GIS in Hospital and Healthcare Emergency Management

Edited by Ric Skinner, GISP

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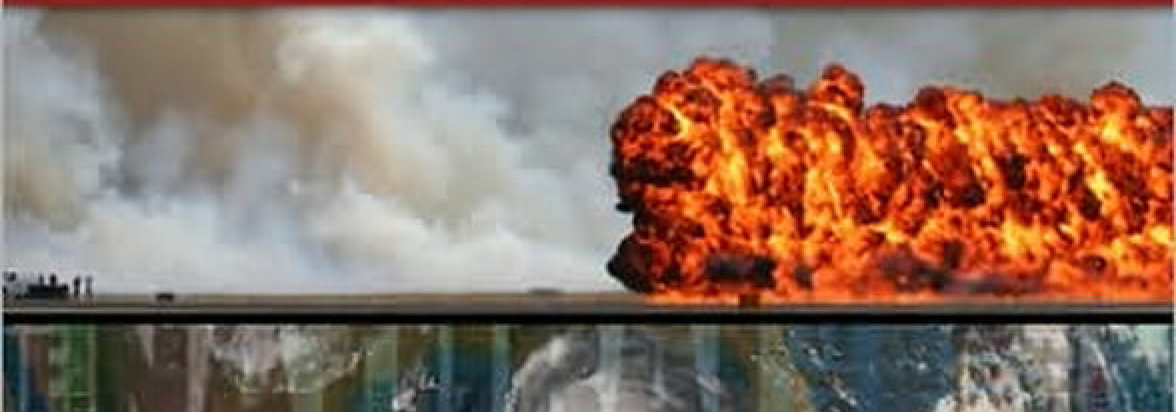

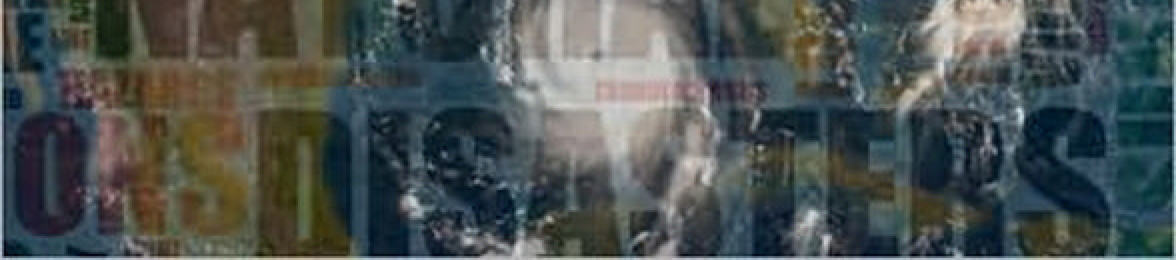

Endorsements

"GIS in Hospital and Healthcare Emergency Management provides us the first resource of its kind to guide us as we move towards increased use of GIS in healthcare disaster preparedness and response. It is an excellent resource that belongs on every emergency manager's bookshelf."

—Angela Devlen
Co-Founder Business Continuity Planning Workgroup for Healthcare Organizations and Managing Partner Wakefield Brunswick, Inc.

"GIS in Hospital and Healthcare Emergency Management is authoritative and comprehensive, covering all areas of emergency management involving GIS and related technologies, in a readable and accessible manner. The book deserves a place of prominence on the shelves of all those concerned with health/GIS, emergency preparedness, hospital management, and public health response systems.

—Omar A. Khan, MD, MHS, FAAFP
University of Vermont College of Medicine & American Public Health Association (APHA)

"This book should be required reading for every emergency manager. The writing style is engaging and the subject matter draws you in—especially because the content achieves the balance between essential wisdom and stay-up-at-night emergency preparedness concerns. If you start reading this book with a neophyte's view of GIS, you will walk away with an intense collection of real-world knowledge."

—Hal Newman
Managing Partner, TEMS

"This text by Mr. Ric Skinner, GISP, et al. takes a bold leap into operationalzing the importance of GIS in all four phases of disaster: preparedness, response, mitigation and recovery for hospitals and healthcare. Mr. Skinner and his contributors should be applauded for opening our eyes to the future."

—James L. Paturas, LP, CEM, CBCP, FACCP
Deputy Director, Yale New Haven Center for Emergency Preparedness and Disaster Response

"As healthcare organizations continue to enhance their Disaster Readiness capabilities, GIS technology will become an essential component of all responses. Ric Skinner's GIS in Hospital and Healthcare Emergency Management is an excellent guide to the future of healthcare emergency management."

—James M. Rush
Chief Operating Officer, JVR Health Readiness Inc., and co-author of "Unprepared"

"Editor Ric Skinner is the real deal, one of America's best minds on the subject of pragmatic GIS applications. In GIS in Hospital and Healthcare Emergency Management, Ric and the contributing authors have taken a very complex subject and made it understandable for local users who want to improve their response capabilities…. a wonderful addition to the emergency preparedness toolbox."

—John J. Shaw, DMD
Program Director, (Hartford, CT) Capitol Region Metropolitan Medical Response System and Chair, RESF 8, Capitol Region Emergency Planning Committee

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To the most important people in my life whose love, inspiration, encouragement, and example have provided me with the ambition and focus to take on and complete this project: Greg, Carrie, Paulette, and my parents.

Think spatially

Decide visually

Act wisely

Be satisfied

—Ric Skinner, GISP

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Foreword

As the Principal Deputy Director at the Office of Preparedness and Emergency Operations for the U.S. Department of Health and Human Services (HHS), I have the distinct honor of supporting the Deputy Assistant Secretary for Preparedness and Emergency Operations, Dr. Kevin Yeskey, and the Assistant Secretary for Preparedness and Response, Dr. Nicole Lurie, in preparing for and responding to public health emergencies across the United States, U.S. Territories, and, on occasion, foreign countries. I lead over 250 full-time employees here in Washington, DC as well as over 6,000 intermittent National Disaster Medical System employees across the United States. We have a 24/7 state-of-art operations center that is connected to our CDC and FDA operations centers as well as the operations centers of the Department of Homeland Security, Department of Defense, Veterans Affairs, and the World Health Organization.

If you want a successful system of emergency management at the local, state, tribal, or federal level, you must utilize Geographic Information Systems (GIS) — period! It will save time, money, and lives. GIS both accelerates the successful planning process and helps ensure that the final plan is executable. And, when the crisis hits, GIS utilization decreases the 'fog of war' that is inevitable in the early moments of a disaster response. And finally, when the storm is over, GIS tremendously assists damage assessments, body recovery and identification, and claims.

In 2005 when Hurricane Katrina, then Hurricane Rita, struck the Gulf Coast, HHS maintained a fledgling GIS capability. By the time Hurricanes Gustav and Ike struck in 2008, we had completed a thorough review of all hospitals and nursing homes in Louisiana, most of Mississippi and the gulf coast of Texas. The monitors within the HHS Secretary's Operation Center displayed details on the locations of hospitals, nursing homes, response teams, patient embarkation sites, patient debarkation sites, etc. 'Clicking' on an icon of a treatment facility instantly displayed address, GPS coordinates, elevation, phone & email for senior managers, as well as details about number of patient beds, etc. We had 'mapped' information on storm surge probabilities and escape routes. Overlays of wind and water damage estimates were easily obtained and available.

In 2009, we increased the depth of preparedness and magnitude of response and it is now standard for all hurricane prone states, major earthquake zones, and principal flood plains. GIS is part of the 'package' of many tools we now utilize routinely – and it remains perhaps the most important.

When we deploy National Disaster Medical Assistance Teams, teams of Commissioned Public Health Officers, mental health teams, Disaster Mortuary Operational Response Teams, or elements from the Department of Defense or Department of Veterans Affairs — any element that supports our role as lead for Emergency Support Function #8 of the National Response Framework — we have them identified on our maps with GIS. When we deploy or store caches of communication gear or medical material, it is plotted with GIS. We essentially plot everything and every person for which we have responsibility.

In today's technology driven environment of computers and satellite imagery, the saying, 'failure to plan is planning to fail', is even more valid. Planning today must include preparing GIS data on the geographic areas and having it at the ready for everyone from long range planners to the incident commander in the field.

Ric Skinner has pulled together leaders and scientists from an incredible cross-section of those who are truly involved in the preparations for, and responses to, emergencies. These authors — leaders in their fields — have managed to explain a comprehensive range and depth of information that will prove to be critical to an organization that wants to ensure success in their planning and response.

My fervent hope is that those involved in emergency planning and operations will derive invaluable benefits and lessons from this book.

R. t om Sizemore III, MD
Principal Deputy Director
Office of Preparedness & Emergency Operations
U. S. Department of Health & Human Services
Washington, DC

Preface

I had been considering starting this book project for several years. As I became more involved with healthcare preparedness while managing the Geographic Information Systems (GIS) program at a regional medical center and through involvement with a regional emergency planning committee, I discovered there were some very good, but scattered, examples of GIS being used in hospital and healthcare emergency management that were not getting the visibility they should so that others might benefit. However, I was employed full time and, consequently, this notion for a book stayed on the "back burner" waiting for the right time when I could devote the time necessary to make it happen.

Then, in 2008, the time became available. My full-time job ended, the economy "went south," and, with limited job prospects on the horizon, I decided to become an independent consultant and started The Stoneybrook Group LLC (Sturbridge, Massachusetts). This situation turned out to provide much more time flexibility than I had envisioned because the consulting opportunities were not stacking up at my door—another manifestation of the floundering economy. So, I moved the book idea to the front burner, started to put out "feelers" for chapter contributors through my professional network, relevant listservs (electronic mailing list, e-list) and via LinkedIn (a business-oriented social networking site) groups. The book began to take shape with the objective of bringing together and, as the first book devoted specifically to this topic, to the forefront the conceptual ideas, applications, and stories about how GIS could be used, and is being used, to enable better planning, mitigation, preparation, response, and recovery in hospital and healthcare emergency management.

Things were moving along nicely during the late spring of 2009 with 25 abstracts or draft chapters submitted. Then, as they say, "*Life* has a way of getting in the way when you're planning everything else." H1N1 came to the fore in 2009 and started "distracting" some of my potential authors who eventually had to drop out of the project to care for the matters at hand. "Life" for another potential author presented itself in the form of a serious automobile accident, and, for another, a death in the family. And yet another was drawn to the Philippines to aid family members following devastating typhoons. Nevertheless, I quickly initiated a Plan B and was able to enlist several chapter authors late in the process who, as you would expect from professionals, came through with quality writing. So, while the 16 chapters in this book form a foundation for this topic, I know there are many more stories that need to be told by those who were not able to participate in this book. Perhaps a sequel? An overview that includes some of the examples not included in this book can be viewed at http://files.healthgisguy.com/URISA_Slides/Skinner_URISA_long.pdf.

Companion CD-ROM

The CD-ROM that accompanies this book contains a user interface providing access to the color versions of the black and white figures printed in the book, access to hundreds of valuable resources, and a composite bibliography of all references cited in the 16 chapters. To access the user interface, insert the CD into your computer, then open it in Windows® Explorer and double click the ***readme.txt*** file and make note of the login and password you will need to access the resources. Then double click ***Resources.htm*** to open the *Book Resources User Interface* in your browser window (works best in Internet Explorer 6 or later, but also Firefox). You will be asked to log in the first time you click a resource link. If you check "Remember me" in the log-in window, you will not have to login for each subsequent link.

I leave it up to you, the reader, how informative and useful this book is to you. I encourage you to let me know what you like, what you don't like, and especially if you know of other examples of GIS in hospital and healthcare emergency management that should be added to the list and given proper visibility.

Finally, I'd like to thank my publishing team at Taylor & Francis Group who made a daunting project much less daunting, and who were very accommodating and easy to work with: Mark Listewnik, senior editor; Amber Donley, project coordinator; Jay Margolis, project editor; and Karen Schober, editorial assistant.

Ric Skinner
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About the Editor

Ric Skinner, a Certified Geographic Information Systems Professional (GISP), is an experienced consultant and researcher whose expertise includes health geographics, hospital and healthcare preparedness, GIS, and environmental monitoring and assessment. He is internationally recognized for "pushing the GIS envelope" in diverse hospital/healthcare areas: clinical/medical, health services and resources, and "hospital-land" security. He has 16 years of experience in "health geographics," a term he coined in the mid-1990s to recognize the application of GIS technology in hospitals and healthcare. In addition to his career in Health Geographics, Skinner has 23 years experience as a Certified Fisheries Scientist and Certified Environmental Professional in environmental monitoring and assessment, including fisheries ecology, aquatic bioassay/biomonitoring, state and federal environmental permitting, wetlands assessment and mitigation, and facility siting.

During his Health Geographics career (1994 to present), Skinner has provided independent consulting services to hospitals and a national health information company, held a position as senior research scientist for three years (1999 to 2001) with the New Jersey Department of Health and Senior Services, Cancer Epidemiology Service/State Cancer Registry, and served as the Health Department's representative on the New Jersey GIS Committee. In 2001, he provided GIS support to the Center for Disease Control and Prevention (CDC) during its anthrax bioterrorism investigation at New Jersey postal facilities by creating internal maps of equipment, personnel areas, and ventilation system for CDC's analysis of FBI and NIOSH (National Institute for Occupational Safety and Health) anthrax sampling locations.

More recently (2002 to 2007), Skinner served as program manager at Baystate Medical Center's Health Geographics Program (HGP) in Springfield, Massachusetts—the only hospital-based, full time GIS department in the United States. While there, he managed the HGP team and participated in a variety of GIS projects including epidemiology, automated vehicle dispatch and tracking/GPS systems, facilities management, hospital/healthcare preparedness, Hazard Vulnerability Assessment, and medical/clinical research. He served on the hospital's Emergency Management Committee. In June 2007, he participated as a healthcare representative during the Joint Chiefs of Staff Coalition Warrior Interoperability Demonstration, Trial 3.27—Integrated Information Management System. He served as a civilian emergency manager role player and provided numerous briefings to visiting U.S. and European military and defense contractors during a two-week assignment in Dahlgren, Virginia.

Currently, Skinner has his own consultancy, The Stoneybrook Group LLC. It is a veteran-owned business based in Sturbridge, Massachusetts, and offers services to clients in hospital/healthcare preparedness, health geographics, and GIS. He has been a role player, observer, and controller in several HSEEP (Homeland Security Exercise and Evaluation Program) table-top and functional exercises.

Skinner initiated and co-chaired the International Health Geographics Conference held in 1998 (Baltimore, Maryland) and in 2000 (Washington, D.C.). He co-edited the book *Geographic Information Systems and Health Applications* (Idea Group Publishing, 2003) and has authored or co-authored more than 100 publications, presentations, and reports on topics in hospital preparedness, Health Geographics, and environmental management. He is a co-founder and on the editorial board of the *International Journal of Health Geographics* (www.ij-health-geographics.com). He actively participates in IAEM, BCPWHO, DMIS-SIG, OPEN-SIG, EIIP, Yahoo Groups Emergency Management Forum, Google Groups Hospital Emergency Management Forum, and URISA.

In his spare time, Skinner likes to travel, pursue outdoor photography, work on his 1:48 scale "Benjamin W. Latham" Grand Banks fishing schooner model, and is researching the "Skinner" genealogy.

Contributors

Gwenn M. Allen, SMS, NRCC-CHO, is the director of Science Laboratories and chemical hygiene officer for Philadelphia University, Pennsylvania. As a certified Chemical Hygiene Officer, she serves as the point person at Philadelphia University regarding laboratory safety issues and supervises the disposal of hazardous waste generated through the university's various academic programs. Allen holds a bachelor's degree (cum laude) in Biology from Loyola College in Maryland (now known as Loyola University Maryland), a graduate certificate in Disaster Management from Philadelphia University, and a master's in Environmental Protection and Safety Management from Saint Joseph's University, Philadelphia.

Charles C. Branas, PhD, is an associate professor in the Department of Biostatistics and Epidemiology at the University of Pennsylvania. He is recognized for his studies to reduce violence and enhance emergency care. As director of the Penn Cartographic Modeling Laboratory, much of his work incorporates human geography and spatial interactions. Dr. Branas sits on various boards and scientific panels at the Centers for Disease Control, the National Institutes of Health, the American Trauma Society, the American Public Health Association, and is a past president of the Society for Advancement of Violence and Injury Research.

Doug Calvert, BS, is the chief of staff for the South Carolina Department of Health and Environmental Control. He has a BS in Biology from the University of South Carolina and is a graduate of the Environmental Management Institute, University of Southern California, and the Southeast Public Health Leadership Institute, University of North Carolina.

Brendan G. Carr, MD, is an assistant professor of Emergency Medicine, Surgery, and Epidemiology at the University of Pennsylvania. He is associate director of the Division of Emergency Care Policy and Research, Core Member of the Firearm and Injury Center at Penn, Senior Scholar in the Center for Clinical Epidemiology and Biostatistics, and Senior Fellow in the Leonard Davis Institute of Health

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Robert Cheetham, SMLA, is the founder and president of Avencia, a geospatial software design and development firm based in Philadelphia. He founded Avencia to develop advanced visualization and analysis software for the Web. His recent projects have focused on public safety, public health, land conservation, cultural resources, economic development, and social services. Prior to founding Avencia, he served as a developer and analyst for the University of Pennsylvania, the City of Philadelphia, and the Philadelphia Police Department. He also serves as an occasional lecturer at the University of Pennsylvania, School of Design, and collaborates with the Penn Cartographic Modeling Lab.

Stephen W. Corbett, MD, PhD, attended the University of Wisconsin for both his PhD (psychology) and MD degrees. He completed a residency in Emergency Medicine at the Loma Linda University Medical Center, California, and is a Fellow in the American College of Emergency Physicians. The emergency department at the Loma Linda University Medical Center is where he continues to practice and teach as a professor in emergency medicine. Currently, he also serves as the chief medical informatics officer for the Loma Linda University Adventist Health Sciences Center.

Isabel Corcos, MPH, PhD, received her PhD in Cell and Molecular Biology from The University of Michigan, and her postdoctoral training at The Scripps Research Institute in La Jolla, California, and a master's degree in Public Health in Epidemiology from San Diego State University. Dr. Corcos is a spatial epidemiologist with the County of San Diego, Health and Human Services Agency, Emergency Medical Services. She oversees the disaster preparedness spatial database that was used during the 2007 San Diego firestorm, and conducts GIS-related projects focused on disaster planning and preparedness, emergency medical resources, and community health.

Vincent J. Gallagher, SMBA, is the director of Data Analytics for the Marketing Department of Alexian Brothers Hospital Network in Arlington Heights, Illinois. He holds a degree in Nuclear Medicine and has worked as nuclear medicine technologist and as an ultrasonographer. His varied background has included applications software consulting on decision support systems as well as an independent consultant on hospital financial systems. The need to analyze the hospital's market strengths, weaknesses, and their competition facilitated his involvement in the use of GIS. Gallagher holds an MBA from Dominican University in River Forest, Illinois.

Jeff Grange, MD, completed his Emergency Medicine residency at Loma Linda University Medical Center (LLUMC), California. He is an associate professor of

Medicine, and currently the Emergency Medical Services director at LLUMC and the EMS Fellowship director. Dr. Grange remains active in the field, flying with the San Bernardino Sheriff's Air Rescue team for over 15 years. He is the current medical director for the Air Rescue program, and has also served as medical director for numerous fire departments and ambulance companies. His research interests include EMS, mass gatherings, motor sports, trauma, telemedicine, and violence.

Omar Ha-Redeye, JD, is a licensed nuclear medicine technologist. He began his clinical career working with veteran populations in Detroit, where he began his research into radiological hazards and participated in bioterrorism response training. His field work includes participating as Hazardous Materials (HazMat) respondent for a major health system, a First Responder for a 24-hour university campus medical service, and a senior administrator for a tsunami relief team that operated in rural Aceh, Indonesia. He is currently pursuing a Juris Doctor (J.D.) degree from the University of Western Ontario in Canada.

Megan Heckert is a PhD student in Urban Studies at Temple University. She previously worked as business development manager for Avencia Incorporated, a Philadelphia-based geospatial software development company, where her projects included proposal writing, presenting on various Avencia projects, and managing numerous GIS research projects including a nationwide analysis of gerrymandering at the local and federal levels, and an assessment of the origins of campaign contributions to New York state legislators. Heckert has a master's in Geography from Temple University, a bachelor's in Aquatic Biology from Brown University, and a Certificate in GIS from Pennsylvania State University.

Christopher M. Hiles, MS, RN, is employed by IEM, Inc. where he is involved in planning for mass casualty and mass fatality incidents including various Technical Assistance Programs through the Federal Emergency Management Agency. Hiles has a master's in Integrated Homeland Security Management, and a postgraduate certificate in Security Assessment and Management from Towson University (Baltimore). He also has a bachelor's in Nursing from Villa Julie College (Stevenson, Maryland). He has worked with the Maryland Emergency Management Agency as a technical assistant to the Office of Homeland Security. He was detached with Maryland Task Force 2 Urban Search and Rescue during their response to Katrina.

Deborah H. Kim, APRN, MSN, is an advance practice registered nurse with 30 plus years experience in healthcare emergency management. Prior to joining IEM, Inc. (Bel Air, Maryland), she was the emergency manager at the University of Utah Hospitals and Health System. She has participated in numerous hospital and community exercises. Kim's current interests reside in the use of GIS to assist with identification of healthcare resources, disease outbreaks, populations at risk, points of distribution, and Emergency Operations Plan (EOP) development. Kim has a master's degree in Nursing from Yale University, and a bachelor's degree in Science from the University of Vermont. She has a Certificate in Healthcare Management from the University of Utah.

