



## Projects Overview

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H. Milton Stewart School of Industrial and Systems Engineering has been ranked the #1 graduate program in industrial engineering for 26 consecutive years by the U.S. News and World Report.

## Examples of Health-Focused Projects

The below research projects contribute to the delivery of healthcare by promoting knowledge about the best network designs, interventions, or policies that ultimately improve the well-being of individuals and society with reductions in cost where appropriate. In addition, the projects often require new modeling or algorithm developments, and it results in new theoretical insights that apply across many sectors.

### *Disease modeling and intervention strategies*

- Pandemic flu: Model the spread of the disease geographically and over time, considering demographic information, travel and mixing patterns, seasonality, virus mutation, etc. Evaluate alternative intervention strategies such as school closures and social distancing. Evaluate the impact of the disease on workforce availability, especially in healthcare facilities and for availability of food, and optimize prioritization of services and other resource allocation. Develop efficient simulations and models that incorporate state-of-the-art variance reduction techniques. See <http://www.ivanhoe.com/science/story/2008/06/434si.html> for a short video.
- Measles: Model the spread of the disease geographically and over time considering population characteristics, immunization coverage, etc. Evaluate the effectiveness of long-term vaccination strategies, e.g., give the first dose at 9 months vs. 12 months. Evaluate strategies for controlling disease outbreaks, e.g., geographic allocation of vaccines under resource constraints.
- Hospital acquired infections<sup>†</sup>: Model the spread of hospital acquired infections (approximately 2 million people are infected each year and 100,000 die in the United States) within a hospital unit (e.g., intensive care unit), an entire hospital, or across hospitals. Evaluate the effectiveness of intervention strategies such as improved hand hygiene and isolation.
- Malaria: Design a supply chain distribution system (including locations of facilities and allocation of resources such as labor and equipment over time) for indoor residual household spraying or insecticide-treated bed nets to maximize coverage of the population during the malaria season in regions (e.g., sub Saharan Africa) with limited resources. Estimate the impact of such an approach and how technology can make an implementation possible.
- Guinea worm: Model the propagation of the Guinea worm parasite in Sudan. Develop a simulation program to study the effects of a number of mitigation strategies, e.g., the impact of procuring additional personal cloth screens for use on infected water.
- Catch-up vaccination scheduling<sup>†</sup>: For children, adolescents or adults who have not followed the recommended vaccination schedule, develop decision support tools to create a personalized schedule considering the age and the vaccination history, to ensure proper coverage against vaccine preventable diseases. (Tools are available for free download from CDC website, see links below under Software.)  
See <http://www.ivanhoe.com/science/story/2008/06/434a.html> for a short video.

- Surveillance: Detect a disease outbreak to effectively initiate response (or mitigation) strategies. Find otherwise hidden clusters of high rates of occurrence of certain cancers.
- Maternal mortality: Develop software and web-based data collection tools to monitor and reduce maternal mortality throughout the world.
- Personalized breast cancer screening: Breast cancer is the most common non-skin cancer and the second leading cause of cancer death in U.S. women. Although mammography is the most effective modality for breast cancer screening, it has several potential risks, including high false-positive rates. The purpose of this project is to develop personalized mammography screening strategies based on the prior screening history and personal risk characteristics of women, to balance of benefits and risks.
- Personalized cancer treatment: Follicular lymphoma (FL) is the second most frequent lymphoma subtype with a rapidly increasing incidence in the Western world, comprising 25% of the total cases of non-Hodgkin lymphoma. Currently, there exists no single standard of care for the initial treatment of FL in the US. We study the optimal time to initiate treatment for FL patients with given clinical characteristics and the optimal treatment sequence for various FL patients?
- Predictive modeling in cardiovascular diseases: Elevated levels of blood pressure (BP) are associated with increased risk of cardiovascular disease (CVD). Most risk estimate models use only patients' current blood pressure and ignore time integrated role of BP. In this project, we assess the role of antecedent blood pressure in predicting CVD.

