

Emergency Response Modeling

Richard Larson, Structured Decisions Corporation
rclarson@mit.edu

1. Overview

The research of our CREATE project focused on Emergency Response planning models and analysis. The products of our work included a new publicly available emergency planning model, publications in the open literature and numerous public presentations. The research results described in the publications yielded new fertile ‘all-hazards’ research areas, some of which are being pursued at SDC, some at MIT and some currently submitted to the DHS as possible follow-on research projects. The all hazards approach has identified research areas beyond the threat of terrorism, including hurricane preparedness and response, pandemic influenza planning and response, and humanitarian supply chain design and analysis. In addition, in response to threats of terrorism, we have identified the need for a background ‘data trawler’ to monitor with vigilance the 911 calls received in a city, in an attempt to identify any evolving terrorist threat before it becomes a brutal reality. The primary research paper responsible for much of this expanded work is “Responding to Emergencies: Lessons Learned and the Need for Analysis,” *Interfaces*, Nov.-Dec. 2006, by R. C. Larson, Michael D. Metzger, and Michael F. Cahn.

The primary software product of our efforts was a modernized and greatly expanded Hypercube Queueing Model for both routine resource planning in urban police departments and emergency medical services and also for preparedness planning for various types of High Consequence, Low Probability (HCLP) events that may occur within a city. The Hypercube Queueing Model, originally invented at MIT in the mid 1970’s under NSF support, has through the years become the ‘gold standard’ for spatial resource planning for urban police departments and emergency medical services. Not only has Structured Decisions Corporation (SDC) implemented the model in many jurisdictions, but also other firms and organizations – in the USA and in other countries – have used it widely.

Our work represents a substantial advancement in publicly available software – incorporating a modern visual interface to the model, a geographical database and logic for response to HCLP events. The response to HCLP events allows the user to determine the type and severity of the scenario being analyzed and focuses on such important issues as the geography negatively affected by the event, the response units incapacitated, the need for extra-jurisdictional units and required hospital surge capacity.

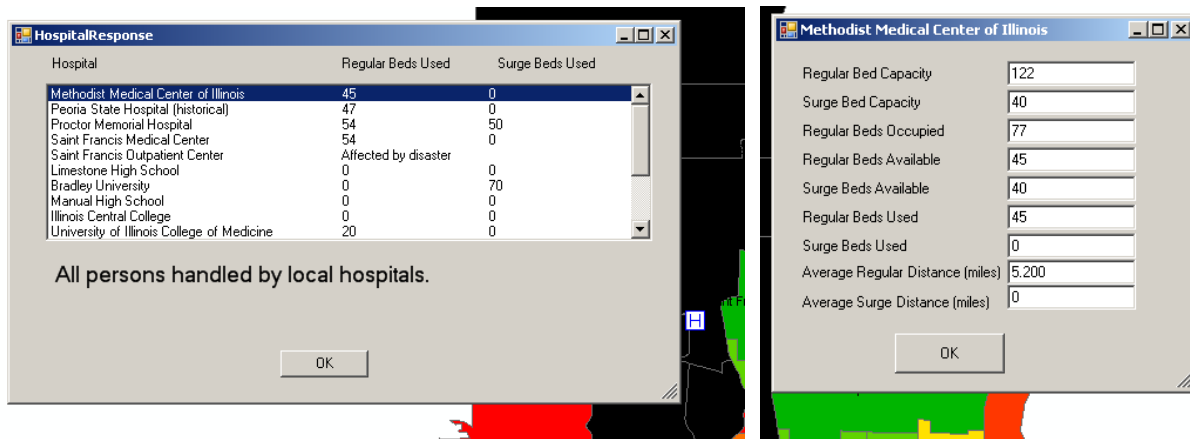
The graphical user interface represents a major advancement over previous ‘batch processing’ versions of the model. Below we show a screen on which the user selects the type of HCLP she is analyzing, and a screen that shows the damaged area and asks the user to make a decision about response.



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There are many screen displays to guide the user in analyzing planning and response options to HCLP events. These include use of hospitals and their surge capacities in aiding those who are injured as a result of the HCLP event. Illustratively, for each hospital and other emergency facility in the map’s ‘hospital layer’, the database describes –and the user can edit – normal and surge or overflow capacities.

Once the disaster has occurred and the user inputs the expected number of required hospitalizations, the model calculates the number occupying regular and surge beds in each hospital and displays the information in new screen screen. (Note that the screen also indicates how many of the hospitalized cases must be handled by resources outside of the local hospitals and emergency facilities, such as facilities in adjacent jurisdictions.) If the user selects one of the local hospitals, a detailed description of its usage in response to the emergency appears, as in the below screen shot.