Richard Max Learner, MSHE, PhD, is the director of the Office of Public Health Preparedness in the South Carolina Department of Health and Environmental Control. He directs the state's public health and hospital preparedness programs and the department's emergency management planning and policy activities. Dr. Learner has served as the director of planning for the South Carolina Community Long-Term Care Project, director of research and evaluation for Maternal and Child Health, director of the DHEC Office of Planning, director of Health Services Programs, director of Cardiovascular Health, and Health Policy advisor. Dr. Learner is a graduate of the University of North Carolina at Greensboro, with a PhD in Child Development and Family Relations.

Jeffrey M. Miller, SPS, is the founder and principle consultant of Warrior Concepts International (WCI) Consulting in Sunbury, Pennsylvania. His focus is on workplace violence in healthcare facilities. Miller's diverse background and accomplishments include: twelfth-degree black belt, former federal police officer, undercover drug enforcement operative, black market suppression agent, and counter-terrorist specialist, He is the creator of the EDR: Nonmartial Arts Self-Defense System™, author of several training manuals and video courses, including, *The Karate-Myth* and *Danger Prevention Tactics: Protecting Yourself Like a Pro*, as well as others.

Johnathon A. Mohr, MBA, MS, is an academic computing analyst and support specialist at Philadelphia University. Additionally, he serves as an independent consultant in the areas of Continuity of Operations Planning, Information Security, and technology adaptation and development for military and first responder operations. Mohr is pursuing his doctorate in Organization and Management with a specialization in Information Technology Management at Capella University (Minneapolis, Minnesota). Mohr holds an MBA and MS in Disaster Medicine and Management. His latest work focuses on surge facility planning as related to primary and secondary medical facilities along with the application of Geographical Information Systems (GIS) to disaster response and planning.

Michael Olesen, CIC, has a bachelor's in Public Health and Life Sciences at the University of Minnesota and has completed coursework toward his MPH in epidemiology. He is a member of the Association of Professionals in Infection Control and Epidemiology (APIC). He is board certified in infection control and is also a certified FEMA Continuity of Operations Planning trainer. He is a member of the MDH/MN-APIC Emerging Pathogens Task Force, the MN-APIC Mandatory

Reporting workgroup, and the MN Center for Healthcare Ethics Pandemic Influenza committee. He also serves on the national APIC emergency preparedness committee. He has been a project site lead for national research in smallpox and MRSA studies.

William Proger, MS, has more than 12 years of experience in GIS, starting with flight simulator terrain databases. He is employed by IEM, Inc., performing data analysis and cartography for disaster response, nuclear plant evacuation studies, and state and local hazard mitigation studies. Proger's current interests lie in the areas of transportation network and critical infrastructure visualization, and terrain data and site visualization for IEM's WebPuff decision support software. He has a master's degree in GIS and Remote Sensing from the University of South Carolina, and a bachelor's degree in Geography from Villanova University (Philadelphia).

James L. Querry, MRP, RLA, is a senior executive in GIS and Information Technology (IT) with more than 25 years of experience in a broad range of related disciplines. He is currently the director of Enterprise GIS with the City of Philadelphia. Querry holds a bachelor's in Landscape Architecture from the Pennsylvania State University and a master's of Regional Planning from the University of Pennsylvania, and was awarded the faculty medal for outstanding achievement. He is active in his local community, teaches at Philadelphia University, and is a frequent guest speaker at conferences and professional events.

Edward M. Rafalski, PhD, is vice president of marketing for Alexian Brothers Hospital Network, Arlington Heights, Illinois. He is responsible for all marketing, data analytics, public relations, and communications activities for Alexian. Dr. Rafalski has an extensive background in strategic planning, data analytics, decision support, business development, marketing, public relations, group purchasing, and managed care contracting. He has a bachelor's degree in Public Policy and a master's degree in Public Health. He received his PhD in Public Health Sciences from the Division of Health Policy and Administration at the University of Illinois, School of Public Health. Dr. Rafalski is a clinical assistant professor at the University of Illinois, School of Public Health.

Holly Shipp, **MPH**, is an epidemiologist specializing in emergency medicine and injury. She is employed by the County of San Diego, Division of Public Health Services, Emergency Medical Services Branch. Her primary responsibility includes the development and management of a countywide Emergency Department Surveillance System, which contains a record for every one of 600,000 patients treated at San Diego County emergency departments each year. Shipp was also involved in the development of the vulnerable populations database using GIS to integrate spatial analysis with emergency medical and disaster epidemiology.

Leslie Upledger Ray, MPH, is the senior epidemiologist for County of San Diego, Health and Human Services Agency, Public Health Services Division, Emergency Medical Services Branch. She oversees the collection, surveillance, and reporting of trauma, prehospital, and emergency department data. She developed the San Diego County real-time prehospital surveillance system, which monitors patient chief complaints, emergency department bypass, and hospital resource availability. Ray is also a guest lecturer for the graduate school of Public Health at San Diego State University and for Urban Studies and Planning at the University of California/San Diego. She has earned degrees in public health, public policy analysis, education, geography, and sociology.

Jared Shoultz, MA, is director of the Division of Public Health Informatics and GIS technical manager for the Division of Biostatistics and Health GIS. He has served as project manager and technical lead for a variety of public health projects ranging from Vital Records to Emergency Response/Preparedness and provides assistance on the technical aspects of integrating GIS into many agency systems. Shoultz has an Honors bachelor's degree in Journalism and Mass Communication with a minor in Geography and a master's degree in Geography/GIS from the University of Iowa (Iowa City).

Kent L. Simons, MS, is employed by IEM, Inc. where he performs geospatial analyses and cartography tasks in support of a variety of projects for both public entities and private sector clients. He also works on population and demographic studies, hazard identification and mitigation studies, and emergency evacuation analyses and simulations. Simons received a master's degree in Geography, with emphasis in GIS and Remote Sensing Applications, from Brigham Young University in Provo, Utah.

Richard t om Sizemore III, MD, is employed by the U.S. Department of Health and Human Services as the principal deputy director for Office of Preparedness and Emergency Operations (OPEO) within the Office of the Assistant Secretary for Preparedness and Response. OPEO is the primary planning and response arm of Health and Human Services for Emergency Support Function #8 (Public Health and Medical Services Annex of the National Response Framework). Dr. Sizemore received his degree in medicine from West Virginia University School of Medicine. He is a Fellow of the American Board of Ophthalmology and the American Academy of Ophthalmology and a member of the American College of Physician Executives. A graduate of the United States Naval Academy, Dr. Sizemore served more than 34 years in the U.S. Navy.

Alan Smith, MPH, PhD, earned his master's degree in Public Health from San Diego State University and completed his PhD in Epidemiology through the joint doctoral program at San Diego State University and the University of California at San Diego. Dr. Smith is currently an epidemiologist with the County of San Diego Division of Emergency Medical Services, where he conducts population-based injury research as well as public health surveillance and analysis. A large part of his surveillance efforts involve integrating GIS into various types of injury data, including trauma response, motor vehicle crashes, and deaths from homicide and suicide.

Barbara Stepanski, MPH, holds a master's degree in Public Health from San Diego State University and is currently an epidemiologist with the County of San Diego, Health and Human Services Agency, Emergency Medical Services. Stepanski is primarily responsible for implementation and maintenance of the county's real-time prehospital database and surveillance system. Her additional responsibilities include prehospital QA/QI, prehospital specialty service databases, such as the county's STEMI and Stroke systems, population-based injury research, and research activities for intermittent studies and grants.

Armand t urceanu, BS, MHA, earned a bachelor's degree in Physics from the University of Bucharest (Hungary) and a bachelor's degree in Computer Science from Northeastern Illinois University (Chicago). He is currently enrolled in the Master's of Health Administration program at the University of Illinois at Chicago/School of Public Health. Turceanu is also participating in the marketing preceptorship program at Alexian Brothers Hospital Network.

Jerry D. VanVactor, DHA, is an active duty medical service corps officer in the U.S. Army where he is a healthcare logistics manager. He has served in the military since 1989 and has been involved in a variety of healthcare supply chain management roles since 1994. His professional résumé includes both civilian and military assignments related to healthcare, law enforcement, and emergency management throughout the United States and abroad. Dr. VanVactor's education includes a doctorate of Health Administration, master's in Healthcare Management, and a bachelor's in Health Science degrees with an undergraduate minor in Procurement and Acquisitions Management. Dr. VanVactor is a Certified Materials and Resource Professional through the Association for Healthcare Resource and Materials Management.

Matthew M. Wakely, BS, is director of Public Relations at Alexian Brothers Hospital Network (Arlington Heights, Illinois). He has over 25 years of experience in public relations, media relations, and public affairs in healthcare, nonprofit, and news media environments. Prior to joining Alexian Brothers, Wakely served as director of Public Relations for The Cradle, an Evanston, Illinois-based child welfare organization funded by the Illinois Department of Children and Family Services. Wakely has a bachelor's degree in Communication from

Loyola University of Chicago and is a Fellow of The Advisory Board Company's Healthcare Leadership Academy.

Elizabeth Lea Walters, MD, is an attending physician at Loma Linda University Medical Center (California). She has undergone specific training in the recognition and response to nuclear, biological, and chemical exposures. She is an assistant professor of Medicine, with special interest in disaster issues and is a frequent participant in providing medical care at disaster sites, such as after Hurricane Katrina, in New York City after 9/11, and at the 1996 Olympics in Atlanta during the Centennial Park bombing. Dr. Walters has been a member of the Disaster Medical Assistance Team CA-2 since 1994 and a member of the National Medical Response Team-West since its inception.

Frank z anka, MBA, ABCP, is a business continuity professional accredited by the Disaster Recovery Institute International (DRII), a member of the Healthcare Best Practices Guide subcommittee, and holds undergraduate degrees in Engineering and a graduate degree (MBA) from Pepperdine University. Zanka recently completed a state-of-the-art EMS data system architecture incorporating the integration of a GIS-based common operating picture (COP) display capability for use by 13 911 call centers directly supporting County Communications and 10 fire agencies, which provide fire suppression, rescue, and medical response services for all 15 cities and the unincorporated areas of Santa Clara County, California.

Guang z hao, PhD, is assistant state registrar and bureau director of the Office of Public Health Statistics and Information Services (PHSIS) in the South Carolina Department of Health and Environmental Control. He oversees statewide operations of vital records and cancer registries occurring in South Carolina. Dr. Zhao holds a bachelor's degree in Biology from Liaoning University (Shenyang City, China), a master's degree in Ecology from the Chinese Academy of Science (Beijing), and a doctorate of Philosophy in Environmental Remote Sensing from Michigan Technological University (Houghton). His professional interests include public health surveillance, biostatistics, GIS and geospatial analysis, remote sensing, public health informatics, environmental assessment, and ecological studies.

Peer Reviewers

The editor and chapter authors wish to acknowledge the following individuals who provided peer review of the chapters. The authors provided the editor with names of two to three individuals from outside the author's organization who were willing and able to serve as a peer reviewer. The editor managed the peer review process for each author and compiled peer reviewer's comments verbatim and provided them anonymously back to the author. Peer reviewer input was invaluable in assuring the quality of material presented in this book.

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Chapter 1

Introduction: The Evolving Role of Geographic Information Systems in Hospital and Healthcare Emergency Management

Ric Skinner, GISP

The National Academy of Sciences (NAS) concluded in their comprehensive report *Successful Response Begins with a Map—Improving Geospatial Support for Disaster Management* (NAS, 2007) that geospatial data and tools (i.e., Geographic Information Systems (GIS) and Global Positioning Satellite systems) should be an essential part of every stage of emergency management, from planning through response and recovery to the mitigation of future events. This is certainly true and, as this book will document, is increasingly being found in the hospital and health-care domain.

There is a widely used "80% axiom" that 80% of healthcare and emergency management information has a geographic relevance:

- Eighty percent (80%) of information needed for decision making has a location or spatial component (Folger, 2009; City of Boston, 2009; Yong et al., 2008).
- More than 80% of all healthcare transactions are believed to have significant geographic relevancy (Davenhall, 2003).
- As much as 80% of information used during emergencies is "spatial" information (Emergency Management Spatial Information Network of Australia, 2004).

The Department of Homeland Security's inclusion of hospitals and healthcare in its list of Critical Infrastructure/Key Resources (CI/KR) (DHS, 2008a) emphasizes that it is essential that hospitals and healthcare be prepared, able to respond effectively, and recover quickly from all hazards: natural, technological, and human-caused. It's only logical to apply GIS technologies to situational awareness, logistical support, decision making, and other areas related to emergency management and disaster preparedness in the hospital and healthcare sector.

Many books and articles have been published on the application of GIS in emergency management and disaster response (Kataoka, 2007; Maantay et al., 2006; Greene, 2002). A number of these have addressed GIS as a tool in public health (Briggs et al., 2002; Cromley and McLafferty, 2002) and a few have touched on isolated stories about GIS in the hospital and healthcare sector (Khan and Skinner, 2002). However, there has been no major publication that attempts to focus on and discuss the important and evolving role for GIS in hospital and healthcare emergency management and disaster response. It should be noted that many of the emergency management and disaster preparedness challenges faced in hospitals and healthcare, such as resource inventory and allocation, situation awareness, decision support, and locational intelligence, are the same that other business sectors face. Therefore, this book is expected to have value outside its primary intended audience.

It is clear from the Department of Homeland Security's *Supplemental Resource: Geospatial Guidance* for the Homeland Security Grant Program (DHS, 2008b) that it recognizes the important contribution geospatial information and technology play in protecting the nation's CI/KR. GIS technologies improve the overall capability of information technology applications and systems to enhance public security and emergency preparedness and efficient response to all hazards. So, it is only logical to apply GIS technologies to support emergency management and disaster preparedness in the hospital and healthcare sector.

This book brings together contributions from 33 subject matter experts (SMEs) in 16 chapters who discuss ***concepts*** (location-based Hazard Vulnerability Assessment, understanding spatial factors in workplace violence, tracking nosocomial infections, logistics of supplies and resources), ***applications*** (trauma center siting, mass casualty incident planning, enterprise GIS, evacuation and sheltering, prehospital and disaster response) and ***case stories*** (flu preparedness, vulnerable populations, needs assessment during natural disasters, regionalized incident planning, and integration of EMS and hospital response). The objective of this book is to show how hospitals and healthcare are benefiting from the use of GIS to improve their emergency management and disaster preparedness mandates and responsibilities.

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CONCEPTUAL APPROACHES

I

Chapter 2

A Spatial Approach to Hazard Vulnerability Analysis by Healthcare Facilities

Ric Skinner, GISP

Contents

Introduction

"Location … Location … Location."

This is something that the emergency management sector of the healthcare industry has in common the real estate industry (Skinner, 2008). Just like when someone is looking for a house to buy, certain criteria are location-dependent. Let's say the desired house would be one in a woodsy setting with a brook or pond within view and in a good school district. Similarly, when analyzing hazard events that a hospital might be exposed to, one should consider the hospital's location with respect to weather patterns, hazardous storage facilities, transportation routes, population demographics, and facilities that could be considered targets, such as government buildings, controversial companies, national landmarks, etc. For example, in a hazards analysis, it should be obvious that a hospital located in a Federal Emergency Management Agency (FEMA) Q3 Flood Zone should consider and prepare for an external flooding event much differently than a nearby patient care facility on higher ground. Perhaps less obvious, a hospital located a half mile downwind from an industrial storage tank containing 10,000 gallons of anhydrous ammonia should give the hazard a higher priority to direct impacts in its disaster analysis than a patient care facility would if it were located a half mile upwind from the same storage tank. However, indirect impacts also need to be considered; for example when a hospital is located upwind of the tank rupture, it can expect to see mass casualties in the emergency room. Thus, an assessment of hazards impacts for a healthcare facility needs to consider hazards from two perspectives:

1. What hazards will *directly* impact my people (staff, patients, visitors), facilities, or business operations because of hazards events (e.g., medical gas system failure, internal chemical spill, workplace violence) that could occur in my facilities?
2. What hazards will *indirectly* impact my people, facilities, or business operations because they are drawn into hazards events (e.g., weather emergency, transportation accident, epidemic) within our service area?

Why Conduct a Hazards Assessment?

Most hospitals and healthcare facilities (hereafter collectively referred to as HCF) in the United States must conduct an assessment of natural, technological, and human-caused events that may impact the facility's people (i.e., staff, patients, visitors), physical plant (i.e., buildings, mobile resources), and operations (i.e., ability to provide services) as part of their accreditation requirements by the Joint Commission (a not-for-profit organization that accredits healthcare programs in the United States)(Joint Commission, 2008). This is typically done once and updated annually. Similar requirements are placed on healthcare facilities accredited by other accrediting organizations, such as the Healthcare Facilities Accreditation Program (http://www.hfap.org/), National Integrated Accreditation for Healthcare Organizations (DNV Healthcare, Inc., 2009), and some state health departments (Reed et al., 2009; Barabas, 2002).

In the Joint Commission's (www.jointcommission.org) new Emergency Management (EM) chapter (Joint Commission, 2008), which became effective in January 2009, EM Standard 01.01.01 of the Hospital Accreditation Program requires that:

> The [organization] engages in planning activities prior to developing its written Emergency Operations Plan.

These activities include identifying risks, prioritizing likely emergencies, attempting to mitigate them when possible, and considering potential emergencies in developing strategies for preparedness, response, and recovery.

In the Elements of Performance for this requirement, the Joint Commission states:

> The hospital conducts a hazard vulnerability analysis (HVA) to identify potential emergencies that could affect demand for the hospital's services or its ability to provide those services, the likelihood of those events occurring, and the consequences of those events.

The Joint Commission requirement for HCFs is for the facilities to work with community partners to make sure its HVA meshes with similar efforts by the community. Although location of the remote healthcare facilities has always been a concern, in 2009, the Joint Commission clarified this importance by stating:

> Hospitals have flexibility in creating either a single HVA that accurately reflects all sites of the hospital, or multiple HVAs. Some remote sites may be significantly different from the main site (for example, in terms of hazards, location, and population served); in such situations a separate HVA is appropriate.

While the term *remote sites* is not defined by the Joint Commission, this can be interpreted as patient care facilities under the same accreditation certificate distantly located elsewhere in a county or state, or proximally located in different sections of the same city. Separation of only a few blocks can result in significantly different risk exposure to certain hazards. An HCF is not required to do multiple HVAs; however, it should consider whether they are needed. Some organizations have many remote sites and may group them for HVA purposes.

The process that HCFs typically follow to determine their vulnerabilities to natural, technological, and human-caused, including hazardous materials (HazMat) risks, i.e., "all hazards" is termed an HVA. The justification for an HVA is to provide a rational and realistic foundation for assuring that the Emergency Operations Plan (EOP) adequately addresses the highest priority hazards that may pose a risk to the HCFs. Therefore, the better the information used in the HVA the better and more responsive the EOP can be designed.

While each of the thousands of HCFs accredited by the Joint Commission is required to conduct or update its HVA annually, a 2007 survey of nearly 1,200 responding HCFs—nearly 60% of which are Joint Commission accredited—in the United States (Skinner et al., 2008) and a second smaller survey in 2008 revealed that, in many cases, HVAs by these facilities:

- Are not uniformly carried out.
- Do not follow a standardized approach.
- Do not share results with nearby or regional HCFs.
- Can result in closely located facilities deriving differing sets of risk assessments.

There is both a practical and a programmatic justification for HVAs. To an HCF chief operating officer (COO), the practical is perhaps the most important: Will the hazard affect my facilities, services, and/or people (staff, patients, visitors)?" Whereas to the HCF chief executive officer (CEO), the programmatic is a primary focus: "Will the hazard impact the 'business' (read *bottom line*) of healthcare for my facility?"

The Hazard Vulnerability Assessment Process

The most frequently encountered healthcare facility accreditation process is the Joint Commission accreditation program that serves as the example in this discussion of all accreditation programs. The Joint Commission accreditation covers a variety of facility types; however, not all are required to conduct a formal HVA:

- Ambulatory care
- Behavioral healthcare
- Critical access hospitals
- Home care
- Hospitals
- Laboratory services
- Long-term care
- Office-based surgery

Many natural, technological, human-caused, and hazardous materials (HazMat) events, including the ones listed in Table 2.1, should be evaluated for their impacts on people (patients, visitors, and employees), property, and business operations. In addition, an assessment of current preparedness, internal response capability, and external response capability should be included. The HVA provides a picture of "Where are we now?" "Where do we need to be?" and, with subsequent planning based on the HVA, "What do we need to do to get there?"

An HVA may be a time- and resources-demanding process that, according to the surveys mentioned above, often does not include much fact-based evaluation of

Table 2.1 Hazard Events That Are Included in Most Hazard Vulnerability Assessments

Natural	*Technological*	*Human-Caused*	*HazMat**
Blizzard	Communications failure (data)	Bomb threat	Blood/body fluid spill
Dam inundation	Communications failure (voice)	Civil disturbance	Chemical exposure, external
Drought	Electrical failure	Economic disruption	Chemical exposure, internal
Dust storm	Explosion, external	Forensic admission	Chemotherapeutic spill
Earthquake	Explosion, internal	Hostage situation	Large spill, internal
Electrical storm	Fire alarm failure	Infant abduction	Mass casualty HazMat (<5 victims)
Epidemic	Fire, internal	Labor action	Mass casualty HazMat (>= 5 victims)
Flood, external	Flood, internal	Mass casualty (infectious)	Mercury spill
High wind	Fuel shortage	Mass casualty (trauma)	Radiologic exposure, external
Hurricane	Generator failure	Missing person	Radiologic exposure, internal
Ice storm	HVAC failure	Patient elopement	Small–medium spill, internal
Landslide/ Subsidence	Information Systems failure	Suspicious letter/ package	
Pandemic	Isolation room failure	Suspicious person	
Severe Thunderstorm	Medical equipment failure	Terrorism, biological	
Snowfall	Medical gas failure	Terrorism, chemical	
Temperature extremes	Medical vacuum failure	Terrorism, radiological	
Tidal wave/ tsunami/seiche	Natural gas failure	Terrorist threat	
Tornado	Sewer system failure	VIP situation	
Vog	Steam system failure	Workplace violence	
Volano	Structural damage		
Wild fire (forest, range)	Supply shortage		
	Transportation failure		
	Water system failure		

[a] HazMat events are sometimes included in either Human-Caused or Technological events.

hazard events. Rather, the HVAs are carried out in many instances relatively quickly by a few people and rely on "recent memory" or subjective estimates. However, including historical or experienced-based information in the analysis would provide a more realistic, albeit, much more resources-consuming (i.e., staff, time), assessment of risks and vulnerabilities resulting in justifiable planning and preparedness measures.