Collaborators: Centers for Disease Control and Prevention (CDC), American Red Cross, World Health Organization, Georgia Department of Education, Georgia Department of Public Health, Cook County Hospital in Chicago, Children's Healthcare of Atlanta, University of Pittsburgh Medical Center, College of Computing, Emory University, Carter Center, City University of Hong Kong, USAID, Emory Winship Cancer Institute, MD Anderson Cancer Center, Emory Clinical Cardiovascular Research Institute

† Partially funded by the Health Systems Institute at Georgia Tech and an IRAD grant from Georgia Tech Research Institute.

### ***Clinical Decision-making***

- Decision support tools in mammography reading: Discriminating malignant breast lesions from benign ones and accurately predicting the risk of breast cancer for individual patients are critical in successful clinical decision-making. The purpose of this project was to evaluate whether artificial intelligence algorithms (e.g., artificial neural networks) trained on a large prospectively-collected dataset of consecutive mammography findings can discriminate between benign and malignant disease and accurately predict the probability of breast cancer for individual patients. We further assessed whether this decision support tool has the potential to reduce intra-observer variability, and aid in shared-decision making.

- Point of Care Testing: Children’s Healthcare of Atlanta conducted over 450,000 point of care tests (POCTs) combined at the Egleston and Scottish-Rite campuses in 2012. There are no guidelines or quantitative best practices for when to employ POCT instead of traditional laboratory testing. The goal of this project is to develop quantitative best practice guidelines focusing on various goals, such as minimizing length of stay in PICU, minimizing mortality, and lowering healthcare costs.
- cEEG Monitoring for detecting seizures in the brain: Continuous electroencephalography (cEEG) is long-term monitoring using EEG – a method to detect electrical activity of the brain. The purpose of this project is to improve the way how monitoring is used in pediatric intensive care units (PICU) through quantitative methods and data sets, and particularly, develop guidelines about who to monitor and how long to monitor. For critically ill children, cEEG monitoring is used primarily to detect seizures. While several studies indicate that some groups of children are under higher risk of seizures there is no predictive model that could assign a seizure risk to a particular patient. Our goal is to develop models to help ICU physicians decide which children should be monitored by cEEG and for how long.
- Utilize gait data to assess the risk of falls and other adverse outcomes : Examine key gait parameters for ambulatory patients and connect them to the medical record for significant outcomes (hospitalizations from falls, for example) and account for other factors known to impact disability and falls (condition progression and severity, cognition-executive function and depressive symptoms).
- Identification and Allocation of Increased Risk Encephalitis Organs: Since 2002, 13 clusters of infectious encephalitis have been transmitted through solid-state organ transplantation. Currently, there is no standardized screening procedure to differentiate between infectious and non-infectious encephalitis. In this project, we developed two decision-support tools: 1) An infectious encephalitis risk calculator for physicians to estimate the probability that a donor has infectious encephalitis. 2) A liver transplant decision aid for the transplant doctor and patient to evaluate the trade-offs between accepting/rejecting an increased-risk encephalitis liver.

Collaborators: Centers for Disease Control and Prevention, Children’s Healthcare of Atlanta, Emory University Brain Health Initiative, MD Anderson Cancer Center.

### ***Modeling and optimizing hospital/clinic operations***

- Efficiency within hospitals or clinics: Model the flow of patients within a clinic, a hospital unit (e.g., pediatric intensive care unit or the emergency department) or across the entire hospital. Identify bottlenecks and what causes them, and develop strategies for improvement, e.g., through process changes, application of “lean” methods, staff scheduling, layout design, and improved communication.
- Integration of HIV and general clinics: Model the flow of HIV and outpatients in health clinics in Africa, where integration is occurring to identify additional HIV patients, reduce the stigma associated with HIV, and share resources. Evaluate the result of integration on the waiting times

of HIV and other patients and determine strategies for improvement. Determine general characteristics of clinics that make them good candidates for integration of the health departments to provide guidance for the country.