A complete User’s Manual of the completed enhanced Hypercube Queueing Model is included in our full submission of research accomplishments. USC has been given the full, enhanced new Hypercube Queueing Model for inclusion in its suite of CREATE-produced software products.

Our research has been guided by the need to create a user-friendly decision support tool for emergency response planners. We have held numerous discussions with those who would be ultimate users of the software, and are confident that the software system that we have created will be readily comprehensible to the user community. Too, the publications we have written are accessible to a non-mathematical audience. While we are operations researchers, we have kept mathematical formalities to a minimum.

2. Research Accomplishments

This work contributes to Emergency Response Modeling. We integrated our work with other operations-research work, especially in emergency response logistics. The generalized Hypercube Queueing Model is primarily a model focused on risk management. The SURGE capacity part of the enhanced Hypercube Model is described as follows:

1. Each hospital in the jurisdiction has two types of emergency SURGE capacities: (1) immediate in-hospital rooms available for injured victims of a terrorist attack or act of Mother Nature or whatever; (2) contingent rooms available on short notice, under the jurisdiction of each respective hospital, these 'rooms' from tents in parking lots, high school gymnasiums, etc. Hospital staff, using overtime and canceling vacations and using trained citizen volunteers, are assumed to be sufficient in numbers to cover patients in both types of rooms.
2. Once the HCLP event occurs, we determine number of injured that need to be transported to hospitals. These are sent via a greedy heuristic: closest available hospital first, using up Type (1) rooms; then again

closest available hospital, using up Type 2 rooms. Any excess of patients not covered are called out as needing emergency medical help from adjacent jurisdictions.

3. Applied Relevance

Our software product was the enhanced Hypercube Queueing Model, with added functionality to plan for High Consequence, Low Probability events and modernized to incorporate a widely available geographical database. This has been added to Table 6.

The 2006 *Interfaces* paper cited herein led to several collaborative projects. One was the identification of the need for a more formal and rigorous methodology for decision-oriented response to a hurricane approaching U.S. coastal waters. That led to MIT-based doctoral research by *Interfaces* co-author Michael Metzger, under the research supervision of Professor Richard Larson, creating a stochastic dynamic programming methodology for decision-making under the uncertainty of an approaching hurricane. Progress on this research has been and continues to be reported in national research conferences of INFORMS, Institute of Operations Research and the Management Sciences. The research is not only mathematical, but also includes important social science and management aspects of the problem. For example, there is a chapter of the Ph.D. thesis that focuses on the ‘Boy Who Cries Wolf’ syndrome, applying to a population’s responses to repeated ‘false alarms’ in the presence of on-coming emergencies. This research led to a collaborative research partnership with the University of Washington and the submission of a major research proposal submitted to the DHS, currently under review.

The *Interfaces* paper also identified the need for a live, 911 background ‘data trawler,’ to spot the possibility of a terrorist attack evolving within a city. 911 calls provide only a partial picture of what is happening. Each caller reports what she or he sees, but on occasion there is a major event, when only small portions of it are reported in a sequence of independent 911 calls. A spatially dispersed attack using biological or chemical agents is an example. Another could be separate reports of seemingly independently rioting youths, where the rioting is in fact coordinated. On occasion we hear over 911 many separate accounts of the same incident. If we recognize that callers are each reporting the same incident, dispatchers will not send redundant response assets to the scene, thereby depleting resources for future serious events. In large cities, multiple calls relating to one incident are likely to be handled by different call takers – not knowing what other related calls have recently been handled. We are not advocating total automation of a process for recognizing one incident from multiple reports, but rather the raising of a “warning flag” so that a professional would quickly investigate the issue further – to clarify and perhaps confirm erroneous initial categorization of such calls.

In response, under a grant from the National Institute of Justice, U.S. Department of Justice, Structured Decisions Corporation (SDC) is undertaking research and then developing a new logic algorithm for municipal police departments. The algorithm will be a “Bayesian Inference Data Trawling Algorithm” (BIDTA). The BIDTA would monitor in real time every 911 call received and encoded onto the Computer-Aided Dispatch (CAD) system. It will be implemented as open-source computer software operating in the background of any 911 call-taking system in which it is installed. Our research seeks to create “*data trawling algorithms*” for 911 call centers. Such algorithms, incorporating statistics, probability, data mining techniques, and expert systems, would continually scan and analyze newly logged 911 calls, searching for those reporting one incident – large or small – rather than separate independent incidents. We are not aware of such a system existing today but, if one were created, tested and perfected, it could be installed as a “background processor” on 911 computer call-taking systems. It would act as a silent sleuth, looking for major emergency events; or, it would identify a smaller single incident reported by multiple callers. We are working with the Boston Police Department and Boston Emergency Medical Services who are providing us with data from their 911 CAD system databases.