The most commonly used HVA tool is one developed by Kaiser Foundation Health Plan and widely referred to as the "KP HVA" or "KP Tool" (Kaiser Foundation Health Plan, 2001). In its basic form, it requires subjective numerical inputs for "likelihood" of various hazard events and "severity" of impacts to people, property, and business as well as ranking of the facility's capabilities to respond. The KP Tool is formatted as a Microsoft® Excel® workbook with separate worksheets, formatted with embedded formulas, for natural, technological, human-caused, and hazardous materials events. Figure 2.1 is the "natural hazards" worksheet from the KP Tool; the other worksheets are similarly set up. A final worksheet presents a summary table and bar chart representing the facility's overall relative threat based on inputs to formulas in the individual worksheets. As the basic form is set up, subjective "values" for "likelihood" of a hazard event; subjective "values" for level of impact to people, property, and business; and a subjective indication of the adequacy of preparedness, internal response, and external response are input. However, there's no reason that the subjective ordinal values could not be replaced by probability calculations based on real data.

While HCFs are not required by the Joint Commission to use the KP Tool, it or a variation is the only one suggested by the Joint Commission:

> A particular HVA tool is not required by the Joint Commission; however, the KP tool, or one of the derivatives, can be a starting point for organizations to evaluate their vulnerability to specific hazards (McLaughlin, 2001).

Much of the fact-based information needed to support an HVA, as will be illustrated later, is available online or from other sources, such as state disaster mitigation plans and local emergency management plans. This is particularly true for natural events (hurricane, wildfire, earthquake, etc.) and, in some cases, the technological (e.g., utilities failures, transportation failure, supply shortage), human-caused (mass casualty, bioterrorism, civil disturbance), and HazMat (external chemical exposure, external radiological exposure) events.

According to Per Schenck, director of the Office of Service Continuity and Disaster Planning at Stanford Hospital and Clinics, Stanford, California:

> We have been using the [KP HVA] Tool for 5 years now and have had reasonable luck with it. I have been the Emergency Manager for 18 years now and know my facilities, their histories, and vulnerabilities

Hazard and Vulnerability Assessment Tool
Naturally Occurring Events

		Severity = (Magnitude-Mitigation)						
Event	*Probability*	*Human Impact*	*Property Impact*	*Business Impact*	*Preparedness*	*Internal Response*	*External Response*	*Risk*
	Likelihood this will occur	*Possibility of death or injury*	*Physical losses and damages*	*Interruption of services*	*Preplanning*	*Time, effectiveness, resources*	*Community/ mutual aid staff and supplies*	*Relative threat**
Score	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = Low* *2 = Moderate* *3 = High*	*0 = N/A* *1 = High* *2 = Moderate* *3 = Low or none*	*0 = N/A* *1 = High* *2 = Moderate* *3 = Low or none*	*0 = N/A* *1 = High* *2 = Moderate* *3 = Low or none*	*0–100%*
Hurricane								0%
Tornado								0%
Severe thunderstorn								0%
Snowfall								0%
Blizzard								0%
Ice storm								0%
Earthquake								0%
Tidal Wave								0%
Temperature extremes								0%
Drought								0%
Flood, external								0%
Wildfire								0%
Landslide								0%
Dam inundation								0%
Volcano								0%
Epidemic								0%
Average Score	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0%

* Threat increases with percentage.

Risk = Probability* Severity		
0.00	0.00	0.00

Figure 2.1 Natural hazards worksheet from the KP HVA Tool. Kaiser Foundation Health Plan, 2001 (http://www.njha.com/ep/pdf/627200834041PM.pdf accessed January 2010).

> well. As a result, I am the editor of the HVA and then have others provide input, while maintaining editorial rights. We have HVAs for each site under the Joint Commission accreditation; that leaves me with about 12 different HVAs. Each site is different because of the utilities, the population it serves, and its location in the geography. Recently, I have been using the GIS maps available from the Association of Bay Area governments (www.abag.ca.gov/) and learned the following from the maps: locations of faults, location of flood zones relevant to the various sites, wild land fire zones, and dam inundation zones. Also, in Santa Clara County, we benchmark our HVA between all 12 hospitals to identify issues. I was able to identify for one hospital that it was in a dam inundation zone and they did not know it. So the [KP HVA] tool is good (best we have right now), GIS mapping is valuable, and benchmarking with your peers is essential. … Only one hospital did not use the [KP HVA] tool. I use the GIS [mapping] for flood, earthquake, wildfire, dam failure, tsunami, and landslides. We pretty much accept earthquakes, but it is interesting to show the [risk exposure] of a wildfire or dam failure. This is not something that people in the flat lands commonly see. But, as the GIS maps show, they are a possibility. (Schenck, 2009, personal correspondence).

By integrating fact-based information into the HVA, an HCF emergency manager can determine a probability for many events, instead of having to rely on a subjective "probability" or "likelihood" of an event occurring using an ordinal scale, such as: 0 = N/A; 1 = low; 2 = moderate; 3 = high. While the same subjective "0, 1, 2, 3" scale can be used with fact-based information, with better information, the scale can be expanded to fine tune the assessment, and, for many hazard events, actual probabilities can be calculated and used. Where data exists on human (death, injury) and property impacts these can be factored into the facility's HVA. The end result is that with fact-based historical data from online, state/local agencies, or facility sources, the overall prioritization of risk can be more realistically determined, which will lead to a more robust, realistic, and responsive EOP.

Another example of the value of incorporating GIS in hazard mapping and vulnerability assessment has been documented by Ryan (2009). She describes how a GIS-based Land Information System (LIS) was developed for effecting planning and better management of land resources. The LIS was proved to be an effective tool in disaster management by implementing it to support hazard mapping and vulnerability assessment on Montserrat, an active volcano on an island of the same name in the West Indies. It has been used to inform residents of impending danger and in the relocation of residents.

A "Spatial" Approach to HVA

What follows are illustrations how HCFs can incorporate "location" into the natural hazards portion of their HVA. Many other sources can be found for individual counties, states, and countries. Briefly, the HVA assessor will access various online resources, and acquire access to local, regional, or state agency and utility company information that provides historical information about certain events (e.g., hurricanes, earthquakes, wildfires, hazardous materials storage, utility outages, etc.) from which a more realistic "likelihood," and, in many cases, probability, can be determined and used in the HVA for that hazard event.

Some of the online resources for a "location-based HVA" include (addresses accessed January 2010):

- National Climactic Data Center Storm Events Database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms)
- USGS Earthquake Hazards Program Archives (http://earthquake.usgs.gov/regional/states/)
- National Geophysical Data Center (http://www.ngdc.noaa.gov/hazard/)
- FEMA Information Platform—Flood Map Viewer (https://hazards.fema.gov/femaportal/wps/portal/!ut/p/kcxml/04_Sj9SPykssy0xPLMnMz0vM0Y_QjzKLd4w39DQESZnFG8Qbm-pHogk5IkR8PfJzU_WD9L31A_QLckMjyh0dFQF0T0jn/delta/base64xml/L3dJdyEvd0ZNQUFzQUMvNElVRS82X0NfUDE!)
- State or County Emergency Management Agency State Hazard Mitigation Plans. For example:
  - http://www.mass.gov/Eeops/docs/mema/disaster_recovery/state_plan_2007_rvn4.pdf
  - http://ema.ohio.gov/Mitigation_OhioPlan.aspx
  - http://www.dem.azdema.gov/operations/docs/mitplan/appendixC.pdf
- State or County Emergency Management Agency Comprehensive Emergency Management Plan, especially ESF-8 Annex. For example:
  - http://www.mass.gov/Eeops/docs/mema/state_cemp-full_plan.pdf
  - http://www.floridadisaster.org/documents/CEMP/Appendices/ESF%208.pdf
- http://www.co.columbia.or.us/emgt/pdf/comp_plan.pdf

Consider the following example: An HCF in Worcester County, Massachusetts, is conducting an HVA and plans to develop a robust Emergency Operations Plan to address the top five hazards in each of the categories. In working with the natural hazards category, they are assessing risk from tornados. In the past 10 years, the HVA team recalls about four to five small (category F0 and F1) tornados causing about $1 million in property damage, but no deaths or injuries. So, in the basic KP HVA Tool, they are prompted to report a "likelihood" of 1 (= low) and severity of impact to people, property, business also as 1. However, one of the newer team members suggests checking the historic record available online from the National Climactic Data Center. The HVA team is surprised to find that since June 1953 there have been 34 tornados, with 13 category F2 *or greater*, resulting in 92 deaths, 1,253 injured, and over $259 million in property damage. Having this factual information, they decide to rate the likelihood of a tornado 2 (moderate) and the severity of impact to people, property, and business also 2. Compared to other hazards ranked in the HVA, tornado was moved up into the top five natural hazards that needed to be addressed in the Emergency Operations Plan.

Another example is that of a hospital system in Utah that needs to assess earthquake exposure in its HVAs for several hospitals in the state. By accessing the U.S. Geological Survey (USGS) Earthquake Hazards Program Web site for Utah (http://earthquake.usgs.gov/regional/states/index.php?regionID=44), a seismic hazards map can be produced from which an HVA assessor, familiar with the location of the HCFs, can make a more reasoned decision on the likelihood of earthquake risk and estimate the severity of impacts (Figure 2.2).

Further examples of the value of a location-based HVA include:

- The risk to a facility due to flooding can be estimated by mapping the facility's location on FEMA's Q3 flood zone map, and then, by overlaying local roads, primary and alternate evacuation routes can be identified.
- The risk to a facility that might occur as a result of local civil disturbance or labor action could be evaluated by mapping the facility's location in proximity to high crime areas (acquired through collaboration with local law enforcement) or low-income population densities (U. S. Census or local census data).
- The direct impact on patients, visitors, and employees from a leaking hazardous materials storage tank a half mile upwind from a facility could be estimated by mapping the facility's location, locations of local hazardous material storage areas (acquired through collaboration with local fire department), and the probabilities of the prevailing wind directions determined from regional weather data.
- Providing a means for gap analysis of the Emergency Operations Plan and Disaster Recovery Plan to identify where, based on prioritized vulnerabilities, these plans should be improved.

Having the resources for a location-based HVA also provides the HCFs with ancillary capabilities to:

- Carry out risk assessments for any facility or site an organization is considering for acquisition or leasing.
- Have a factual basis for seeking a reduction in property loss/liability insurance premiums.

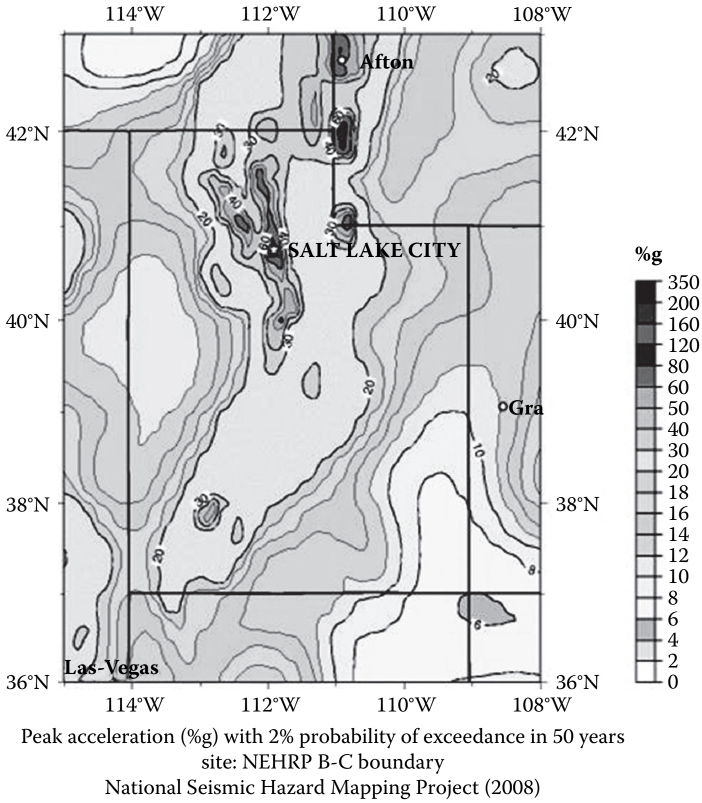

Figure 2.2 Screenshot of seismic hazard map for Utah (http://earthquake.usgs.gov/regional/states/index.php?regionID=44; accessed January 2010; Information in the public domain; credit: U.S. Geological Survey, U.S. Dept. of the Interior).

- Be a foundation to enable a means for "roll up" of certain information to regional/state hospital preparedness agencies to provide a regional picture of healthcare preparedness.

Additional Sources to Support a Location-Based HVA

In addition to online sources, there have been a number of software applications developed, such as HAZUS-MH (http://www.fema.gov/plan/prevent/hazus/accessed January 2010), which is a free application available from FEMA's Publication Warehouse (http://www.fema.gov/library/viewRecord.do?id=2898 accessed January 2010):

> HAZUS-MH (Hazards U.S.–Multihazard) is a powerful risk assessment methodology for analyzing potential losses from floods, hurricane

> winds, and earthquakes. In HAZUS-MH, current scientific and engineering knowledge is coupled with the latest geographic information systems (GIS) technology to produce estimates of hazard-related damage before, or after, a disaster occurs.
>
> Potential loss estimates analyzed in HAZUS-MH include:
>
> - Physical damage to residential and commercial buildings, schools, critical facilities, and infrastructure
> - Economic loss, including lost jobs, business interruptions, repair, and reconstruction costs
> - Social impacts, including estimates of shelter requirements, displaced households, and population exposed to scenario floods, earthquakes, and hurricanes (from the HAZUS-MH Web site)

There has been much in the news about the Great California “shake-out” (http://www.shakeout.org/accessed January 2010) and statewide planning for a major earthquake. The Hospital Association of Southern California has recently used HAZUS-MH to calculate estimated physical damage and functional loss from natural hazards. One of the outputs of the HAZUS-MH analysis was computing acute care bed availability for hospitals in the region following earthquakes of various magnitudes (Blakenship, 2009).

Another software tool is the Consequence Assessment Tool Set (CATS: http://www.esri.com/industries/public_safety/resources/cats.html accessed January 2010) that also is available free to federal, state, and local emergency management organizations:

> CATS provides a comprehensive package of hazard prediction models, casualty, and damage assessment tools, and population and infrastructure data. CATS focuses on chemical, biological, radiological, nuclear disaster analysis, and support of a wide range of response applications and access to remote databases for custom analysis.

An extra advantage in using these software tools is that “what if” scenarios can be played out and impacts of the various scenarios compared. Two drawbacks to these software tools are that they require GIS software, which is not free, and someone knowledgeable in GIS to run the applications. However, state and local emergency management organizations are more frequently found with GIS capability either in-house or through contract consulting services, and these resources may be available to the HCF through Memorandums of Agreement or other arrangements.

Conclusion

Identifying risks from hazards and assessing a hospital or healthcare facility's vulnerabilities to these risks is fundamentally about having the right information, and, in many cases, spatial information. The Joint Commission and other HCF accrediting organizations and agencies recognize the importance of all-hazards vulnerability assessment and require HCFs to conduct or update an HVA annually in a formal, documented process.

An HVA is the process that identifies the internal and external risks of "all-hazards" disasters (natural, technological, human-caused, and hazardous materials related) most likely to affect facilities and the probable severity of impacts on response and recovery if they were to occur. By understanding risk exposure, the HCFS should be better able to develop adequate mitigation, preparedness, response, and recovery actions for those risks, thus reducing vulnerability and impact to the organization making it more resilient.

A facility's emergency preparedness and its ability to respond and recover from disasters depends on how well it has identified and prepared for the historically real and most likely hazards to which it could be exposed, and how well it has estimated the frequency and severity of impact of those hazards on people (i.e., patients, employees, visitors), facilities, and operations.

The importance of the HCF's geographic location in estimating the probability of an event affecting a facility, along with the risk itself, historical data, and proximity to local/regional high-risk locations (e.g., a chemical manufacturer, nuclear plant, "tornado alley," coastline, etc.), should be included in HVA discussions with community response partners and local emergency managers. These collaborative interactions are required by the Joint Commission.

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Chapter 3

Using GIS to Improve Workplace and Worker Safety Crisis Management

Jeffrey M. Miller, SPS, DTI

Contents

Introduction and Background

In the world of hospital and medical facility emergency management, one of the most underdeveloped areas is that of worker safety and protection from danger arising from the actions of aggressive human beings. While the threat to healthcare workers from biological, toxic, and other natural and manmade dangers—dangers that are medically and scientifically centered—is readily apparent and acted upon by managers and administrators, other threats, such as those stemming from violence in the workplace, are, more often than not, treated as add-on policies, if they are addressed at all.

However, according to the Occupational Safety and Health Administration and other agencies, such as the National Institute for Occupational Safety and Health and the U.S. Department of Health and Human Services (National Institute for Occupational Safety and Health, 2006), an average of 17 workers are murdered and another 33,000 are assaulted every week while on the job in the United States (Centers for Disease Control and Prevention, 2004). Reports from international labor and healthcare organizations all across the globe—groups, such as the World Health Organization, The International Council of Nurses, and Public Services International (Riggs, 2009)—clearly indicate that this is not a uniquely "American" problem, nor is the healthcare field immune to this epidemic (Sadki, 2002), as the numbers seem consistent regardless of location. What does differ from region to region and, in the case of even different departments within a single hospital setting, is the types of attacks and the means used by perpetrators to inflict damage. And, since attacks range from simple assault and harassment, to aggravated assault, rape, and even murder, as outlined in the Cal/OSHA Guidelines for Workplace Security (California Dept. of Industrial Relations, 2005) categories of violence, it is easy to overlook the shear magnitude and complexity of the problem without the right tool to accomplish the task. And this is where Geographical Information System (GIS) software and mapping can be used to not only make sense of the apparent chaos and provide a much clearer picture, but also to speed up the time line between the recognition for action and the actual implementation of the necessary training and procedures that will prevent harm and save lives.

My aim here is to not only show how GIS-based research can significantly impact the quality and outcome of employee-centered training in the realm of workplace violence, but also the critical need for better policies and crisis management training that will prepare workers to be able to prevent, neutralize, and survive acts of violence in a medical, clinical, or hospital setting.

If a facility's management and administration refuse to see the threat present to their workers, then little can be done to prevent the job-related stress, high employee turnover rates, and loss of life, financial resources, and legal liability that can cripple an organization when the "unthinkable happens" (Centers for Disease Control and Prevention, 2004). However, because this book is directed toward proactive professionals seeking solutions to problems, I am approaching the topic from the perspective that I do not have to convince the reader of anything. So, the focus will remain steadfastly on the need for training for healthcare workers in the realm of workplace violence as a part of an overall crisis management system, and the role that GIS can play within the overall project and in ensuring the development of the best training system possible.

Workplace Violence in the Health Sector: A Unique Perspective

While the recognition of violence in the workplace is not new by any means, any more than workplace violence is an "American thing," the medical sector is waking up to the reality that it is in a so-called league of its own. Hospitals and larger medical centers, like universities, have a unique structure in the world of business in that they are, in large part, open to the public. As virtual small cities, they are divided into departments, centers, and areas, each with its own unique dynamics and flow of visitors and resources.

Unlike most typical business entities that restrict the flow and access to the greater part of their operation, hospitals have relatively few restricted areas in the overall structure of their makeup. Unfortunately though, for years, the medical sector has been treating the issue of workplace violence as though hospitals, clinics, and doctor's offices were no different than factories. Those who did take measures to prevent violence in the workplace—who did create workplace violence plans, polices, and procedures for handling this important issue—did so as though they were "just like everybody else." And, they have come to find that nothing could be farther from the truth.

The Reality of Workplace Violence in the Health Sector

The truth, when it comes to workplace violence in the healthcare field, is that the healthcare sector has one of the lowest rates of employee-initiated incidents in the corporate world. However, the healthcare sector has one of the highest numbers of incidents of violence perpetrated against workers on the job. There are many reasons why this is true, but what's important now is the fact that the healthcare community made a serious error in judgment. They operated under the premise that they had the same problem that every other company did, and they could use the same measures (Privitera et al., 2005).

In fact, when it comes to violence in the workplace, the health sector is in such a unique position that the U.S. Federal Bureau of Investigation (FBI) has created a separate listing and considerations for healthcare professionals in the world of workplace violence (Rugala and Isaacs, 2003). Some of the reasons for this include:

1. The typical attack on a healthcare worker is perpetrated by an assailant who “does not” fit the profile established using standard workplace violence data and statistics.
2. The typical assailant in an attack on a medical professional lashes out for very different reasons than a typical attacker in the general corporate world.
3. Healthcare workers are in a very unique position when it comes to dealing with an attack, in that he or she must protect themselves while “simultaneously” providing aid to their assailant.