- Impact of pay for performance programs: Healthcare associated infections have significantly contributed to the rising cost of hospital care in the US. The implementation of pay for performance (P4P) programs has been one approach to try to improve quality at a reduced cost. We quantify the impact of Highmark’s Quality Blue (QB) hospital P4P program on central line-associated blood stream infections (CLABSI). The impact of years of participation in QB on CLABSI is also evaluated. We also examine the impact of a similar program in the US Army healthcare network.
- Predictive analytics in hospitals: Estimate length of stay of a patient based on several factors. Help determine if the patient will satisfy the CMS “two-midnight rule” to be admitted as an inpatient. Develop a longitudinal estimate for the risk that a patient would develop severe sepsis or septic shock.
- Health information exchanges: Estimate the impact of health information exchanges on Emergency Department length of stay.

Collaborators: Children’s Healthcare of Atlanta, Wellstar Kennestone Hospital, Dekalb Medical Center, an NGO in Zambia Emory University Hospital, Grady Memorial Hospital, University Hospital in Augusta, GA, Emory University Dermatology Clinic, Emory Winship Cancer Institute, Highmark, US Army, Geisinger Healthcare, University of California – San Diego, Centers for Disease Control and Prevention, AHRQ.

### ***Health Policy***

- Asthma: Evaluate various intervention strategies for pediatric asthma and with the goal of informing decision making by state Medicaid agencies (or other insurance payers) on where interventions are needed and which may be most helpful.
- Hepatitis C: Evaluate testing and treatment decisions, i.e., where, when and how, considering prevalence of disease, accuracy and cost of test, progression and cost of disease, and cost reduction through disease awareness. Recommend changes to policy guidelines for overall and high-risk populations.
- HIV: Examine the role that bathhouses play in the transmission of HIV in the MSM population. Quantify whether closing bathhouses would result in a decrease in incidence. Recommend most cost-effective interventions (within or related to the bathhouses).
- Health network design: Design the best distribution network of community health care clinics to meet the needs of a population in a way that maximizes health outcomes or promotes access to primary care. Evaluate the role that clinics play in increasing access to health care and compare this to policies that address “coverage” of health care costs.

- Medicaid optimization: Evaluate various decisions related to public health financing (e.g., what to cover, what incentive structures to use, etc.) and recommend changes to promote better health outcomes and/or reduced costs, particularly when there are limited resources and the system must ensure participation of providers.
- Eye diseases: Evaluate the role of telemedicine for screening of diabetic retinopathy and estimate the vision loss averted of the program instituted by the Veterans' Administration. Using stochastic disease modeling, quantify cost-effectiveness and changes to equity or access due to the new program. Recommend changes in screening guidelines or where new telemedicine facilities should be located to promote health outcomes and equity.
- Oral health: Quantify the oral health need in high-risk populations such as the elderly and children, which can be used to inform resource allocation. Analyze the role of Practice Acts (which define which types of medical personnel can perform which types of activities) with respect to quality, outcomes, care, and cost. Recommend changes as appropriate.
- Childhood obesity: Design an effective distribution system to support a farm-to-school program in Mexico that sources from local farmers. This includes network design, resource specification, and menu design. The focus is how to most effectively incorporate fresh fruits and vegetables into school lunches.
- Food deserts and obesity: Food deserts are geographic regions where the population has limited access to fresh fruits and vegetables. Research has shown a relationship between food deserts and obesity in the US. We estimate the impact of food retailer density on obesity in food deserts. A contracting model using block grants and reduced loans is developed to support the location of appropriate retailers to help reduce obesity.
- Optimal liver cancer surveillance policies: Liver cancer prognosis remains poor due to late diagnosis and often associated cirrhosis. Early detection is imperative but patients are often asymptomatic, so surveillance is necessary. In this project, we consider optimal liver cancer surveillance policies for various cohort of patients.
- Cost effectiveness for cancer screening and treatment: Assess the cost-effectiveness of various intervention strategies for selected cancers, including colorectal cancer, lung cancer, leukemia and lymphoma.

