this area, researchers need to thoroughly understand the environment and context to contribute to improved coordination; however, OR and MS can help toward better joint effectiveness,
allocation of common costs or resources, and incorporating the human element of coordination in a variety of problems.

Clearly, the research needed for the broader humanitarian sector extends well beyond disasters. Many NGOs have program or development efforts to deliver food or water, implement public health initiatives, promote education, and improve agriculture; all these areas can have issues such as allocation of limited resources, coordination, planning, and logistics management. For the problems in health care, many areas of future research can incorporate disease modeling with policy analysis (Alagoz et al. 2009, 2011) or with logistical response (Ekici et al. 2010). Researchers looking toward the broader humanitarian sector may want to focus their efforts on some of the problems projected to be important to humanity (as we list above). A focus on NGOs and their associated missions is also not limited to the large, international NGOs. Many needs exist in each researcher’s own country, including the developed world. Researchers may find that local collaborations with a food bank, museum, literacy group, or health clinic for the medically underserved may be much easier to establish and still yield benefits to society. In these areas, OR and MS may not only focus on costs and resources, but may want to consider the equity of service (Balcik et al. 2011), innovative ways to approach modeling, or problem solving that do not require large technology investments or a strong quantitative background for users; these might include developing spreadsheet tools or innovative modeling that do not have inhibiting language (Kaplan 1995). Local collaborations can be created not only for graduate-level research, but could also be performed through undergraduate research or classes, which also expose students to the variety of ways that OR/MS methods can be used.

The public sector has had a rich history of research from the OR/MS areas (Pollock et al. 1994, Ritchie et al. 1994, Johnson and Smilowitz 2007); examples include urban emergency service systems (Chaiken and Larson 1972), criminal justice (Blumstein 2007), policy modeling (Kaplan 2008), and airline safety (Barnett et al. 2001). Yet many opportunities remain for OR/MS to get involved in public sector research. The education system is one area that could use greater attention; its problems may vary from the more traditional topics (e.g., the scheduling of classes or the routing of buses) to issues around the link between education and long-term equity or growth. In the United States, children’s foster care is another area in which researchers could make a difference, for example, by improving long-term tracking of children in the system through innovative technologies, research to determine the most effective investments for long-term potential, or examinations of the flows into and out of the system. Many more areas exist in which OR and MS can contribute to the public and civic sector; these range from local organizations (public or nonpublic), to state, federal, and international organizations.

When doing research in the humanitarian and public sectors, it is important to think not only about the research, but also about how decisions could be changed or implemented, and how long-term sustainability could be promoted. In many of the areas discussed above, it may be useful to think about ways to impact decisions both through traditional journal papers, and by publishing opinion-editorial articles (e.g., Wein 2011, Ergun et al. 2011a), which can serve to steer decisions by changing the nature of the conversation. Education in general also remains an important area in which to focus humanitarian and public activities, by involving students in projects or by developing case studies that improve knowledge of an area (Tomasini and Van Wassenhove 2009, Ergun et al. 2011b). This can help to promote understanding, cross-fertilization of disciplines, and greater entry of OR/MS graduates into nontraditional fields. In both education and research activities, we would like to highlight the value of establishing strong collaborations and the willingness to think beyond the tools of one discipline. We hope that you will be as inspired as we are to work on humanitarian applications, and that this special issue will provide some introduction to both established and new areas.

References