Healthcare Facilities Need Procedures Based on Specific Data Instead of General Business Practices

Recently, the medical community has been waking up to the realities of workplace violence as it relates to its unique industry, problems, and circumstances. Administrators, managers, and crisis management leaders are reexamining their beliefs, policies, and procedures and seeing the lack of real protection for healthcare workers who are exposed to potentially aggressive patients and visitors each day. What was once seen as a by-product of the job, where healthcare workers received little in the way of support, understanding, or training with regards to attacks from patients and others, more and more organizations are emerging from this almost sleepwalk mode of operating and seeing attacks on its professionals for what they are—acts of workplace violence.

In fact, many facilities, just like many standard companies in the corporate world at large, are realizing that, instead of preventing, reducing, or deterring incidents, the workplace violence plans, policies, and procedures they have in place just might be creating the very “same” liability issues they were first developed to prevent

This new perspective and reevaluation couldn’t have come at a better time. The relative ease with which GIS can be used to help crisis management teams hone in on and clarify the needs of their facility, as they relate to both historical data, and focus an eye on the geographics of their region, more than justifies the use of this powerful tool.

Leading facilities in the healthcare field, organizations like the University of Rochester Medical Center in Rochester, New York, already have dedicated committees whose sole purpose is to manage, educate, and facilitate training to ensure that medical workers are prepared to deal with this threat. With GIS, as an additional tool in their arsenal, these committees can take the next step in helping resistant administrators to see the need and viability of physical defensive and other much needed training courses to ensure the safety of their facility’s core assets.

GIS is a perfect tool to highlight and expose these truths. Instead of looking at spreadsheets, statistics, and reports filled with numbers, the dynamic nature of GIS layering and mapping allows administrators to visually see the reality of who the perpetrators of violence are in the healthcare setting. They will be able to see that the solution to the problem, and the training required for their employees, requires a different approach than that with which most hospitals apply.

Understanding the True Scope of Workplace Violence and the Need for a Tool Like GIS

According to a definition included in the Occupational Safety and Health Administration's (OSHA) Fact Sheet on workplace violence, "Workplace violence is violence or the threat of violence against workers. It can occur at or outside the workplace and can range from threats and verbal abuse to physical assaults and homicide, one of the leading causes of job-related deaths. However it manifests itself, workplace violence is a growing concern for employers and employees nationwide." (OSHA, 2002).

This is an excellent place to begin our research and understanding of the topic and the basis for a complete, efficient, and effective emergency preparedness plan. There are many different variables both onsite and off that can trigger a workplace violence incident, but it must be remembered that the true scope of this danger to healthcare workers is that it is not limited to actions taken by employees against fellow workers.

For years, healthcare workers have simply been left to deal with assaults and aggressive attacks from patients, family members, and other visitors to their departments on their own. And those who were given guidance were given information based on the general profile developed for the typical business model where human resources personnel could actively identify potentially dangerous individuals before they become part of the workforce.

However, in the medical arena, there is no sure way to predict human behavior and, while there may be warning signs, there is no specific profile of a potentially dangerous individual that, alone, can be used to guarantee the safety of workers in the healthcare sector. One of the reasons for this vagueness is in the very nature of the healthcare environment. While most attackers who lash out in the typical workplace do so from a personally driven motive and sense of purpose, the typical perpetrator within the healthcare setting is more likely to do so as a result of pain, grief, frustration, or adverse reactions from medications (Privitera et al., 2005). What this means is that he or she is under the influence of behavioral, psychological, or life-influencing stressors that may cause one to be habitually or temporarily predisposed to aggressiveness in social settings. Finances, trouble at home, or an inability to interact well with others can cause workers to react aggressively when confronted with additional elements.

While this type of possibility is still present in the healthcare setting, the healthcare professionals more often than not find themselves facing an attacker who is reacting to pain, grief, or an adverse reaction to medications. In fact, these elements and their combination, along with fear and other known and unknown factors, can cause a usually passive, kind, and controlled person to act out in an uncharacteristic fashion.

And, it is these elements and the way they create a specific dynamic within a healthcare setting that can be used to form a foundation for the development of policies, procedures, and training programs to ensure the safety of healthcare workers, support staff, and visitors to a facility. Data mined from previous incidents and mapped using GIS technology can verify this truth and also create a much clearer picture of exactly which factors are affecting a facility in general, or a clinic individually, and how.

A Critical Element in Making the Medical Facility Workplace More Safe

The first thing that must be done by the crisis management team charged with the project of developing or updating a facility's workplace violence training and prevention system is to conduct a facility analysis. The purpose of this analysis is to gather as much information as possible to identify, not only areas and departments at risk, but also the level of risk and types and severity of violence that is most likely to be encountered in each setting.

While many see GIS as an "outside" tool used on a large, geographical scale for entities like municipal and community development, global trends like weather tracking, and other outward-based information-gathering needs, software can be developed or focused on data drawn from "inside" the medical facility itself. The beauty of the system is the ability of the software to convert what would be conventionally rendered as numbers and graphs, to graphic maps and images that allow for quick interpretation of the data being extrapolated. And, while it is true that the very nature of violence is random, violence, like most everything else, has a spatial quality. What I mean by this is that violence and its forms do not occur in a vacuum, but in specific places and under specific circumstances. And, certain types of acts of aggression can be seen to appear in specific environments with common variables or elements.

While the actual incidents of violence themselves are random, we can use data to not only isolate areas and departments that have a greater risk factor for the number of violent incidents, but to also:

1. Ensure that the training we are providing to our workers allows them to be properly prepared for the most likely forms that danger will take place within their realm.

Table 3.1 Cal/OSHA Categories of Violence

Type I Criminal intent	The perpetrator has no legitimate relationship to the business or its employee and is usually committing a crime in conjunction with the violence. These crimes can include robbery, shoplifting, trespassing, and terrorism. The vast majority of workplace homicides (85%) fall into this category.
Type II Customer/client/ patient	The perpetrator has a legitimate relationship with the business and becomes violent while being served by the business. This category includes customers, clients, patients, students, inmates, and any other group for which the business provides services. It is believed that a large portion of customer/client incidents occur in the healthcare industry in settings such as nursing homes or psychiatric facilities; the victims are often patient caregivers. Police officers, prison staff, flight attendants, and teachers are some other examples of workers who may be exposed to this kind of workplace violence (WPV), which accounts for approximately 3% of all workplace homicides.
Type III Employee-initiated	The perpetrator is an employee or past employee of the business who attacks or threatens other employees or past employees in the workplace. Worker-on-worker fatalities account for approximately 7% of all workplace homicides.
Type IV Personal relationship	The perpetrator usually does not have a relationship with the business, but has a personal relationship with the intended victim. This category includes victims of domestic violence assaulted or threatened while at work, and accounts for about 5% of all workplace homicides.

Source: California Dept. of Industrial Relations, 1995; NIOSH, 2006.

2. Find and implement best practices and procedures in situations and phases of patient treatment, customer contact, and visitor interaction identified as potential "trigger points."

Again, using GIS technology and a clear understanding of the different forms that workplace violence can take, the astute administrator can create different maps, each focused on one of the Type 1 to Type IV violence categories as outlined by OSHA (Table 3.1).

Managing the Scope of the Facility Analysis

While many more areas and layers of information may be included in the facility analysis, for brevity and to provide the basis for the work to be done, I will limit my example to actual incident types. The management team can extend its research to include many other factors or, where the team lacks the necessary strategic thinking with regards to violence and what I call "the attacker mindset," an outside professional may be consulted to give a more fine-tuned direction so that the correct information can be garnered from the research in the shortest amount of time.

The scope of the facility analysis can be generally divided into internally and externally focused factors. Each will give a different visualization and necessary piece of the overall scope and reality of what's going on.

Internally, information can be collected about past incidents that have occurred hospital-wide and in each department. This is a critical piece of the puzzle and should not be overlooked, as the tendency is to assume that the emergency services and psychiatric departments are the only departments that require specific attention. However, unless the facility is relatively new, a very different picture will emerge after all the information has been collected and assimilated and GIS maps have been created using each of the OSHA category types.

Information can also be gathered from outside the hospital: from within the local and regional geographic area that surrounds the facility. By extending focus outwards, and through partnerships and coordination with local law enforcement, similar data can be collected to better identify possible trends and patterns of violence that may be common to an area.

As mentioned before, the assumption about workplace violence in the healthcare setting is that it comes from the inside, limited to employee-initiated attacks upon other employees, just like every other business. Again, due to the very nature of a medical facility's open environment, especially hospitals, and the fact that most attacks for this industry are perpetrated by visitors from outside the organization, makes this kind of information vitally important if we are to be properly prepared.

As I said, violence is random by nature, but knowing what kinds of violence and the most common types likely to arise in a given setting allows us to develop training and procedural systems that are similar to those we would develop and use for handling trauma, civil emergencies, biological containment hazards, or any of the other crisis management systems within the medical sector.

Using GIS Research to Design More Effective Workplace Violence Training Programs

When examining the data from our research, we are looking for not only the number of incidents overall, but we are looking for patterns. By reviewing the types of variables that I described earlier, we can create a much clearer picture of the trends and needs within certain departments and settings.

For clarity, here's an example of a typical mapping layer from data within a facility. Let's assume that, out of all the incidents that occurred facility-wide, your emergency management team wants to see what patterns exist with regard to the incidents that were triggered by pain. By narrowing my search, I can see which clinics have had the most incidents and, therefore, which professionals are more likely to be at risk for pain-induced aggression.

Perhaps, we then add another variable and set out to examine the types of attacks and category of violence. We can divide our work data so as to see where striking, grabbing, use of weapons, or incidents where attackers used available medical implements or even furniture, to get a different layer or picture as to what the incidents are like.

By extension, we can use GIS data from local law enforcement, local government, and social service agencies to explore the community around the facility. We can look at factors, such as, not only crime rate versus socio-economic status, but what types of violence is prevalent in our local community. An increase in the number of gang-related violence could mean that not only will our emergency department be seeing more wounds and trauma from that sector, but it also signals the potential for that violence spilling over into the facility itself as more and more of these types of visitors will be entering the workplace as victims, visitors, or family members.

The point here is that crisis management, human resources, and emergency preparedness professionals now have a better tool, and an excellent opportunity to structure their system development, procedural policies, and training programs around solid, objective information that has a basis in fact. Programs and training to ensure worker safety can be individualized to a particular facility's unique internal and external geographic state rather than based on theory or the procedures used by hospitals in other unique regions.

There will, of course, arise out of the use of this tool some common truths about what healthcare facilities need on a global basis. But, just as each facility is unique, so is the geographics of its unique location. And these individual factors and elements, when examined, can be seen to create very specific dynamics that will be played out in a given facility.

Extended Data Layer Possibilities for Human Resources and Crisis Management Professionals

As more and more medical centers and hospitals in general are adding and maintaining services that extend beyond their facility and out into their community, it is prudent to add some additional thoughts pertaining to the personnel who work in these capacities. They include:

- Emergency medical responders—whether ground or aircraft-based

- In-home care and hospice workers
- Counselors and psychiatric service providers
- Disaster response teams

For these healthcare providers, the knowledge that can be derived from mapping data about the communities in which they serve can be not only beneficial, but it can be lifesaving. By including GIS data concerning streets, neighborhoods, even specific addresses, and any known past activities that can assist the healthcare worker with not only doing his or her job, but also giving them foreknowledge about any potential threat or danger that might be present, we increase the likelihood that these providers will be able to deal with an incident in the safest and most professional way possible.

Garnering this information and translating it into specifically tailored training that will give professionals the skills to diffuse, neutralize, or escape from potentially harmful situations, will not only reduce job-related stress among these workers, but it will also translate into less lost-time issues, fewer EAP (employee assistance program) referrals, reduced employee turnover, and, of course, a lower occurrence of liability complaints that arise from the collateral damage caused by personnel who are untrained and unprepared for a violent attack.

Conclusions

There is no doubt that GIS should be an integral part of hospital emergency response systems and procedure development. It is my contention that it not be overlooked as a tool for the development of unique and specific training programs to ensure that healthcare workers are prepared and capable of dealing with a threat that most never considered when choosing their occupation: the threat of violence in their workplace.

The random nature of violence makes determining when an attack will occur difficult, but the use of GIS as a tool to map relevant data can provide a clear picture about the types of incidents that do occur within an area. This spatially related information can be used to tailor specific training within departments to ensure that not only does each department, clinic, or facility get what it needs most, but it also cuts down on costs for unnecessary and even inappropriate training, and the financial loss related to an incident by way of property damage, injuries, liability issues that may arise out of the collateral damage caused by untrained personnel, and the effects of negative public relations, both in the community and within the hospital itself as employees and visitors alike share their feelings and perceptions about these incidents.

It is the job of healthcare service providers and workers to treat consumers who come to them as a result of injuries and trauma. But, these professionals are also at risk, more often than nearly any other profession, from being attacked by the very people they are trying to help. It is, therefore, imperative that administrators use every tool at their disposal to ensure that their policies, procedures, and training models reflect, with clarity, the needs and solutions that will prevent and protect those who they depend upon. GIS is such a tool and can be used to provide a very clear picture of what is needed, by whom, and why. With that information, administrators and managers will then be able to provide for a safer, more stress-free, and enjoyable working atmosphere. While this does not guarantee that violence will not enter the medical worker's workplace, it does provide for the best training and procedures for handling any problem that does arise, and in the same way that medical professionals handle the routine trauma that comes to them every day.

In the end, facility administrators must way the cost of using GIS technology against the losses caused by violence in the workplace. Aside from property damage and loss of life from catastrophic incidents, also to be considered are factors, such as lost time, high employee turn-over, high stress among workers, lower productivity, and even the cost of health issues for workers exposed to the constant fear of danger on the job. In this light, adding GIS technology and trained staff to its emergency management team could be one of the most beneficial decisions a cutting-edge facility can make.

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Chapter 4

Infectious Disease Surveillance and GIS: Applications for Emergency Management

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Contents

Introduction

Geographic Information Systems (GIS) have been used in infectious disease surveillance and management for many years, yet still remain underutilized for these purposes (Graham et al., 2004). Usage has generally been centered on macro environments with focus around public health and animal health (Sanson et al., 1991), particularly in zoonotic diseases (Mott et al., 1995; Norstrøm, 2001) at the county or state level. Environmental contamination poses an exposure hazard and the use of GIS can enhance understanding of its role on health by providing information to allow benefits, such as "data analysis, hypothesis generation, confirmatory data analysis, and decision making" (Tim, 1995). The need for this type of data around health outcomes was made especially clear after the 1986 Chernobyl nuclear power plant disaster in the Soviet Union (Tim, 1995) in assessments of emissions on air quality (Dent et al., 2000; Levy et al., 2001; Ackermann-Liebrich et al., 2005; Mindell and Barrowcliffe, 2005), pesticide use (Brody et al., 2002), and other chemicals (Jarup, 2004).

Bioterrorism poses an additional threat where the use of GIS would be of benefit to link spatial data to human disease. One example is the spread of anthrax spores through a U.S. Postal Service (USPS) facility in September 2001 (Zubieta et al., 2003). GIS could have played a useful role in identifying the areas that may have been most highly contaminated and allowed for focused decontamination efforts. However, this would have required tracking many items and personnel through the facility in real time and would have necessitated a very sophisticated system. This was further compounded by the problems inherent in the characteristics of the anthrax spores that were used, which were prone to easy dissemination. The mechanical mail handling process itself could have contributed to the aerosolization and dissemination of the spores in the facility. The investigation was further complicated by the lack of access to employee data due to fears of further dissemination of spores by fans in the computers. This example also indicates the need to consider housing the application and data offsite or as an Internet-based service.

The environmental health model for GIS forms a good framework for application in a GIS application for healthcare settings. Geographic healthcare data can garner some of the same benefits gained by providing a method for "efficient organization, manipulation, analysis, and presentation" (Tim, 1995) of temporal and spatial health outcome relationships.

In a study by Zwarenstein et al. (1991), GIS has been used in healthcare for assessments of population per hospital bed ratios and access to hospitals based on race in South Africa. However, it was recognized as well that there may be true geological barriers that prevent access to healthcare that were not ascertained through the GIS application. When there are multiple variables that contribute to health outcomes, multiple layers of data need to be collected using GIS to fully understand the complex problems posed in healthcare. In the hospital setting, these layers can include the physical location of the patient, equipment, and staff to help recognize vectors that can be contributing to disease transmission.

Careful recognition of some of these limitations of collecting this data is necessary before making policy decisions. Zwarenstein et al. concluded that access problems were primarily around a rural versus urban hospital distribution leading to lack of care in rural areas and overcrowding in urban hospitals.

There has been very little in the way of using GIS as a tool for assessing infectious disease transmission in hospitals or for emergency management purposes, although there are a number of applications for GIS technology in these settings. An analog for this application has been used to assess canine gastrointestinal illness in animal shelters (Sokolow et al., 2005). Even more focused areas for GIS applications have been identified as well (Garb et al., 2007) indicating a need to do further research beyond the public health level where most health-related GIS information is collected and analyzed.

GIS Technology

Process

GIS data processes must be automated in a healthcare environment. Infection preventionists (IPs), who are the likely professional group working with this type of data, are generally stretched too thin conducting their day-to-day activities. The less manual work that is required to collect, manage, and analyze this data the more likely it is to be put to use in a way that will benefit patients, staff, and visitors in preventing disease transmission.

The user interface (UI) of this system will be critical for its successful implementation. If the interface is not designed well, the end user will not use the system to its full potential from day to day and, therefore, may not have the proficiency to use it during a disaster. The system will be most beneficial during an emergency if the end users are familiar with the system from regular use. A well-designed UI will ensure that the application is a useful tool for the IP who may not have the technical skills required to use a more complicated interface. In addition, the system components must all work in a self-contained user interface instead and not spread over separate applications. There has been a call for integration of the different functions within the same application as well for public health data (Rushton, 2003).

Douven and Scholten (1995) identified a cyclical process in the stages of the use of spatial health data. These stages include "(1) the collection and preparation of disease data; (2) the mapping of data to identify spatial disease patterns at a variety of scales; (3) applying objective statistical tests in order to consider whether the variation is significant and, if so, at what spatial scales; (4) measuring the association between disease and other spatially varying factors; (5) the interpretation of the results of the previous stages, the indication of areas interesting for further research, and eventually the generation of hypotheses; and (6) searching for possible causal relationships."

Collection

Data collection must be automated for a GIS application to function in a healthcare setting. This will require the integration of data from various health information systems (HIS), including laboratory information systems (LIS), admission–discharge–transfer systems (ADT), as well as other clinical data from the electronic medical record (EMR). This only serves part of the data need for a comprehensive system, however. ADT data only collects the assigned location of the patient. This leaves data gaps when a patient may roam the halls or leave their room for procedures and tests. These gaps can be addressed with other technology.

In addition, data must be automated for the spatial portion of the data collection. One method that might serve this purpose would be the use of active radio frequency identification (RFID) tags. The most familiar use of these devices is for automated collection of payments in vehicles along toll ways. These devices are also used regularly in inventory management systems. In the healthcare setting, they could be used to track the entry or exit of people or equipment from rooms or use of hand hygiene facilities. Capturing patient data specific to place and time can later be linked to clinical data, such as infectious diseases or the presence of antibiotic resistant organisms.

Mapping

It will be important to collect data with different scales of resolution (Wittie et al., 1996). Data need to be reviewed at the room and unit/floor/service level for analysis. If there are statistically significant rates of transmission at broader levels, it may be a flag to review data at the individual room level as a method to provide detail for further review of potential causal factors The opposite is also true to identify broader problems within an area that can be leading to transmission. A GIS system designed for a healthcare system should have this functionality built into the product.

A developer of a GIS system for this application will also need to determine if vector-based (i.e., points, lines, polygons) or raster-based (i.e., image or cell-based) data are the best solution for a healthcare setting. Raster data can be implemented using digital versions of hospital blueprints. The general concept is that a hospital digital facility drawing, or "blueprint" (e.g., from a computer-aided drafting (CAD) system), is overlaid on a coordinate system. Each cell of the coordinate system is assigned an "x, y" location and attributes for identifiable features in the CAD drawing. It's really more complicated than this because the coordinate system has to be customized for each floor of the facility and should include a "z" (vertical) coordinate so each area of the CAD drawing can be assigned x and y horizontal coordinates as well as a z (height above floor) coordinate. This approach is beyond the scope of this chapter.

A vector model is another approach, but may be more difficult to construct for each site. In this approach, it is conceived that all features of interest are created in the vector system as points (e.g., hand hygiene stations) or polygons (e.g., beds, rooms, units). To adequately pursue either the raster or vector model, or a combination of the two, the facility should form a project committee of user and designers to assure all issues, functionalities, and situations are addressed.

In addition to data layers of patient room and individual patient flow as collected by RFID devices through the facility, it would be helpful to have another layer representing staffing patterns as well. This would help provide data on the relationship between staff assignments and transmission of disease. This layer may be one of the more problematic to implement due to logistical problems, staff perceptions, and legal/ethical issues around staff monitoring.

Statistical Testing

Random variation in spatial data will lead to incorrect inferences without performing careful analysis. Statistical tests that account for geographic variation must be incorporated as a means to eliminate inaccurate conclusions from GIS data. The statistical tools for the analysis of geographic data are continuing to evolve in this rapidly changing field (Kulldorff, 1999). However, since the boundaries delineating spaces in healthcare settings are not as arbitrary as those of geopolitical boundaries, there might be less impact on statistical measures compared to data sets with much larger geographical boundaries. Still, it is important to remember that "distribution of disease, therefore must be considered in a population as well as in space before the significance of incidence can be assessed accurately" (Koch and Denike, 2001). This can be accomplished by both simultaneous Kernel estimation and cartogram methods (Koch and Denike, 2001) as well as other approaches (Rushton, 2003).