Collaborators: CDC, the Veterans' Administration, SAGARPA, Emory Winship Cancer Institute, MD Anderson Cancer Center.

***Allocation of scarce resources for improved health outcomes or emergency response***

- Interagency emergency health kits: Evaluate the kit composition for its effectiveness in meeting health needs after a disaster. Quantify unmet need and/or extra supplies across diseases,

populations, disasters, and regions. Optimize the supplies in the kit to minimize suffering after a disaster, and recommend corresponding changes to the guidelines for the kit.

- Blood allocation: Determine efficient ways to allocate limited blood supplies across different hospitals associated with a blood collection center in a way that maximizes health outcomes and promotes equity with respect to demand for the blood and age of the allocated products. Integrate analyze in a decision support tool that supports visibility of the blood allocation system and improved decision making.
- Geographic assignment of healthcare personnel: Developed a decision-support tool that takes into account the location preference of each health care employee, with consideration for the needs of each province, and suggests personnel-location assignments. The provincial needs include the number of each type of cadre and the available budget at each province to hire additional employees. The tool has been implemented using data from Mozambique. By implementing a data-driven deployment process, the Ministry of Health can more accurately address the needs of its constituencies at the patient level and improve overall health in the community.

Collaborators: World Health Organization, College of Computing, Task Force for Global Health

### *Others*

- Developing a comprehensive global strategy for cholera prevention and control: Produced the logistics and procurement section of a document summarizing existing recommendations and guidelines for preventing and controlling cholera, identifying outdated recommendations and gaps, and recommending new guidelines as suggested by existing research (or identifying areas for further research). Suitable for a broad audience, including policy makers and implementers, donors, clinicians, researchers, etc. This is part of the efforts of the Coalition for Cholera Prevention and Control (CCPC) project: a coalition of partners focused on developing a comprehensive strategy for the prevention and control of cholera, to include appropriate use of oral cholera vaccines, in both endemic and epidemic settings. The project is supported by the Bill & Melinda Gates Foundation, which provided funding to The Task Force for Global Health.

Collaborators: The Task Force for Global Health.

The above research projects contribute to the delivery of healthcare by promoting knowledge about the best network designs, interventions, or policies that ultimately improve the well-being of individuals and society with reductions in cost where appropriate. In addition, the projects often require new modeling or algorithm developments, and it results in new theoretical insights that apply across many sectors.

For more information, please visit <http://humanitarian.scl.gatech.edu>.

## Examples of Humanitarian-Focused Projects

The following research projects contribute to the area of humanitarian operations by promoting knowledge about the best network designs, response plans, or policies that ultimately improve the well-being of individuals and society with reductions in cost where appropriate. The projects often require new modeling, algorithm development, and theoretical insights that apply across many sectors.

### *Preparedness and Pre- Planning for Disasters and Developmental Aid*

- Pre-positioning of inventory for emergency response and long term development aid: Advanced purchasing and pre-positioning of aid items can save humanitarian organizations valuable time and money. For example, during and after a major disaster, large quantities of supplies are needed to provide relief aid. The shortage of supplies may cause emergency response to be ineffective and result in increased human suffering. Until recently, most non-governmental organizations did the procurement and mobilization of emergency relief supplies after a disaster occurred. On the other hand, even for long term aid, advanced purchasing leads to more efficient and timely procurement and transportation of aid items due to being able to take advantage of seasonal low prices and establishing contractual relations with suppliers and carriers. We worked with several organizations evaluating strategies for pre-positioning relief items, and provided recommendations.
  - For CARE International, we developed a model to evaluate the effect of relief items pre-positioning on CARE's average emergency response time. We identified the cost-benefit trade-off between different number of prepositioning warehouses and response time. The proposed network configurations minimize the average response time, given an initial investment. For the United Nations High Commissioner for Refugees (UNHCR), we developed forecasting and network design models to preposition supplies around the world for refugees.
  - For the United Nations World Food Programme (WFP), we developed a mathematical model to evaluate several strategic changes to WFP's ongoing operations' supply chain. Our recommendations included using advanced funding mechanisms for pre-purchasing and pre-positioning food in depots around the world. Our analysis showed that the number of beneficiaries receiving food aid on time can increase while keeping the total procurement and transportation costs the same if pre-purchasing and pre-positioning are implemented. WFP is currently starting a pilot program for pre-positioning in Mombassa, Kenya.
- Inventory Management: Inventory management tools help organizations to keep the right levels of inventory and determine for each item how much and when to order given the uncertainty in demand and supply for the item. Keeping the right level of inventory in turn enables the organizations to attain a desired service level while keeping costs minimized. Many humanitarian organizations are in need of standardized inventory management procedures and tools. Those responsible for inventory management at these organizations work in the field and often have many other roles to fulfill. In most humanitarian operations, field personnel experience a

relatively high rate of turnover or position change, which adds to the challenges of finding experienced inventory managers and or training new ones at additional cost. As a result the inventory experience level of inventory managers ranges from veteran to little or none.

- For the United Nations World Food Programme (WFP), we created an Excel-based inventory model. The model is based on standard industry practices but was customized to the WFP operational needs through continued communication with WFP staff. We then used this model and historical data to predict the effects of distributing the tool for use by inventory managers in the field.
- For training purposes, we created an Excel-based tool for the decisions of how much and which products to order and stock at each distribution center before a hurricane season begins. The user can use the tool to quantify the profit or service impact of their decisions, or optimize based on particular criteria. The tool has been integrated in a classroom game for students at Georgia Tech as well as ones worldwide from the humanitarian sector.
- Forecasting Relief Item Requirements: The demand for relief supplies is based on factors such as the following: type of disaster or crises, magnitude and location of the event, and the size and vulnerability of population affected. First, most information on disasters is highly variable. Second, most estimations done by the local responders lack consistency, do not contain any statistical analysis or historic data, and tend to favor recent memories of the forecasters.
  - For CARE, we developed a tool to estimates the number of people affected by disasters for each country and region where CARE is present. This tool also calculates the demand for relief supplies for the estimated population affected. The tool consists of 100 years' worth of disaster data gathered from the EM-DAT Emergency Events Database. After gathering EM-DAT data, the data is manipulated and using statistical techniques predicts the number of people that might be affected given a disaster type and location.

Collaborators: CARE International, UNHCR, WFP.

### ***Disaster Response (Emergency and Long Term)***

- Locating Distribution Points for Emergency Relief Items: During and immediately after a disaster, many communities rely on aid items for their survival, including food, water, shelter and medicine among other things. To distribute aid items, organizations taking part in disaster relief establish Points of Distributions (PODs) in the affected area for the community members to go and collect their necessities. Locating PODs in an effective way requires the analysis of trade-offs between proximity to the affected population, accessibility for replenishment, space availability, and operational costs. Given the large scale and complexity of most disasters requiring the establishment of PODs, we developed decision aid tools for locating PODs in a given community.
  - For the Atlanta Fulton County Emergency Management Agency (AFCEMA), we developed an analysis of how and where to locate PODs for distributing water during a drought. This emergency water distribution plan includes identifying the optimal location of Logistic Staging Areas (LSA) for pre-event staging and inventory buffering, and Points of

Distributions (POD) that would serve the entire Fulton County’s population. The trade-off between service level and implementation costs was analyzed. The solution includes layout and process design, labor scheduling, and water replenishment planning tools for the PODs.