Association Measures

It will be important for a GIS system to either have datamining capabilities or be able to easily communicate data to common datamining systems used by IPs. These systems find associations between data sets and alert the IP of an incident worth further investigation.

A healthcare GIS package should include tools for calculating measures of association between variables. End users may not have backgrounds that afford them an understanding of the strengths of association, so the output needs to be produced in such a way as to simplify the understanding of these measures. In addition, the package should have an advanced user set of features for those who are more familiar with the meanings of this type of data allowing the IP to perform their own detailed analysis as well.

Hypothesis Generation and Causation

The data should be presented in such a way that the end user can determine possible interventions based on suspected causes. The outcomes of these interventions then can be assessed statistically during the next data collection phase to determine if the intervention has improved patient outcome or decreased risk.

Application for Infection Prevention

A well-designed GIS system for healthcare settings would be beneficial to the IP by allowing for the analysis of the potential of disease transmission related to time and place. The volume of data that must be reviewed and analyzed does not allow for assessment of environmental risk factors. There are a number of areas in the workflow of a busy IP that could benefit from this technology.

IPs spend much of their time monitoring for cases of antibiotic resistant organisms, including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *enterococcus* (VRE), and other less common organisms. They also must monitor for common diarrheal organisms, such as *Clostridium difficile* and norovirus. Other easily spread diseases are commonly present in hospitals, including chickenpox and tuberculosis, to name a few.

Exposure Management

A GIS system could help the IP and employee health department manage exposures to infectious disease. For example, tuberculosis can often go undiagnosed for days or weeks when a patient is admitted. This delay in diagnosis can lead to hours or days of additional work for the IP. This is due to the process of manually reviewing the medical record to identify individuals who may have been exposed during the course of the patient's stay. If data were collected on the patient and healthcare worker's (HCW) location, the remaining investigation would be to ascertain the level of risk of each exposure with notification to staff of their exposure status for follow up. Much of this investigative work could be automated with a well-designed GIS system.

This type of system could be useful in identifying clusters of other occupational exposures as well. These are often categorized as needle sticks, sharps exposures, and splash exposures. These most commonly occur in procedure areas, such as emergency rooms and operating rooms. However, linking place and time data may provide recognition of patterns in other departments where processes should be reviewed to minimize these risks to HCWs.

Outbreak Management

Outbreaks and clusters of disease also can be common problems in healthcare settings. There are a number of factors that place patients at risk for the development of a healthcare-associated infection (HAI). These risks can be either intrinsic or extrinsic in nature. Intrinsic risk factors are those that are inherent to the status of the patient, such as age, severity of illness, and overall health status. Extrinsic factors are those that are a result of being within the healthcare environment, including medical practices, invasive devices, and even cohorting with other ill patients in the same room. A GIS system could provide data that would allow for the early identification of clusters of disease in a particular area of a hospital. In addition, it could link transmission to particular HCWs or pieces of equipment by collecting GIS data on their locations.

Hand Hygiene Compliance Tracking

One of the most important roles of the IP is monitoring hand hygiene compliance. It can often be difficult to collect valid data due to barriers like time constraints or the behavioral changes that occur when someone knows they are being observed. An RFID-based GIS system could aid in this process by collecting data on hand hygiene use by measuring time of HCW at sinks or proximity to alcohol hand rub dispensers.

Application for Emergency Management

A GIS system in a hospital could be beneficial during an event that would activate a disaster response. A few examples would be around exposure ascertainment to contaminated or ill victims, pinpointing victim locations during a structural failure, and providing situational and status updates during an evacuation.

Exposure Ascertainment

During a naturally occurring or terrorism-related event, it will be useful to be able to ascertain the exposure status of anyone seeing patients who is either contaminated with chemicals or radiation or has become ill with a transmissible disease. This situation is similar to what could be accomplished for IPs during routine exposure management activities and may be one of the most beneficial routine uses of such a system in an emergency situation. Protecting the safety and health of the HCWs is one of the most important goals during an incident. This would allow for the rapid assessment of exposure and the need for decontamination, treatment, or prophylaxis of disease.

Victim Pinpointing

A GIS system could assist with pinpointing the likely locations of victims within the facility during a major disaster, such as an explosion, earthquake, or other catastrophic event leading to a structural failure. If the locations of the highest numbers of staff and patients are available due to GIS tracking, focused rescue efforts could be made in those areas with the greatest chances of finding survivors.

Situation and Status for Evacuation Purposes

A third application of GIS would be for patient tracking in evacuation situations. Situational awareness is crucial in an emergency command center. A GIS system would provide real-time data for patient tracking purposes to provide the command center with an accurate picture of both the patients remaining in the facility and the HCWs available as resources once their units are cleared. The data file could also include a field for the entry of final patient disposition data, which would facilitate the locating of patients by family members.

Barriers to GIS System

There are a number of barriers to the development and acceptance of a GIS system in healthcare settings. These include the lack of awareness of the benefits of a relatively new technological application as well as the costs of development by a potential vendor in a marketplace where the adoption of the technology by healthcare organizations is unknown.

Collecting staffing data will be more difficult than simply collecting data for logistical reasons. These data are often not available electronically, requiring manual entry of staffing assignments, unless a facility uses electronic methods. This can cause a barrier in that it adds an extra step to the data acquisition process.

A larger barrier around staff assignment data may be related to perceptions from staff that the administration is taking a “Big Brother” approach to monitoring. Union groups may oppose the collection of this type of data because of the potential perception that this may lead to punitive action for staff when there is a possible documentation of an association between a staff member and the spread of infection among patients.

There are also ethical and legal considerations that are important before implementing a process that would track staff. These are likely the two most important problems that will need evaluation before implementing a GIS system that collects data on staff movements. The American Civil Liberties Union logs more complaints about workplace rights than other issues. Extreme care will need to be taken both from a vendor perspective and also from that of a healthcare organization before implementing a system that monitors employees electronically.

Lack of Awareness

Except in the case of medical technology that directly impacts patient care, healthcare settings are rarely early adopters of new technology. This is due to both a lack of awareness and a sense of good stewardship surrounding unproven technology. It will be important to take the lessons learned from other GIS applications, particularly from public health and veterinary health settings, and apply them to explaining the potential benefits for use in human healthcare settings.

Costs and Economics

The reluctance to early adoption by healthcare facilities will create a barrier to entry into the healthcare GIS marketplace by developers. Developers may perceive that the risk may far outweigh the potential gain. GIS developers can redevelop their products to include a healthcare specific application. Other opportunities for partnerships can be formed between a GIS developer and an infection prevention datamining provider to provide a service that is not offered by any other datamining vendor in the marketplace. This strategy minimizes individual risk as it brings two existing functions together with the need for only minor revisions to make a useful application in the healthcare setting. A third partner in this technology of real-time tracking with devices, like RFID tags, could further strengthen this technology package for potential customers.

Conclusion

Healthcare settings can greatly benefit from the application of GIS. Hospitals represent a newly emerging marketplace for this type of technology. They could prove to be a financially viable opportunity for an organization willing to bring the right resources together for a product that will both reduce hospital costs and improve outcomes. Proper development could lead to a product that could be marketed for the benefit of both routine use and during an emergency.

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Chapter 5

Role of GIS in Interagency Healthcare Logistical Support during Emergencies

Jerry D. VanVactor, DHA

Contents

Introduction

Most healthcare organizations have some form of emergency response plan embedded within standing operating procedures. To facilitate an efficient and effective response during catastrophic events, logistics readiness must be included in response planning. Knowing how supplies are being delivered to a healthcare organization, from where deliveries are originating, to whom the supplies are being delivered, and how the material is being delivered are essential elements of emergency response, planning, mitigation, and recovery. Geographic Information Systems (GIS) is a key component in effective supply chain management and respective Information Management/Information Technology (IM/IT) systems should be embraced and included in disaster planning efforts.

Logistics planners tend to err because they spend a great deal of time planning for the most recent event after it has already occurred and to consider future events may seem foreign to some planners when evaluating an intra- or interhospital capability. Perceptibly, healthcare logistics is what takes place when a ward or department requests supplies from a warehouse and receives items from the hospital storeroom. Although this may be a common perception of logistics management, the idea is ill founded, especially when evaluating the impact of interagency sustainment during a catastrophic event. To effectively orchestrate an effective response to emergency scenarios, healthcare logistics planners should think of the relational value of interagency response and employing available tools to ensure the right products, quantities, and requirements are being shipped to the correct customers in a timely manner.

Logistics is defined as the implementation and controlling of the efficient and effective flow and storage of goods, services, and information between a point of origin and a point of consumption to meet end users' requirements (Vitasek, 2006). Pagonis (1992) relates that supply chain management, an element of logistics sustainment, includes the integration of transportation, supply, warehousing, maintenance, procurement, contracting, and information management into coherency in a manner that prevents the suboptimization of any of the individual activities. Sustainment includes the provision of personnel, logistics, and other types of support that aid in maintaining operational capabilities until successful mission accomplishment can be achieved. This concept is especially not evaluated, in some instances, as a capability interwoven into the fabric of a healthcare organization's emergency management plan.

Logistical needs extend beyond the needs of first responders at the scene of a catastrophic incident or during a crisis response phase. Ultimately, the purpose of a supply chain is to serve end users effectively by providing a process through which product is moved from initial production through consumption via multiple layers of internal and external stakeholders (Schutt, 2004). Defining and communicating with the appropriate stakeholders is part of the challenge associated with effective healthcare supply chain management (Cunningham, 2006). The

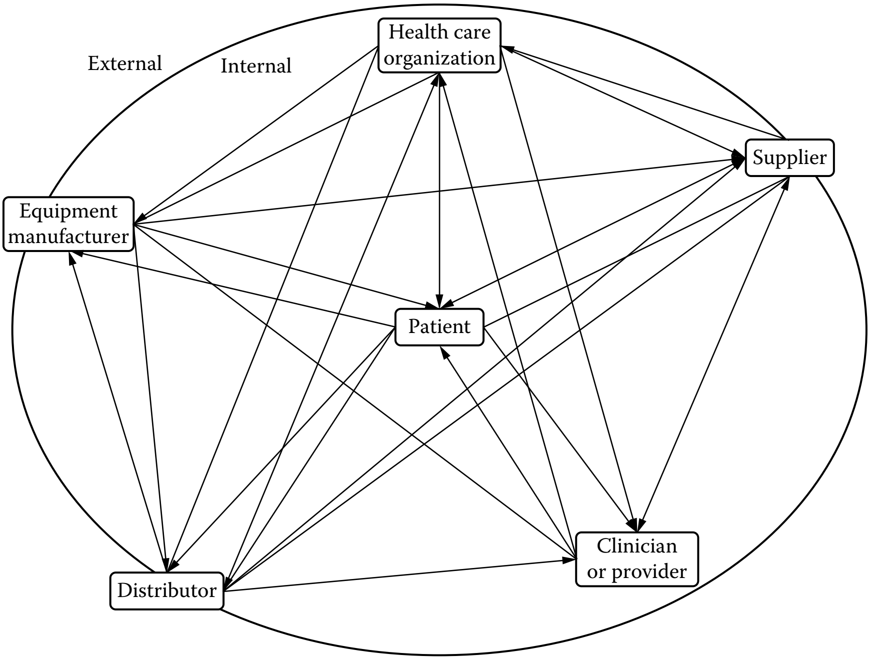

Figure 5.1 Multidimensional logistical support.

challenge in healthcare occurs when, as Schneller and Smeltzer (2006) indicated, the stakeholder within a healthcare value chain (internal) assumes numerous identities. Stakeholders within a healthcare environment (customers with immediate needs within the organization) can include the patients, clinicians, nurses, ancillary care providers, and employees within organizational departments. Stakeholders in a healthcare value chain can also be external (customers and suppliers external to organic business practices and processes) to the organization, such as third party delivery agencies, external suppliers of goods and services, printing services, publishing agencies, and so forth (Schutt, 2004). Healthcare logistics support is multidimensional and multifaceted and can be complex in many cases, as illustrated in Figure 5.1.

Contingency planning should provide for interagency collaboration regarding logistical support prior to a catastrophic event occurring. Every disaster situation is unique. Preplanning and preparation can often anticipate many issues that can arise during a trigger event. Emergency preparedness, when done right, pays significant dividends when a disaster strikes. Disasters can take a variety of forms from naturally occurring events, such as catastrophic storms or wildfires, to more recent, prominently focused manufactured catastrophes, such as workplace violence and other random acts of terrorism. Regardless the size, magnitude, or location of a catastrophic event, logistical preparedness is integral to overall preparedness for such events. While there is no one basic plan that fits every situation, appropriate planning is essential for such events regardless the typology (Schneid and Collins, 2000). Logistical difficulties that may arise during emergencies can relate to the lack in predictability for operations, limited knowledge concerning length or location of an event, the speed at which an event can occur, along with the duration and intensity, potential recurrence, and mitigation of future events (Alexander, 2002).

Preparedness is a dynamic state in which an organization can reside; logistics is a support mechanism for emergency response planning. As stated by Zaric et al. (2008), no individual agency is singularly prepared to respond completely and effectively to a catastrophic event. Because of this, healthcare organizations must develop emergency response plans that embrace interagency response—preparing to provide assistance across a wide gamut of mutual aid scenarios. Disasters never strike one individual at a time. Catastrophic events can be large, rare, and can often cause unusual amounts of damage to not only external stakeholders' infrastructure, but can have an adverse effect on the overall healthcare management system itself (Kapucu and Van Wart, 2008).

Why then should logistical readiness be considered in the healthcare institutions emergency preparedness planning? Logistics management processes and practices, in disaster management, provide healthcare leaders an ability to identify, dispatch, mobilize, and demobilize support teams and track, record, and manage critical resources needed during a catastrophic event. Finding ways to get necessary supplies to personnel and facilities during a disaster requires logistical networking, flexibility, and creativity (Kapucu et al., 2007). In addition, planners can use "spatial thinking" to support an understanding of where supplies are, where they need to go, and how and by what route customers are going to receive material is critical to preemergency planning. For a healthcare logistics support agency to act effectively in disaster situations requires sharing and using information effectively (Kapucu, 2006) through the most appropriate and effective information technologies, such as GIS.

Logistics during Four Phases of Crisis Intervention

There are four identified phases of emergency management and crisis intervention: preparation, mitigation, response, and recovery. Preparation permits an organization to be ready at the time of a catastrophic event and prevent, where possible, second and third ordered effects related to a disaster's occurrence. Mitigation is action taken to reduce the impact of a disaster throughout an organization or community. Response is action taken during and immediately after a disaster's occurrence. Finally, actions related to recovery are taken in the immediate aftermath of a disaster and throughout the long-term afterward to return an organization or community's functions and activities to normal as quickly as possible. As is illus-

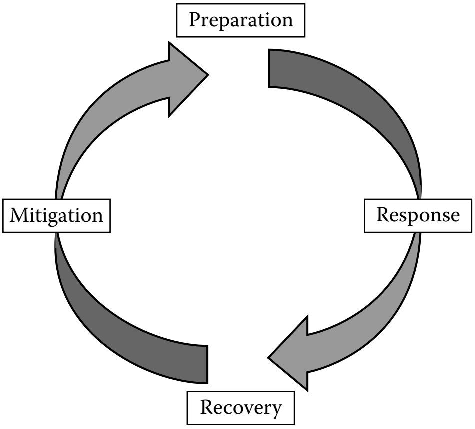

Figure 5.2 Phases of emergency management. (Adapted from FEMA, 2006a.)

trated in Figure 5.2, the four phases occur over a contiguous cycle and each phase contributes to the success or failure of the next.

Preparation

Preparation is likely one of the most critical aspects of logistical readiness. As Berke and Campanella (2006) indicate, a well-conceived plan conveys a sense of demonstrated foresight when the logistics leaders charged with emergency response responsibilities present an appearance of being well organized and in charge, carefully considering issues and contingencies prior to a crisis actually occurring. One goal of crisis mitigation planning is the actual prevention of a crisis prior to its occurrence. By giving logistical readiness some forethought, this could include supply storage locations and alternate supply locations, alternate supply routes, shipping methods, sources of supply, evacuation routes, alternate facilities, and so forth, for an affected healthcare organization. To plan for such countermeasures requires coordinated synchronicity and collaboration among multiple stakeholders—often external to a healthcare institution (Howarth, 2003). Events, such as the 2009 H1N1 flu (swine flu) pandemic, response related to natural disasters, such as recurring wildfires and widespread flooding, and manmade disasters like random acts of terrorism can quickly escalate beyond the control of a single agency. Logistics managers should bear in mind that first responders, first receivers (e.g., emergency departments), and those resources supporting these entities can often become the targets of catastrophic events as well.

Preparedness involves the actions taken prior to an event's occurrence that may reduce the impact of a crisis when one is imminent (FEMA, 2006b). Each catastrophe scenario is unique; prior planning and preparation can often anticipate issues before they arise. Disaster response is often made worse if coordination efforts among a variety of agencies are poorly administered (Kapucu and Van Wart, 2008). An integrated plan facilitates more resources working together, broadens the scope of interagency efforts, and provides more stakeholders with access to a wider slate of planning and regulatory tools (Berke and Campanella, 2006).

Commensurate with recent efforts to develop emergency response planning based on an all-hazards approach, disaster planning is often based on a set of incidents and not the interconnected sets of circumstances. Emergency planning, because of this lack of potential interconnectivity related to mitigating the effects of crises, remains an unacceptable reactive exercise in healthcare (Erickson, 2006). Preparedness is a continuous process that involves a concerted effort at multiple levels of government and among government and private sector (nongovernmental) organizations to identify threats, determine vulnerabilities, and identify required resources (FEMA, 2006b). Especially in logistics preparation and planning, a reactive approach is not ideal in disaster mitigation efforts. The advantage, logistically, is fostered when interconnected agencies are able to communicate requirements through multiple mediums to ensure supply availability during a catastrophic event. One element of planning may involve a collective understanding that many incidents require similar materials across a broad spectrum of occurrences; separate agencies can develop an ability to cross-level supplies during an emergent time of need. If healthcare logisticians learn to evaluate the circumstances leading up to and resulting from a variety of catastrophic events, a more proactive capability can begin to be embraced by planners.

Mitigation

Mitigation involves actions taken to reduce the impact of future crises. Logistics, while often indirectly involved in patient care, can have a direct impact on the provisioning of necessary health-related response capabilities. One of the foci of emergency planning is to reduce the risk to life and limb as a result of actual or potential disasters, reduce damage, help ensure public safety, and care for victims and survivors (Alexander, 2002). Logistics capabilities are interwoven among the fabric of response planning and crisis mitigation capabilities.

Healthcare logistics is a critical element and function of disaster mitigation and management (Schneid and Collins, 2000). Mitigation tends to be viewed from macro levels of influence. By understanding alternate sources of supply, available routes to and from specified locations, alternate mediums for the transportation of goods and patients during evacuations, and assistance capabilities for facilities upkeep and management during catastrophic events, healthcare organizations can be better prepared to face events as they occur. While it is impossible to identify every condition that could be generated by specific sets of hazards, an ongoing situation analysis can assist logistics leaders in emerging managerial assessments of organizational strengths, weaknesses, and opportunities internal and external to the organizational environment (Perry and Lindell, 2007). GIS can aid in this aspect of emergency management by providing real-time data to managers as events transpire and can allow those managers to facilitate a more orchestrated response during catastrophic events by providing a means through which to "see" the larger picture of what is taking place in a geographically affected area.

If the event is a small-scale event, the incident command structure and response may be very limited and logistics may occur after the fact. In larger-scale incidents, however, a formalized chain of command may have to be implemented and logistical support may become one of the functions of the incident command team. Part of a mitigation strategy involves a predetermined set of responses for an event once the disaster strikes. As events begin to unfold, circumstances will begin to result in immediate decisions, actions, and impacts at multiple levels of management. When the crisis begins to exceed the capacity of a singular organization, managers may begin to experience a *fog of war* wherein perceptions will begin to yield to a misunderstood inability of an organization to cope and may begin to compound into inactivity and apathy, feelings of disjointedness and inadequacy, and irrational decision making. By developing a plan before the event occurs, logisticians can mitigate much of this, even though each incident will be different than the last.