- In advance of the pandemic, we worked with the American Red Cross Metro Atlanta chapter to support their efforts to design a distribution network for food in case the pandemic was so severe that not everyone could obtain food commercially. We simulated how the disease would spread geographically and over time in the state of Georgia, developed a model to determine the food distribution network over time, and analyzed intervention strategies. This work has also supported activities in the State of Georgia’s pandemic planning committee.
- Procuring and Transporting Relief Items: Efficient and effective procurement and transportation of relief items requires the analysis of local, regional, and global procurement and transportation of goods on cost and lead times. Furthermore, an analysis of transportation modes and contracts are needed to establish a good transportation policy. We worked with several organizations to improve their procurement and transportation operations.
  - For CARE, we developed an “Emergency Procurement” tool, intended to be utilized immediately after a disaster strike, considering vendors to purchase relief supplies. The tool will provide CARE with suggested relief supply orders after considering local, regional and global vendors in addition to items stored in warehouse facilities.
  - For MedShare International, we developed a long-term strategy for procuring transportation services to enable the organization to maximize its resources, taking into account its current locations and future growth strategy. MedShare is an NGO that seeks to improve healthcare through the efficient recovery and redistribution of surplus medical supplies and equipment from U.S. hospitals, manufacturers and distributors. MedShare procured transportation services when needed from the cheapest carrier at the moment, resulting in high costs and low service quality. Our recommendations included the use of contractual agreements with strategic shipping partners through Request for Proposals (RFPs). MedShare adopted our recommendations and is currently procuring transportation services through RFPs.

Collaborators: AFCEMA, CARE International, MedShare International, Red Cross, State of Georgia.

### ***Post-Disaster Recovery***

- Debris Collection: Post-disaster debris collection operations are in general not planned in advance and are done in an ad-hoc way after an event. Issues in tactical and operational planning include clearing quickly, widely, and considering environment and health impact. We are developing tools for prioritizing road clearances immediately after a disaster, and tools and analysis for efficient collection of the debris from the cleared areas and its disposal while minimizing its short and long term societal and environmental effects.

Collaborators: FEMA, USACE

## Vaccination Catch-Up Scheduling Decision-Support Tools

F. Engineer, P. Keskinocak, L. Pickering (2008), “Catch-up Scheduling for Childhood Immunization,” <http://www.cdc.gov/vaccines/schedules/easy-to-read/child.html>,

<https://www.vacscheduler.org> - 170,000+ visits since January 2012

- For children between ages 0-6 who fall behind the vaccination schedule recommended by the Centers for Disease Control and Prevention, this tool creates a personalized schedule given the child’s vaccination history.
- A new version was released on CDC’s website in January 2012
- The tool has been downloaded over 107,500 times between June 2008-March 2012.
- Implementation of the tool is currently under way for other countries including Canada and Turkey

H. Smalley, P. Keskinocak, L. Pickering (2010), “Catch-up Scheduling for Adult Immunization,” <http://www.cdc.gov/vaccines/recs/Scheduler/AdultScheduler.htm>

- For adult vaccination schedules, including rules for individuals with special conditions such as diabetes, HIV, pregnancy, etc.
- 58,000+ downloads between January 2010 - September 2014.

H. Smalley, F. Engineer, P. Keskinocak, L. Pickering (2011), “Catch-up Scheduling for Adolescent Immunization,” <http://www.cdc.gov/vaccines/schedules/easy-to-read/preteen-teen.html>

- The tool has been downloaded over 40,600+ between March 2011 - September 2014.

The online version of the Catch-up Scheduling for Childhood Immunization (2012-2013)

<https://www.vacscheduler.org>, <http://www.cdc.gov/vaccines/schedules/easy-to-read/child.html>

- This version was released on CDC’s website in January 2012 and has been visited over 280,000 times between January 2012 and September 2014.



Online scheduler keeps track of missed immunizations

**The Washington Post**  
**For Parents, an Easier Way to Track Vaccines**  
 Tuesday, July 16, 2008  
 Quick: Which shots have your kids received -- and which do they still need? The Centers for Disease Control and Prevention has a free online tool that can help.

The Catch-Up Immunization Scheduler (go to <http://www.cdc.gov/vaccines>, click on "Immunization Schedules," then "Interactive Catchup Scheduler") you plug in your child's birth date and see what's missing.



Tool Creates Personalized Catch-up Immunization Schedules For Missed Childhood Vaccinations

**Entrepreneur**  
 Catch-up immunization software.



A New Tool to Manage Your Child's Vaccine Schedule