As depicted in Figure 5.3, a baseline decision-making model becomes helpful when establishing criteria for preevent logistical support. Mitigation involves, prior

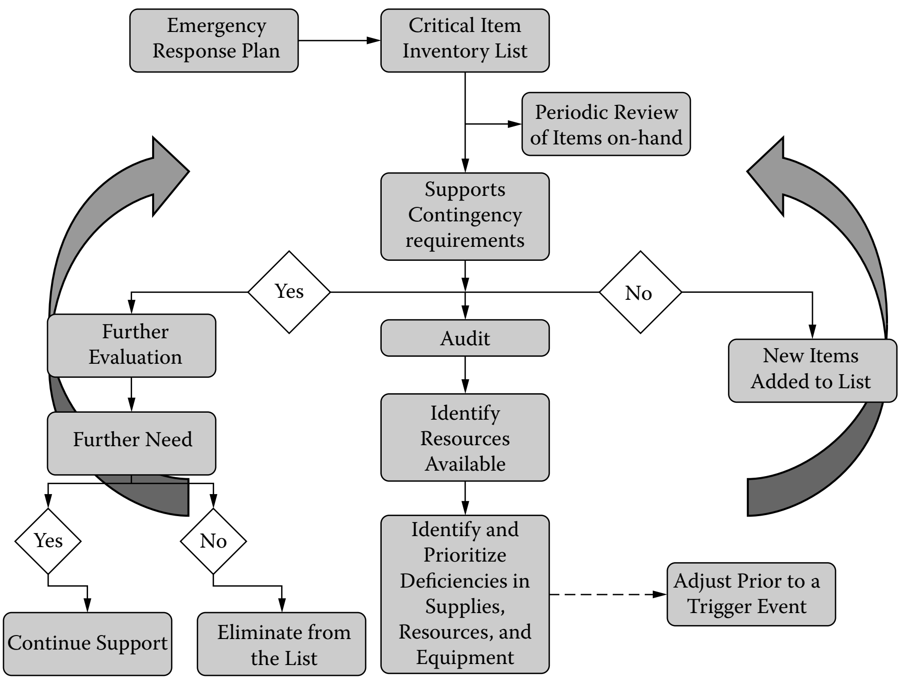

Figure 5.3 Emergency management logistics algorithm.

to an event occurring, a periodic review of critical items in an inventory and determining if those items are still necessary. If an item is no longer needed, it should be removed from an inventory listing. In a similar vein, if during the review, a determination is made that an item should be included where it was not previously, it should be added to prevent a supply chain disruption when an event occurs. The predominant factor that should be evaluated is whether or not an item being considered supports a contingency plan. If the item serves no purpose and does not support the plan then the item should not be included in future policies and procedures until a determination is made that the item should be returned to the inventory listing.

During the initial response effort for an event, there will be little time for deciding among events and there may be a period of extremely rapid supply consumption that will taper as the length of an event extends (Alexander, 2002). Any function that supports the delivery of essential services must be considered an element of the logistics chain and planned for accordingly (Perry and Lindell, 2007). Much like preparation, mitigation involves the identification of common characteristics of hazards most likely to affect operations in supply chain management.

Response

Response involves the immediate action taken during the occurrence of an event and during the immediate short-term aftermath (FEMA, 2006b). Crises can involve direct (i.e., damage to facilities, contents, personal injuries) and indirect (i.e., loss of employment, revenue) losses. Both may persist over varying amounts of time depending on the levels of loss sustained (Alexander, 2002). Some of these losses can be attributable to inefficiencies in planning and mitigation strategies once the response phase begins.

Policy related to disaster response must be written in a way that addresses life safety, property protection, continuity of operations, and protection of the environment (Schneid and Collins, 2000). Response involves the activities associated with addressing short-term, direct effects related to an incident. A logistics-related planning process should focus on key principles of supply chain response. By employing GIS technology, response efforts can be better synchronized to provide more accurate and effective provisioning of supplies and services to the most affected areas during catastrophic events.

As related by Federal Emergency Management Agency (FEMA, 2006a), cascading events can occur as a result of a catastrophic event. Cascading events were defined as events that occur resulting either directly or indirectly from an initial event. As an example, one need turn to the circumstances resulting from Hurricane Katrina in 2005. Many hospitals through southern Louisiana, Mississippi, and Texas were unable to receive critical medical supplies due to rising flood waters and the impassability of major thoroughfares throughout the region. Critical patients were moved to alternate hospitals and lifesaving pharmaceuticals were brought into the region, sometimes by boat. During this type of catastrophic event, alternate courses of action must be known to mitigate the second- and third-order effects of not being able to care for patients in an affected area.

Logistics management can be a key player in this aspect of emergency planning. As a component of an Incident Command System (ICS) or Emergency Response Plan (ERP), the logistics professional must be cognizant of support requirements and the availability of support and services for various types of emergencies. This cognizance must also include policies related to the management of resources, reporting, tracking resource needs, tracking the source, availability, and use of resources, procurement, and compensation for owners of private property used by the community during the response (FEMA, 2006b). There will be, invariably, shortfalls in the emergency plan; overcoming those shortfalls through an interagency approach could be considered a significant win for healthcare organizations.

Especially in the response phase, problem areas will be highlighted more prominently than in any other. Alexander (2002) related that the provision of health and medical services involves a plexus of problems during an emergency. Critical in this concept is the fostering of an interagency and interorganizational view of emergency response and planning. Multiple stakeholders have a vested interest in the type of information, types of plans respective agencies have, and an opportunity to maintain operational consistency and complementary content among message traffic being provided to the general public (Perry and Lindell, 2007). Three shortfall areas of consideration are identified in this text and include such aspects as gaps in planning, plans becoming outdated too quickly, and confusion related to a plan being too detailed.

Gaps in Planning

The possibility of anticipating every contingency that can create an adverse effect on an organization is not feasible. Every logistics support and sustainment plan will have gaps. The time to discover these gaps in support is not during the response phase of a disaster. However, once the response phase begins, should gaps in support be discovered, logisticians must work aggressively to rectify any shortcomings related to the health and safety of an affected population at risk. Gaps in an emergency management plan can be overcome in a variety of ways. Ideally, though, they should be overcome by identifying appropriate and sometimes alternate sources of supply, designating facilities for use during the crisis, and aiding citizens in being more prepared for when an event occurs (FEMA, 2006b).

Plan Specifics May Become Quickly Outdated

"Planning can make a difference in mitigating against the effects of a disaster, including saving lives and protecting property, and helping a community recover more quickly from a disaster" (FEMA, 2006b). Ideally, the emergency plan for an organization describes how the entity will do business when an emergency occurs;

the plan, however, is not an end-all document. This plan cannot become a static document. An imperative of emergency planning efforts related to interagency response is a periodic review of planning documents. According to Alexander (2002), the viability of any emergency plan will not remain fully functional over time unless it is routinely reviewed and revised as needed and as area and environmental elements change. Updates to the planning documents should be recorded and adjusted, as necessary, on a cyclic basis.

Too Detailed a Plan Can Become Cumbersome and May Confuse Priorities

Alexander (2002) relates that few people called upon during a crisis to devise and operate an emergency plan have the necessary training and skill sets to perform tasks with the utmost effectiveness. An example of this would be a hospital mass casualty scenario where anyone who is not in a critical function area reports to a labor pool to provide hands during the emergency. During the actual occurrence of an event is not the time to discover that an overly detailed plan has produced confusion related to the prioritization of emergency support. This is especially important where interagency response is involved, such as is often seen in logistical sustainment operations; all suppliers are not medically oriented and may not understand the scope of healthcare-related requirements.

Emergency planning should involve a conceptual approach to planning where a functional response is indicated; planners embrace an all-hazards approach while realizing that specific incidents will require isolated types and methods of response. Planners should match skill sets and organizational capabilities, as much as possible, to the needs produced by trigger events related to the impending disaster. Interorganizational preparedness will pay enormous dividends once a disaster strikes.

Many notable quotations exist about planning. Of note is one attributed to Field Marshal Helmuth Carl Bernard von Moltke (1800s Prussian army chief of staff) when he related that “no battle plan ever survives the first encounter with the enemy.” Once a disaster response begins, many existing planning documents may quickly be voided due to different sets of circumstances. Because of this, many planners feel that once an emergency response plan is written the document becomes a standing operating procedure and forget that the plan needs to be revisited, rehearsed, and adjusted as requirements change; “*What is the point?*” becomes a dangerous mantra that should be avoided.

Especially when evaluating needs related to emergency management, requirements will invariably change and will vary depending on the event. Each event will be a unique scenario that will require a potentially different set of response criteria. Because of this concept, a plan should never be considered an end-all document. Dwight D. Eisenhower once related that a plan is useless, but the need for planning in advance of a situation is essential. Nowhere could this be more of a reality than in preparing a healthcare organization for responding to emergencies.

Some would posit that logistics is a separate entity far removed from any form of operations management. There is, according to Stinson (2002), a requirement for a far more integrated relationship between logistics and operations. This marriage needs to occur especially within the field of emergency management. Logistics requirements during emergency situations need to be specifically focused on anticipating results and adapting logistical flow toward what is happening within an affected area. Instead of being reactionary (as is seen in most push–pull relationships) logistics, during emergencies, must be anticipatory. Strategy must involve interagency collaborative efforts and remain steps ahead of second- and third-order requirements that may be resultant of catastrophic events.

The ability to communicate, coordinate, synchronize efforts, and collaborate effectively with multiple stakeholders can be a major factor in the success of interagency support planning (Schneid and Collins, 2000). Too much detail produces complexity. Staff members at multiple levels should be inculcated with the question of that if a crisis occurs, what will be needed to ensure an effective continuation of patient care? By identifying this as an element of risk mitigation, logistical support becomes an organizational resource enabler through effects-based orientation. Sustainment becomes more end users focused by providing the right items to the right customers in the right time and as the items are needed.

One concern that any healthcare organization will continue to have relates to the loss of communication assets during an actual emergency. While this can happen, redundancies of technologies (e.g., cellular, Internet, satellite phones, radio, etc.) and within a network of service providers can yield support when seemingly all is lost. The key to surviving a disaster scenario during short-term occurrences is for a network to retain its connectivity while not incurring any systemic network failures. Communications hierarchies perform badly in emergencies because, if any nodes fail, they isolate larger networks from one another. System and technologies redundancy can distribute information congestion associated with communication disruptions across the system and minimize the possibility of failure, which is fundamental for resiliency of an organization under uncertain emergency conditions (Kapucu, 2006).

As related by Kapucu and Van Wart (2008), leaders minimize or maximize the effects of a trigger event by their actions and competence in dealing with difficult sets of overlapping and inconsistent tasks. Emergency management is a complex set of circumstances that require flexibility, adaptability, and patience as no singular event will ever transpire according to a set script of outcomes. Leaders, during crisis events, must be rehearsed and prepared to employ planned responses to sets of circumstances and tools at their disposal to yield more effective outcomes when catastrophic events occur. While this is an opportunity, in many cases, immediately following a catastrophic event, planners must look beyond the immediacy of recent events and factor in future contingencies as well. Often, too many lessons observed are embedded in planning documents that never get reviewed with adequate frequency producing complex response plans that cannot be easily interpreted by multifunctional organizations.

Recovery

Recovery is the process of repairing damage, restoring services, reconstructing damaged facilities, and replacing lost infrastructure after an event has occurred. The goal of recovery is to return an organization's systems, function, and activities to normal as quickly as possible (FEMA, 2006a). Optimally, this process takes place in the immediate aftermath of an incident, but can take years to accomplish if the trigger event was a large-scale catastrophe. Healthcare logistics leaders, as will likely be seen in multiple functions throughout an organization, may find this phase of emergency management extremely difficult due to the need to support, rebuild, and strengthen affected community assets while responding to organizational as well as personal needs. Effectiveness during a recovery phase depends not only on the characteristics of the disaster, but on the collective behavior of organizational leadership as they too begin to sort needs and establish prioritization in requirements.

Success in large-scale disasters is based on developed networks and coordination at both local and interagency levels to protect and prevent singular entities from becoming overwhelmed pursuant to a crisis (Kapucu and Van Wart, 2008). The location of logistical support assets and resources is essential to an effective response and recovery effort. A comprehensive emergency management plan will address logistical responsiveness across all four phases of emergency management (McGlown, 2004). McGlown continues to explicate disaster response planning by indicating that the intent behind planning for contingencies is to improve outcomes afterward, save lives, reduce injuries, and return a chaotic and compromised environment to a state of normalcy after an event has occurred.

Interagency Logistical Impact on Emergency Management

Logistics personnel must realize the complexity of crisis response and need to appreciate interdisciplinary solutions based on lateral thinking and concerted strategies (Alexander, 2002). Throughout an event, there likely will be many separate emergency operations plans in effect at the same time and in some instances for the same event. Integration of multiple agencies' plans must be incorporated to aid in avoiding confusion, duplicity in effort, and waste of resources (Alexander, 2002).

Logistics is but one of the functions of an ICS and may be further divided into various subcomponents of logistical support (e.g., evacuation, transportation, supply and support, shipping, etc.). One key element in providing contiguous logistical support throughout an incident is an ability to control the demands and priorities of multiple affected customers using a unified command structure and a centralized locus of control (Schneid and Collins, 2000). In emergency response scenarios, the need for and public impression should see a unity in effort from multifaceted support agencies and leaders.

Drawing from military doctrine related to interservice support, *Joint Operations, JP 3-0* (DoD, 2006), defines unity of effort as the necessary coordination and cooperation to achieve common objectives even if the participants are not from the same organization. Collaboration in provisioning, staging of contingency supplies, and distributing resources is critical in meeting community needs during a crisis (Kapucu et al., 2007). Logistics leaders must remain knowledgeable, flexible, adaptive, and eager to engage in interagency and community preparedness efforts regardless the circumstances that set a plan into motion (McGlown, 2004).

Emergency response typically begins at the local community level. When logistics leaders and community agencies are well prepared and mobilized, they are better equipped to solve problems more efficiently and effectively yielding better results than when interagency planning has not been engaged. A key component of effective interagency emergency planning involves asking for assistance before, during, and after a crisis has occurred (Kapucu and Van Wart, 2008). Each phase of emergency management involves an element of logistical readiness and intervening measures that can be taken to stave off some of the effects of a catastrophe.

Logistics managers must rely on an element of flexibility in the conduct of support and sustainment missions. To plan only for the response during the initial period of a disaster defeats an overall understanding of logistical implications associated with readiness planning. Logistics support will be required during multiple phases of emergency management. As Alexander (2002) relates, there are multiple levels of emergency response at local and federal levels; interwoven among these levels are required elements of support (Table 5.1).

GIS Impact on Logistics Involvement

GISs offer a different way to articulate information related to managing logistical throughput. The technology ties digital information with records stored in a database and broadcasts the information to a common network of users (Figure 5.4). Developing a network of users is a key component in making logistical sustainment effective. The benefit achieved by this process relates to logistics serviceability and enables providers to capture necessary data, store information about the network of suppliers, analyze contingency information, manage supply chain processes, and present alternate courses of action related to a specified location involved in a

Table 5.1 Four Levels of Emergency

Individual emergencies	This type of emergency may require some form of support from such agencies as law enforcement, fire service, emergency medical service, but on a very small scale (example: vehicle accident involving injuries).
Incidents	This type of emergency may be dealt with at a municipality level or jurisdiction without requiring resources external to the community or area of responsibility (example: building collapse or localized natural disaster).
Major events	This type of emergency involves regional or interjurisdictional resources and requires a response from agencies external to a community and area of responsibility (example: large-scale industrial fire or natural mishap that requires specialized resources not available inside a community).
National-level incidents	This type of emergency involves an event large enough to prompt a federal response. The scale of this incident is very large scale and may sometimes require international aid as well (example: pandemic influenza or large-scale natural disaster response).

Source: Adapted from Alexander, 2002.

trigger event. GIS permits organizations to view, understand, question, interpret, and visualize data in ways that clarify relationships between agencies, patterns in data, and trends in the form of maps, globes, reports, and charting tools. For the logistician, this can be a significant asset in the management of a supply chain and for the support of multiple organizations during an emergency.

GIS can be instrumental in deciphering means for accomplishing support and sustainment factors in an affected area, such as a geographic location during a catastrophic event. GIS involvement can be associated with multifaceted processes, such as transportation, warehousing, inventory planning, material handling, facilities management, scheduling, purchasing, and other types of ancillary factors associated with fulfilling customers' demands. Effective logistics management is related to getting the correct items to the correct customer in a timely fashion and fulfilling the customers' demands.

Efficiency often drives economic change for organizations. Many healthcare organizations have transitioned to just-in-time (JIT) logistics management. Through JIT, items are managed on a needs-based process wherein items are delivered to the

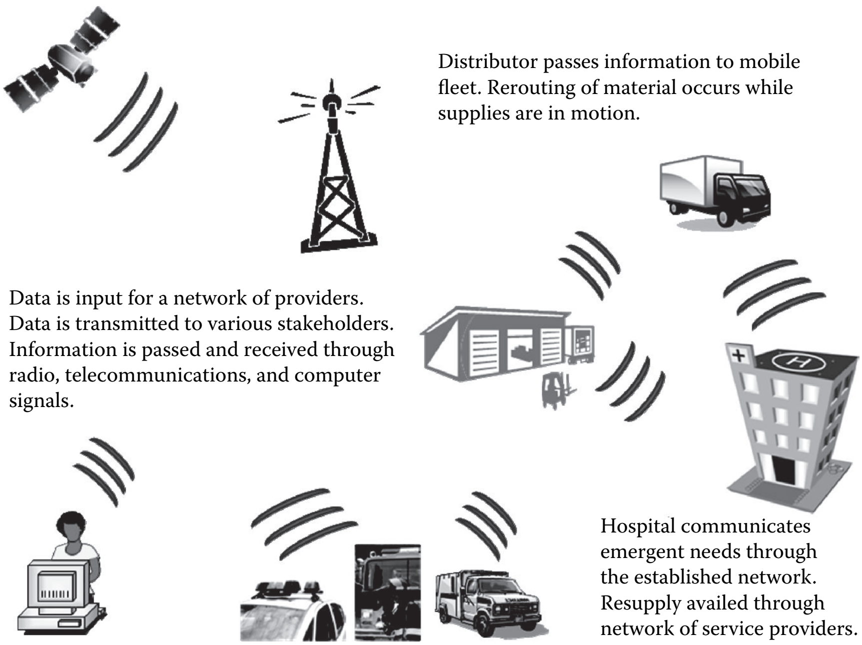

Figure 5.4 GIS through networked service providers.

facility as they are required instead of on a more routine cyclic order, replenishment basis. In many instances, this has reduced the overall handling requirements for many healthcare organizations by reducing the amount of inventory that is maintained on hand. One element to be considered, however, is that, with reduced inventory, organizations are more susceptible to loss when a disaster strikes (Perry and Lindell, 2007). While JIT yields short-term efficiency for organizations, unintentional supply chain disruptions can result from an inability to process necessary resupply when a catastrophe occurs. Once the disaster strikes, organizations must know to whom they can turn for assistance if a supply chain disruption occurs.

Logistics agencies can employ GIS as a solution for bridging voids in interagency cooperation and collaboration when disruptions occur. Many logistics agencies now employ, with marked levels of regularity, GIS technologies—radio frequency identification (RFID) tags, in-transit visibility (ITV) markers, microchipping, navigational tracking devices, etc.—to monitor and manage loads and priorities of shipments as they are moving between suppliers and designated customers. Through the employment of such technologies, loads designated for end users can be better managed during emergencies by realigning priorities to the most affected areas and facilitate the continued resupply of critically necessary material. During a crisis event, working together and across traditional agency boundaries becomes an imperative. Corporate competition must be overshadowed by an overarching need to provide aid to the affected population throughout a catastrophic event. Using GIS, healthcare agencies can work toward more interoperability, coordination, and collaboration at multiple levels of municipal, local, state, and federal support (McGlown, 2004). The process, once initiated, becomes circuitous and no singular agency can afford to operate unilaterally.

This concept becomes especially critical in crisis scenarios when the timelines for reaction and response are severely constrained and resources become quickly limited. Once a trigger event occurs, site selection, demographic analysis, and competition become secondary efforts, while mitigation, response, and recovery become the priority. GIS technology provides clarity and direction in instances where it is needed most.

Scenario and Application

To provide a better understanding of how GIS integrates with healthcare supply chain management, we use the following scenario (Figure 5.5). Each phase of this simplified fictional scenario is made possible with technology tools. Some of the tools include mechanisms observed every day, but are not always thought of as emergency management enablers, such as RFID tags, UPC labels, bar codes,

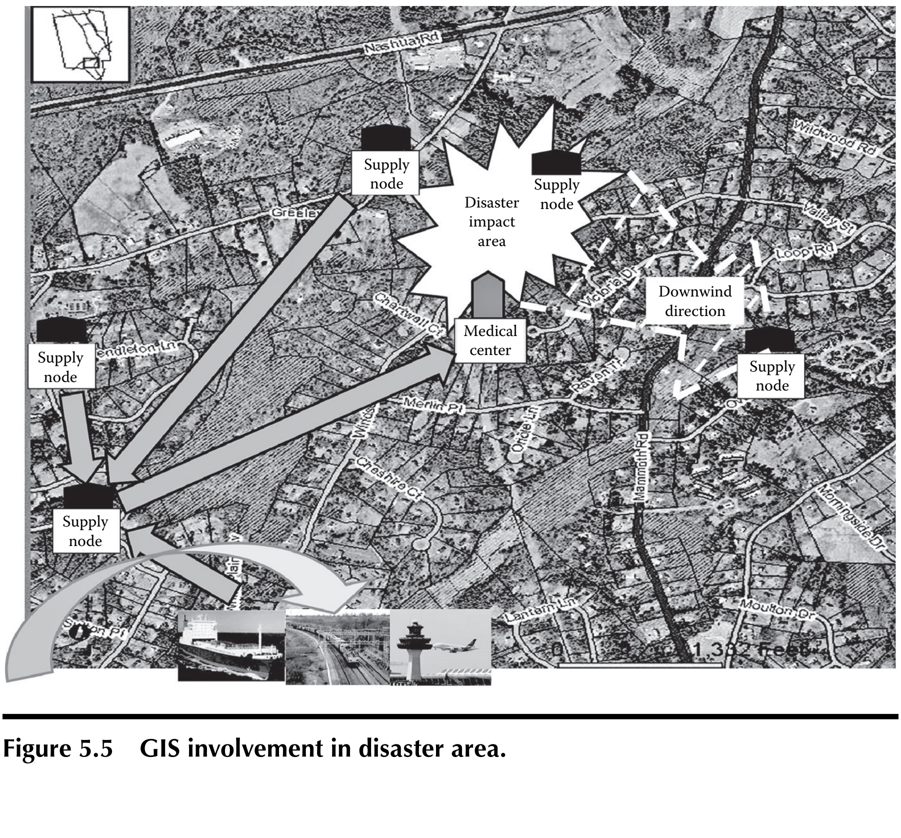

Figure 5.5 GIS involvement in disaster area.

microchips, and so forth. There is a wide gamut of GIS tools that are available and can enable a healthcare organization in logistical sustainment efforts.

Consider the following example. A regional medical center receives supplies from various suppliers throughout a geographic area. The suppliers are located at multiple locations along major road networks that are rarely affected by traffic congestion or delays and use as many routes to transport supply upon request. One day, and unexpectedly, a catastrophic explosion occurs at a nearby industrial complex causing a large number of casualties and emitting a vaporous cloud of toxic gases into the air around the medical center. A large area of a local populace is affected by the incident and the event triggers community-wide emergency management plan activation. The affected hospital, commensurate with community needs, activates an emergency response plan and begins to prepare for a mass casualty event commensurate with standing operating procedures.

In this event, however, wind speed and direction is carrying the toxic cloud directly over the hospital and is laden with potentially deadly fumes downwind, affecting many businesses and more of the population in its path including routine suppliers for the facility at risk. Road networks become quickly congested with people trying to escape the disaster and with emergency vehicles attempting to respond to the event. To add to the frustration and confusion, in the aftermath of the event, the hospital closest to the trigger event begins to receive more patients than expected and is now responding to a mass casualty event.

As the facility begins to receive affected casualties from the incident and treating the *walking* or *worried well*, supplies begin to dwindle. The need for resupply cannot be minimized and is being realized with each new entrant into the facility. The internal logistics department places calls, per standing operating procedures (SOP), to two of the closest distributors that provide medical supply. One of the suppliers advises the medical facility that, while it can assist, all road networks between the two facilities are blocked and resources are being diverted to an alternate site; the other supplier is downwind of the hospital and is reacting to the toxic cloud as well. The other of the two suppliers was close enough to the blast to have been affected directly. Additionally, all road networks between the two entities are closed. Because of the disrupted road networks and the direct impact of the trigger event, the supplier decides to begin processing orders through an alternate site.

The distributor begins to check a database that interfaces with multiple other agencies and identifies other available sources of supply that can process the requests and are not directly impacted by the trigger event. The initial distributor contacts the other sources and begins to transmit data concerning events as they transpire and processes customer demands through a proxy service. Already informed of the issues through real-time transmissions, the alternate sources of supply receive hospital needs over data networks and begin to respond accordingly. The alternate agencies process the orders through transporters that are already in motion; trucks and other cargo mediums begin to be dispatched and rerouted via in-transit visibility mechanisms and supplies are pushed toward the affected medical facility through alternate routes not affected by the disaster. The medical facility's demands begin to be fulfilled and necessary supplies are replenished. As the event culminates, the medical facility begins to be resupplied through the alternate sources of supply. Affected patients continue to receive care without disruptions in the lines of supply and agencies continue to operate at a somewhat status quo.

As is notable through a simplistic, fictional scenario, GIS tools can enhance logistics management throughout a concerted response to emergencies. Healthcare logistics managers can use GIS to visualize logistics processes through networks of information and service providers availed through established systems designed for such visibility. Through GIS, managers can integrate data with locations, spatial modeling to aid in inventory management and decision making, routing of supply in routine and contingency operations, and understand the interoperability and networking of sources of supply. GIS provides digital knowledge associated with routing, in-transit visibility, and numerous other applications.

Summary and Conclusions

GIS interfaces permit healthcare logistics managers the opportunity, especially during crisis events, to better respond to immediate demands from affected healthcare organizations by enabling them to see routes and identify alternate sources of supply as an event unfolds. By taking advantage of this capability, healthcare organizations can be better equipped to meet customer demands during a crisis without creating preventable costs associated with being ill prepared. Paper maps and push pins has evolved into a digital world that can now be used at the end user's level. By embracing and employing this capability, supply chain disruptions can be mitigated and patient care can be continued with minimal adverse impact related to a nonavailability of supply resources.

Healthcare logistics managers can use GIS to calculate realistic travel times and evaluate route information to balance workload and permit truer scheduling. GIS also enables logistics managers and agencies to create delivery schedule plans and better rates in accuracy that can consider multiple variables at once, such as availability of supply, traffic conditions, and weather information to enhance supply chain effects. Unfortunately, many healthcare agencies are separate entities that lack policy and protocol for interagency coordination and cooperation. Effective emergency management preparedness and response relies on effective coordination of diplomatic and economic efforts.

During an actual catastrophic incident, electronic communications can play a key role in each phase of crisis intervention and incident mitigation (Erickson, 2006). Integrating health service support with other locales and on a regional basis is critical for successful emergency operations. Key in this concept is an overlapping redundancy and availability in sustainment capabilities related to support mechanisms available. In most cases, both patients within a facility and the workers are vulnerable categories of people and are susceptible to the effects of a trigger event. Effective interagency planning, communication, and support throughout an event are essential.

Modern society is complex and the range of possible emergency scenarios is always evolving. Managers of various types of agencies are being forced into greater levels of specialization and bureaucratic compartmentalization within the traditional realms of healthcare and emergency preparedness. No one group or organization is singularly equipped with the necessary training, knowledge, equipment, or legal mandate to facilitate reaction to every type of crisis (Erickson, 2006). A key function of an effective logistics manager's strategy related to contingency management and related to planning for emergencies is knowing when and how to ask for assistance before, during, and after a crisis has occurred.

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Chapter 6

Design Concept for a Location-Based Hazard Vulnerability Assessment Tool for Healthcare Facilities

Ric Skinner, GISP

Contents

Introduction and Definition of the Problem

Identifying risks from all hazards and assessing a facility's or organization's vulnerabilities to these risks is fundamentally about information, i.e., assuring that *the right people have the right information in the right format and at the right time*. The Joint Commission recognizes this and has been requiring hospitals and healthcare organizations that it certifies to conduct a Hazard and Vulnerability Analysis

(HVA) and update it annually in a formal, documented process (Joint Commission Resources, 2002; Joint Commission, 2008).

As discussed in Chapter 2, an HVA identifies the internal and external risks or disasters most likely to affect facilities, and the likely severity of impacts if they were to occur. This is to determine the vulnerability of facilities, people, and operations to all hazards situations (natural, technological, human-related, and hazardous materials-related). With regards to impacts on people, a healthcare facility (HCF) needs to consider not only people inside the facility, but also where its medical/healthcare staff lives in a community. For example, a large hazardous chemical release can affect essential off-duty medical and healthcare staff that might be notified to report to work to assist in treating mass casualties resulting from the incident, but because of their location cannot get to the facility or may even be casualties themselves. This is illustrated in Figure 6.1.

By understanding risk exposure, the facility is better able to plan for and develop adequate mitigation, preparedness, and response to these risks, thus reducing its vulnerability. While no particular HVA method is prescribed by The Joint Commission, it cites a widely used scoring tool: Medical Center Hazard Vulnerability

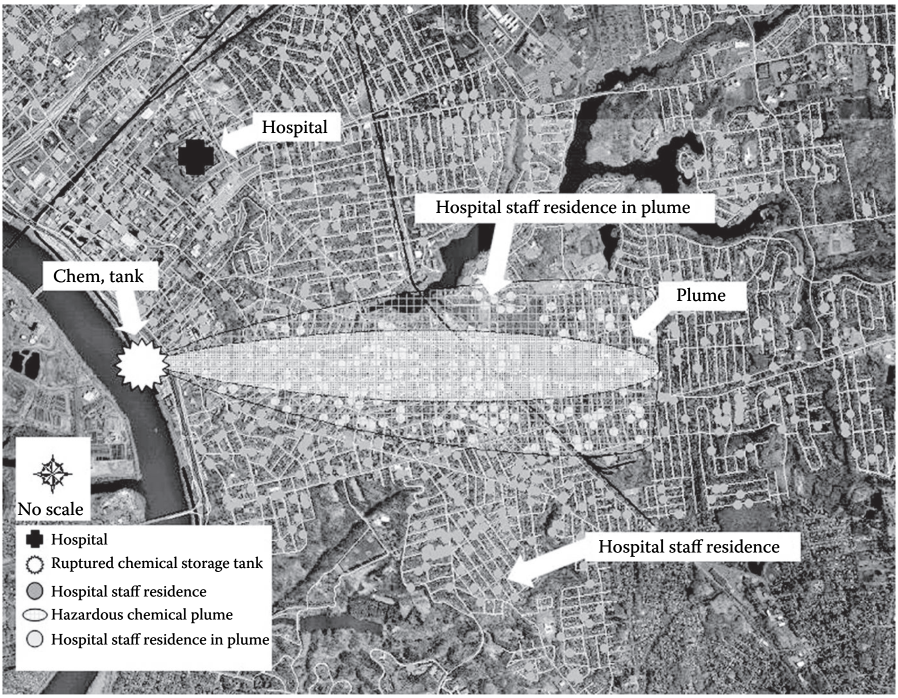

Figure 6.1 Hypothetical impact upon hospital employees potentially exposed to a hazardous chemical plume resulting from a ruptured storage tank. Dot represents employee residence in the community.

Analysis Tool (Kaiser Foundation Health Plan, 2001; McLaughlin, 2001). This is widely known as the KP tool. An enhancement of the KP tool, which goes into much more detail, allowing for input about community resources and assets, and provides some references, is the Kaiser Permanente "Resilience Assessment" tool (Kaiser Foundation Health Plan, 2003).

Using the KP Tool, or a similar HVA tool, an HCF can rank disasters based on their qualitative scores and determine where to focus its preparedness and mitigation efforts in development of its Emergency Operations Plan. However, the KP HVA tool is essentially a blank form requiring manual input. No probabilities based on regional or local information are included in the tool and, unless the HVA evaluators take the time to research local data, it doesn't get factored into the HVA process. In defense of the evaluators, however, it is no easy task to research, identify, and quantify event probabilities and severities, especially if multiple facilities in multiple locations need to be considered. Therefore, making an assessment of the impacts of regional and local events upon facilities is usually left up to the evaluator's (or a group of evaluators') personal knowledge, recollections, and consensus to rate each event.

Research via two national surveys in 2007 and 2008 conducted by this author and colleagues (Skinner et al., 2008) revealed that most hospitals and healthcare facilities conducted HVA in a manual, time-consuming consensus process. Where multiple facilities were part of the the Joint Commission certification, the resulting HVA, in most cases, was a *composite* assessment across all facilities covered by that certification. In other words, any location-specific differences between facilities would be generalized into a single HVA.

The Joint Commission (2008) recognizes the importance of a facility's geographic location in estimating the probability of an event:

> Hospitals have flexibility in creating either a single HVA that accurately reflects all sites of the hospital, or multiple HVAs. Some remote sites may be significantly different from the main site (for example, in terms of hazards, location, and population served); in such situations, a separate HVA is appropriate.

However, the HVA tools commonly used by most healthcare facilities are designed for single facility use and do not support a composite score except perhaps through "ad hoc reasoning." In other words, HVA evaluators for a multilocation healthcare organization may consider all facilities to have the same risk of external flooding or utility outage or workplace violence without actually doing the homework to understand how individual locations may influence risk, i.e., facility's location relative to a flood plain or poor drainage areas, number and location of electric or gas supplies to the facility, and location of facility in urban or high-crime areas.

Along with the risk itself, historical data, presence of nearby or upwind local high-risk locations (e.g., a chemical manufacturer, nuclear plant, hazardous materials storage), and discussions with local emergency management knowledge experts should all be consulted for a well-founded HVA. However it is unlikely these resources are commonly tapped due to the staff that would need to be devoted to this fact finding. Another relevant information category that The Joint Commission considers important for some risks (e.g., epidemic, mass casualty, workplace violence) is population density. This can be interpreted to apply in the context of the community population as well as a facility's occupancy (e.g., employees, patients, visitors).

The level of vulnerability to which HCFs and their operations may be exposed due to impacts of a hazard event, or combination of events, can be summarized as a function of:

- Specifics of the potential or real hazard event (e.g., flood, fire, pandemic)
- Facility attributes (e.g., structural design, age, location)
- Operational attributes (e.g., staffing, operational modes, facility purpose)
- Likelihood of the occurrence of the hazard/hazardous event (e.g., local or regional history)
- Consequence severity of possible impacts (e.g., death, injury, disruption of services, recovery delay)
- Mitigation and preparedness plans and resources (e.g., evacuation routes, inventoried supplies, reserve staff)

A challenging and resources-demanding set of tasks would be necessary to consider all these aspects using the tools currently available. What follows is a conceptual design for a Web- and GIS-based HVA tool that facilitates incorporating location-specific hazards information relevant to a facility's location.

Design Concept of a Location-Based HVA

Design for a location-based HVA depends on semiautomating the HVA process in a browser application that uses a facility's address to access certain location-relevant online and external facility database information to create a customized HVA report for the facility. This tool is dubbed HVA Fact Finder. It is characterized as "semiautomated" because some online information, e.g., from online sources, such as NOAA, USGS, FEMA, or facility-specific data, such as from engineering or financial data bases, is automatically linked, while other information may need to be manually input (similar to the current HVA tool process). Keep in mind that HVA Fact Finder does not currently exist.

Probabilities calculated from the data would be used to populate (either automatically or manually) specific cells in the HVA spreadsheet. The browser application would have appropriate security features so that only authorized staff could view and/or edit any of the HVA information. Using the KP Tool as a model, the HVA Fact Finder would include all hazards categorized as natural, technological, human-related, and hazardous materials-related events (Table 2.1). Recognizing that many event probabilities cannot be quantified, the HVA Fact Finder would enable the user to enter a qualitative value of "probability" (essentially what is done now with the manual KP HVA tool). The HVA Fact Finder would provide the user with an HCF-specific HVA report.

In addition to meeting The Joint Commission requirements for an HCF HVA, the HVA Fact Finder would provide a basis to evaluate a facility's existing Emergency Response Plan (ERP) and identify where planning, mitigation, response, or recovery actions may need to be revised. After the first run of the HVA Fact Finder, annual updates will compare information obtained from the various automated sources between the previous year and the current year to reveal any risks that might need to be updated in the HVA or ERP. For example, perhaps an upwind chemical facility has closed down, removing the risk of a hazardous chemical release from that facility, or flood control measures (e.g., river dike, regional storm water retention facilities) have been constructed reducing a flooding threat.

Another benefit of the fact-based approach to HVA may be in providing justification for seeking a reduction in a facility's liability insurance premium (not a small cost for a third-party insured HCF) by making the case that if real risks are known and the facility has taken identifiable actions to minimize them, then this should be reflected in the risk-based insurance premium.

The "out-of-the-box" HVA Fact Finder would have a number of online data sources already integrated and from which information needed for most of the natural hazards and some of the other hazards can be acquired. Part of the initial setup would require adding or eliminating hazards events on the various lists. For example, volcano or tsunami can be eliminated for many states. Online information sources that can be included:

- National Climactic Data Center Storm Events Database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms). At this link, history of natural events can be accessed for drought, dust storm, flood, fog, funnel cloud, hail, hurricane and tropical storm, lightning, ocean and lake surf, precipitation, snow and ice, temperature extremes, thunderstorm and high wind, tornado, waterspout, and wild and forest fire.
- USGS Earthquake Hazards Program Archives (http://earthquake.usgs.gov/regional/states/). From this link, one can access Google Earth Files for Earthquake Catalogs from 1973 to present and magnitudes 0 to 9.9.

- National Geophysical Data Center (http://www.ngdc.noaa.gov/hazard/). This link provides historical information about earthquakes, tsunamis, and volcanoes.
- FEMA Information Platform—Flood Map Viewer (https://hazards.fema.gov/femaportal/wps/portal/!ut/p/kcxml/04_Sj9SPykssy0xPLMnMz0vM0Y_QjzKLd4w39DQESZnFG8Qbm-pHogk5IkR8PfJzU_WD9L31A_QLckMjyh0dFQF0T0jn/delta/base64xml/L3dJdyEvd0ZNQUFzQUMvNElVRS82X0NfUDE!). This link provides access to flood zone maps and risks.

Additional steps to set up and customize HVA Fact Finder for first-time use would require a commitment of resources to research external information sources not already integrated with the application and extract the data relevant to the facilities into a facility-specific HVA database. However, once this is done, the information resources serve as the basis for future annual HVA updates. These other resources might include:

- State or County Emergency Management Agency State Hazard Mitigation Plan. For example:
  - http://www.mass.gov/Eeops/docs/mema/disaster_recovery/state_plan_2007_rvn4.pdf
  - http://ema.ohio.gov/Mitigation_OhioPlan.aspx
  - http://www.dem.azdema.gov/operations/docs/mitplan/appendixC.pdf)
- State or County Emergency Management Agency Comprehensive Emergency Management Plan, especially ESF-8 Annex. For example:
  - http://www.mass.gov/Eeops/docs/mema/state_cemp-full_plan.pdf
  - http://www.floridadisaster.org/documents/CEMP/Appendices/ESF%208.pdf
  - http://www.co.columbia.or.us/emgt/pdf/comp_plan.pdf)
- Facility historical records from Engineering (e.g., equipment failure and maintenance records), Accounting (e.g., expenditure related to specific emergency situations), Human Resources (e.g., seasonal employee sick days, work stoppages), Security (e.g., baby abduction events, internal fire), Information Systems (e.g., critical system downtime frequency and duration), Infection Control (e.g., hospital-wide or unit-wide nosocomial infections), or other sources.

A conceptual view of HVA Fact Finder is shown in Figure 6.2.

Once the HVA Fact Finder is installed and set up, a facility's HVA evaluators would enter the facility's street address. The HVA Fact Finder connects to the custom HVA database and online resources. A reference map centered on the facility would display with all available data layers (e.g., flood zones, hazardous storage facilities, major roadways, etc.) and the option to turn layers on and off. Each layer might have a hazard risk zone (HRZ) displayed based on criteria set during HVA

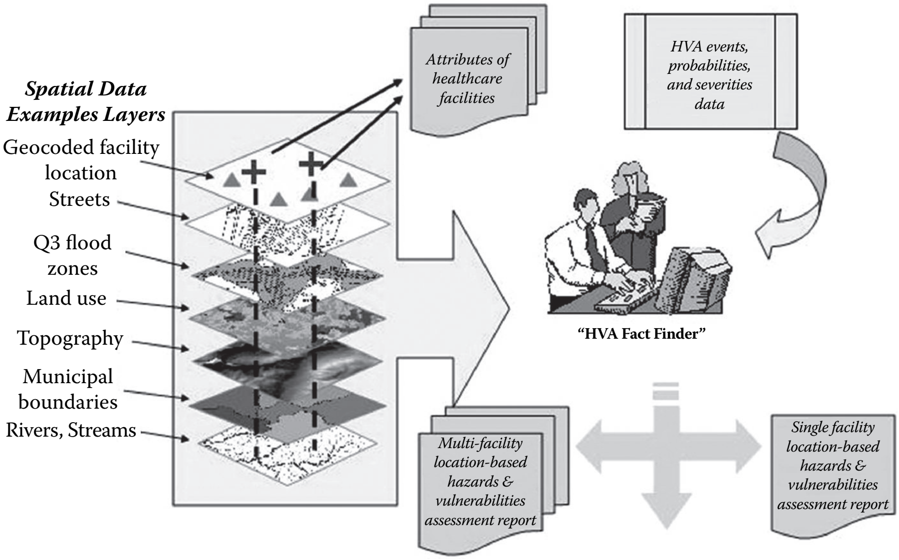

Figure 6.2 Conceptual representation of HVA Fact Finder.

Fact Finder setup. For example, a facility that is 1,000 feet downwind of a chemical storage tank might be given an HRZ rating of 5 (on a scale of 0 = little risk to 5 = high risk), whereas the same facility 1,000 feet upwind from such a potential hazard might be given an HRZ rating of 2. The HVA evaluators would continue to enter all the impact estimates—based on historical data, institutional knowledge, or both—and then the HVA system would factor all the entries into an overall facility risk.

Custom algorithms, based on published resources that take into consideration location-, facilities-, and operations-relevant factors would be provided in the HVA Fact Finder. The algorithms result in a quantitative or qualitative value indicating the level of exposure a facility might experience due to each event. Qualitative expressions of mitigation, preparedness, and response capabilities would be developed, which also recognize location, facilities, and operations relevant factors. The quantitative and qualitative results would be combined resulting in a ranking of facilities based on their vulnerabilities to individual and composite events. HVA Fact Finder also would enable exploring "what if" scenario risks of multiple hazards co-occurring, such as an epidemic during severe winter weather, or HazMat spill during extensive flooding.

After the single facility HVA Fact Finder is developed, it would provide a foundation for enhancement to a multi-HCF HVA, and "roll up" capability to provide regional and state organizations to access an overall picture of regional or state healthcare preparedness.

Conclusions

As mentioned at the beginning of this section, HVA Fact Finder is a conceptual model at this time. There is certainly justification for an easily run, but robust tool for conducting the required hazard vulnerability analysis of healthcare facilities. If the HVA Fact Finder can improve the HCF's overall HVA process, then it can be better assured its Emergency Response Plan, based on the HVA, represents the real world of risks.

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APPLICATIONS II

Chapter 7

Trauma Center Siting, Optimization Modeling, and GIS

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Contents

Introduction

In trauma, the concept of the *Golden Hour*—the relatively short period of time following injury—points to the importance of prompt access to definitive care (Trunkey, 1983). Treatment at a definitive care facility (e.g., Level 1 trauma center) has been demonstrated to provide a substantial decrease in mortality (Mackenzie et al., 2006). The siting of trauma center hospitals, however, is more complex than just using maps of land area coverage showing ringed bands around each hospital. To be viable, a trauma center must serve a large enough population of severely injured people to maintain the skills of its healthcare providers and offer high quality care. To address these concerns, researchers from the University of Pennsylvania have developed the Trauma Resource Allocation Model for Ambulances and Hospitals (TRAMAH), a mathematical optimization model that simulates the effects of newly sited trauma centers based on population, the speed and locations of helicopters and ambulances, the locations of existing trauma centers, and the spatial relationships among these resources. The TRAMAH is also currently deployed on an interactive Web site that uses ArcIMS and ArcSDE to enable visitors to identify the locations of current hospitals and trauma centers and their accessibility via ambulance or helicopter. ArcIMS is software that can be used to build and deliver maps, data, and tools over the Internet and ArcSDE manages the physical storage of geometric features using standard data types on an ArcGIS server.

Background

"Effort at scene proves trauma center's worth," proclaimed the *Reading Eagle* in March 2009 (*Reading Eagle*, 2009). The editorial that followed—and a related news article (Urban, 2009)—told the story of a recent car crash. Early on a Friday morning, a 32-year-old man swerved his truck to avoid a deer and crashed head-on into a tree along Route 345 in French Creek State Park, a few miles outside of Reading, Pennsylvania. He was trapped inside the smashed vehicle for hours, his ankle pinned beneath the wreckage. The paramedics and emergency medical technicians working to free him feared that amputation would be necessary. The team dispatched a local ambulance service to bring a trauma surgeon from nearby Reading Hospital to the crash scene. The surgeon helped stabilize the driver, and the team was able to extricate him from the truck without having to amputate his foot. He was rushed to a nearby helicopter landing zone and then flown to Reading Hospital for treatment. "That so many options were available to save [his] life and limb is no accident," reported the *Reading Eagle*. "The proximity of the trauma center made it possible." If there had been no local trauma system in this rural area—and no trauma surgeon available to race to the scene—this type of specialized treatment would have arrived much later, if at all. "The trauma center is an irreplaceable boon to local accident victims," proclaimed the newspaper.

A major difference between life and death (or life with a crippling disability) for trauma victims is the amount of time it takes for them to receive proper medical treatment. Trauma centers, like the one at Reading Hospital, are designed to handle victims of serious injury, providing a level of multidisciplinary care, including emergency surgery that is usually unavailable at nontrauma center hospitals. Patients suffering severe injuries have significantly higher death rates when treated in nontrauma center hospitals as compared to patients with similar injuries who are treated at trauma center hospitals (MacKenzie et al., 2006). The patient in the crash described above survived and is expected to fully recover, in no small way because of the definitive care he received from a nearby trauma center.

Public Health Challenge of Trauma Care

The successful treatment of injuries is more than just a concern of individual victims and their families, it's a major public health issue in the United States. Injury, also known as trauma, is responsible for about 170,000 deaths each year in the United States and is the leading cause of death for children and young adults in this country and around the world (Branas, 2008). In addition to the loss of life, injuries take a severe economic toll, with injury-related expenses estimated at $117 billion annually (National Center for Injury Prevention and Control, 2006). A 2005 Harris Poll (Harris Interactive, 2005) has demonstrated overwhelming support from the U.S. public for prompt access to definitive trauma care facilities.

A very effective strategy for reducing the economic loss and death rate due to injury is to use a systems approach to the delivery of trauma care (Nathens et al., 2000). Given this evidence, many states have developed coordinated trauma systems to facilitate geographic access to care as well as a rapid and appropriate medical response for victims of trauma. These trauma systems usually include a network of emergency medical service (EMS) units, ground and air ambulances, that link up with one or more trauma centers. The location of trauma centers within this network and in relation to other nearby trauma centers is critical.

Determining optimum sites for trauma centers such that the largest proportion of people who are severely injured are treated in the shortest possible time is a big challenge for emergency service planners. History, local politics, and the competitive healthcare environment all shape the process. Many early Geographic Information System (GIS)-based attempts to maximize coverage were based on land area or distance to facilities, which do not necessarily equate to maximal coverage of the people and places with the highest need for specialized trauma care services (McLafferty, 2003).

As a result, the geographic distribution of trauma centers now varies widely across states, and the strength of the U.S. trauma center safety net could be bolstered with better planning decisions as to the locations of trauma centers. In many areas of the country, particularly rural regions, citizens have no timely access to trauma centers (MacKenzie et al., 2003). In many urban areas, there may be unnecessary duplication of trauma care services, possibly leading to inefficiencies, lower patient volumes per center, and reduced quality of care (Branas et al., 2000).

The specialized training, equipment, and resources needed by trauma centers are expensive, making it essential that trauma centers be sited judiciously to save resources while at the same time save lives. To be viable, trauma centers must be sited in locations with large enough populations and cases of severe trauma to ensure sufficient use of the facility and maintain the skills of its medical providers. But, on the other hand, trauma centers must not be sited in locations that are so isolated that they ostensibly become the "only game in town," leaving them with a volume of patients so large that the demands overwhelm the resources, the providers, or both.

Trauma Resource Allocation Model for Ambulances and Hospitals (TRAMAH)

To address these concerns, researchers from the University of Pennsylvania have developed a mathematical optimization model called *TRAMAH*. The TRAMAH model determines access to current trauma centers and helps find the best site for new ones, based on patient access and available resources. In addition, TRAMAH simulates the effects of newly sited trauma centers based on population, the speed and location of helicopters and ambulances, the number and location of existing trauma centers, and the spatial relationships among these elements. TRAMAH is supported by an interactive Web site that enables visitors to map the locations of current hospitals and trauma centers and their accessibility via ambulance or helicopter. The rest of this chapter describes the development of TRAMAH and two best-practices implementations of the model at the state and national levels.

TRAMAH was developed to assist in optimizing trauma system resource allocation, particularly with regard to trauma centers and medical helicopter depots. TRAMAH is a mathematical model that uses population data and access to existing trauma centers based on geographic relationships to trauma centers and base helipads. From this, the model is then able to complete several operations, such as simulating the effects of newly sited or newly removed trauma centers and helicopters.

For its most basic use, TRAMAH employs a computer algorithm, compiled in Fortran or C++, to determine existing geographic access for people within a defined area, usually a region, division, or state. Using specific response time standards (usually 60 or 45 minutes), this algorithm pairs trauma centers and helicopter depots in calculating geometric ellipses of coverage that are then compared with the point representations of where people live or where they are injured (Figure 7.1). These point representations are usually the centroids or population-weighted centroids of block groups, census tracts, or zip codes. If the locations of the points where people live or where they are injured fall within the ellipses, they are counted as having geographic access to (or "covered by") the trauma system within some time standard.

Some trauma centers and helicopter depots are co-located as same-site pairs, while other helicopter depots are located as satellites to trauma centers. As one early contribution of this work, it was determined that the satellite location of helicopter

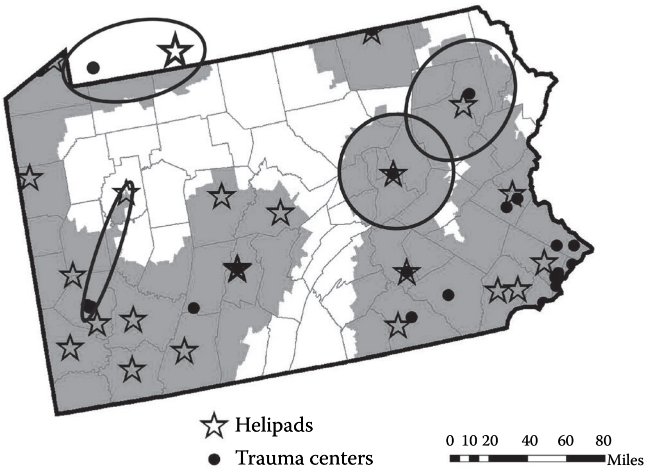

Figure 7.1 Trauma center–helicopter depot ellipsoid pairings and the resulting coverage shown for Pennsylvania (TC = trauma center, HD = helicopter depot).

depots was a much more efficient approach to maximizing coverage (Branas, 2000). This is because underlying geographic demand by actual people for a trauma center never forms perfect concentric rings or bands around that trauma center, but is much more varied, following road networks and other, more irregular geographic entities. This is a major caution to GIS users and policymakers who simply consider bands of concentric circles around trauma centers and expect that such bands represent coverage, which, very likely, they do not. Thus, the use of ellipses formed by trauma center–helicopter depot pairings allows planners to best evaluate real-world phenomena in which trauma centers are served by multiple helicopter depots, and helicopter depots serve multiple trauma centers, both situations that can be mapped to best suit the underlying geographic demand for trauma care by the population (see Figure 7.1).

In addition to being able to evaluate an existing system of trauma centers and helicopter depots, TRAMAH is also engineered to determine the optimal locations of these resources. The model does this using a mathematical enumeration algorithm for basic problems, such as where to place the next trauma center in the absolute best location that will maximize the number of residents who have access to the system. For more complex problems, TRAMAH uses optimization software to obtain similar results.

Maryland Prototype and Expansion to Other States

Early work applying the TRAMAH optimization algorithm was done in the State of Maryland. Geographic data were collected on the longitude–latitude coordinate locations of trauma centers, nontrauma center hospitals, and helicopter depots. The locations of Maryland residents who were injured were also collected from hospital discharge data and state death certificates. The spatial profile of severe injury in Maryland was created by calculating a count per zip code across the state, revealing that the highest concentrations of severe injury occurred, not surprisingly, in and around the state's largest population centers, the Baltimore and Washington, D.C. metropolitan areas. This facilitated both calculation of existing trauma center coverage as well as testing of alternative approaches in modifying the trauma system to reach more people and minimize resources used by the trauma system.

Given the often challenging costs of building a new hospital facility from the ground up, as compared to upgrading a nontrauma center hospital to make it a trauma center, only existing nontrauma center hospitals were considered as candidate trauma center locations. Ground ambulance depot locations were not explicitly included in the model due to both the prohibitively large numbers of these facilities and the fact that only a very small percentage of ground ambulances are dedicated to severe trauma. An adjustment factor was included to account for the effect of these ground ambulance depots and the time it would take to drive to each trauma center. Each zip code centroid was considered as a possible site for a helicopter depot. Using these data, calculated driving times between towns, and linear distances between zip codes, a ground and air travel matrix was calculated.

TRAMAH was then applied to the Maryland Trauma System modeling two scenarios. The first: "Clean slate" approach assumed no existing trauma care resources and allocated trauma centers and helicopter depots based solely on eligible sites and the severe injury spatial profile. The second: Incremental approach began with the existing trauma system and made changes to the existing system to improve coverage.

By optimally redistributing the same number of resources as the existing Maryland Trauma System, TRAMAH was able to achieve nearly 100% coverage through the clean slate approach. The clean slate approach also demonstrated that Maryland could achieve the same percent coverage using significantly fewer trauma centers and helicopter depots, a potential cost saving to the state. However, the clean slate approach was not an especially realistic scenario for a state with a trauma care system as mature and developed as Maryland's system. Such clean slate approaches are likely better applied in states where the trauma care system is less developed.

Because of this limitation in the clean slate approach, TRAMAH was also used incrementally in two scenarios to try to improve on that coverage. In the first scenario, all helicopter depots were held constant and trauma centers were removed and optimally replaced singly or in pairs. This approach led to an increase in coverage by an average of 4.16% for single trauma center relocation and an average increase in coverage of 6.96% for optimal replacement of two trauma centers. The second incremental approach held the locations of all the existing trauma centers constant and optimally sited helicopter depots. TRAMAH achieved the same percent coverage as the current system by optimally relocating fewer than half of the state's existing helicopter depots, an important lesson in location efficiency.

Based on a grant from the Agency for Healthcare Research and Quality, TRAMAH was subsequently applied in 12 additional states: California, Florida, New Jersey, New York, Oregon, Washington, Colorado, Iowa, North Carolina, Oklahoma, Pennsylvania, and Utah. TRAMAH simulated helicopter depot and trauma center locations that offered greater patient access and/or required fewer facilities compared with the locations of existing trauma care facilities in all of these 12 states. The model demonstrated interstate variation in the percentage of severe trauma patients that were offered timely access to the hospital–ambulance system in each of these 12 states as well as differences in patient access between the states that had fully established trauma care systems and those that did not have fully established trauma care systems.

National Trauma Center Access

TRAMAH was then applied to national datasets of trauma centers and helicopter depots to assess trauma center access for the entire United States at the national, regional, and state levels for 2005. The Trauma Center Inventory from the American Trauma Society was used to determine the locations of all 703 level I, II, and III trauma centers in the United States, while helicopter depot data taken from the Atlas and Database of Air Medical Services identified all 571 base helipads and 683 helicopters in the United States. Population estimates were calculated at the census block group level and assigned coordinates as block group centroids, weighted based on population distribution. As with the Maryland prototype, exact locations for ground ambulance depots were not included, and estimated driving times were multiplied by an empirically determined constant to account for time from the ambulance depot to the injury scene.

Trauma center access was then determined for each mode of transportation at 45-minute and 60-minute time standards based on both land and population coverage. The results indicated that 69.2% of U.S. residents have access to a level I or level II trauma center within 45 minutes and 84.1% have access within 60 minutes. Access differed significantly across regions, with the highest levels of access in the Northeast (85.8% in 45 minutes and 96.9% in 60 minutes) and lowest levels in the South (58.9% in 45 minutes and 76.1% in 60 minutes). There was a stark contrast between rural, suburban, and urban block groups, with 89.4% of urban block groups having access in 45 minutes, 72.7% of suburban block groups, and only 8.4% of rural block groups. Strong differences were also observed in the number of trauma centers accessible as well, with 33.8% of Americans having access within 60 minutes to one to four trauma centers, while 14.6% have access to 20 or more centers within the same timeframe.

While trauma systems are generally run at the state level or lower, it is important to consider that, for populations near state borders, the closest trauma center may be in another state. This was particularly relevant for the 1.9% of residents whose only access to a trauma center within 45 minutes depended on a trauma center, base helipad, or both located across state lines. The percentage increased to 3.1% when considering access within 60 minutes.

Sharing TRAMAH via the Internet

A geographic analysis of trauma center access is only part of TRAMAH's functionality. As demonstrated in the prior state-based case studies, TRAMAH also can serve as a valuable planning tool to improve trauma system resource allocation and increase access to appropriate care. TRAMAH is, however, a mathematical model, well understood by researchers and GIS professionals. However, during the course of the project, it was determined that the model's value would need to be democratized by improving how it can be used by the hospital industry as well as the general public.

The researchers worked with Avencia Incorporated, a Philadelphia-based software development company, to develop a Web-based GIS application as a means of providing greater accessibility to these national data and models in a more usable manner. Web-based GIS has multiple advantages for this type of scenario, in particular, the fact that it can be made easily accessible to a large, geographically distributed, user community. Desktop GIS requires considerable training and expertise. Web-based applications are generally easier to use and do not require the specialized GIS training often required to run desktop applications (Schuurman et al., 2008).

The first phase of the Web site, which leverages ESRI's ArcIMS and ArcSDE technologies, was deployed in 2006 displaying trauma center access based on the most current census, hospital, and helicopter data. The Web site (http://maps.amtrauma.org) is accessible to the general public and enables users to specify timeframes of 45 or 60 minutes and transportation by ambulance, helicopter, or both. It returns a map displaying areas with access at the specified level as well as estimates of the percentages of population and land covered. Users can also select a specific state and choose whether or not to display areas covered by trauma system resources of another state, providing planners with a sense of coverage in their states as well as the specific reach of their state's system.

The underlying data have been updated to include 2008 population estimates and a second phase is planned that will enable trauma system planners to input potential trauma center locations and calculate the effects on-the-fly. To date, the Web site continues to experience hundreds of hits per day and its users come from within the United States to as far as Jamaica, England, Taiwan, and other countries around the world. As the United States and other nations develop their trauma care systems, and the Web site is further developed and publicized, the user base of

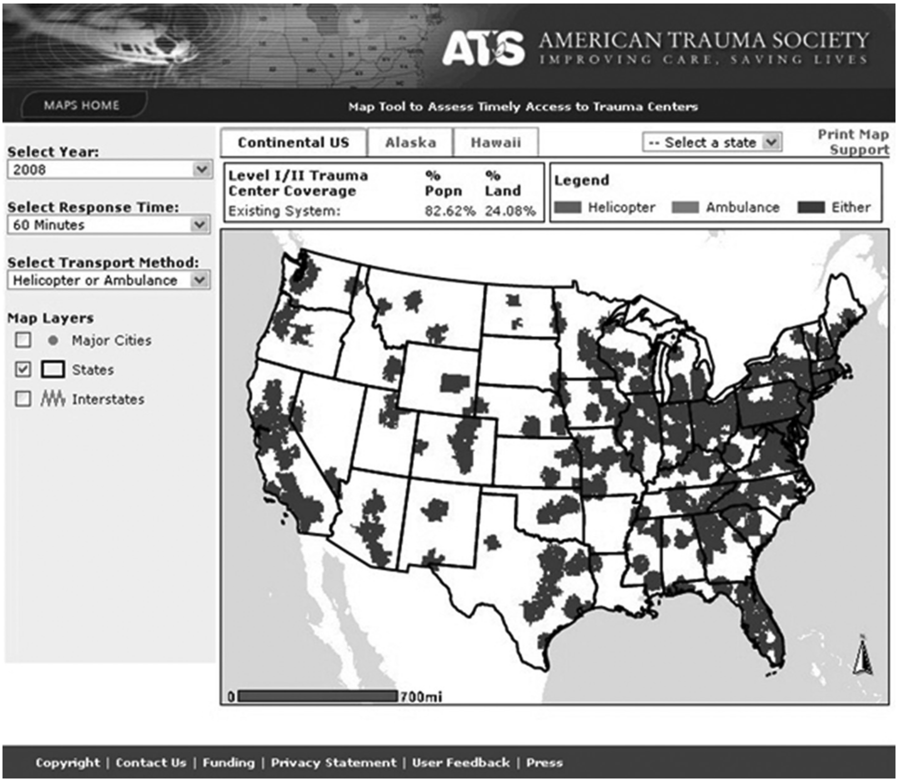

Figure 7.2 Web-based interface sponsored by the American Trauma Society connecting the TRAMAH to government agencies, the hospital industry, and the general public at http://maps.amtrauma.org.

planners that employ the TRAMAH Web site (commonly referred to as the "purple maps" Web site) will grow (Figure 7.2). Similarly, Figure 7.3 shows an example of a state-scale map for Pennsylvania.

The studies described here demonstrate that trauma care access across the United States is highly variable, with significant disparities in access in certain regions and states. Across the United States, the number of people with no access to trauma centers within 60 minutes was roughly equal to the number of people with access to 20 or more trauma centers. It should also be considered that areas of dense population may require access to a greater number of trauma centers to adequately address greater numbers of injuries. While a single trauma center might geographically cover large segments of the population, it may not be adequate to meet all of the trauma care needs of that population. TRAMAH is currently being modified to potentially consider these variations in patient volume by geography.

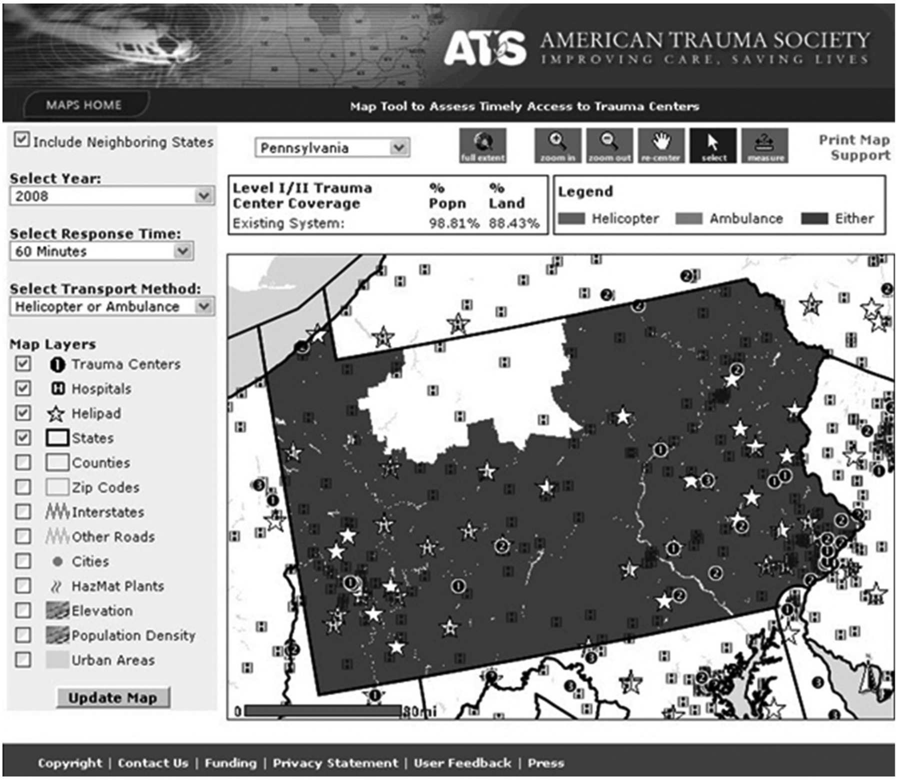

Figure 7.3 State-scale TRAMAH map for Pennsylvania.

In addition to measuring current access, TRAMAH can also play a valuable role in trauma system planning, both in terms of identifying optimal locations for newly designated trauma centers or helipads, and in choosing current sites that might be best de-designated (i.e., sites taken out of service). Compared to non-trauma center hospitals, the specialized equipment and training required to supply and staff trauma centers are considerably more expensive. In a 2002 survey, state trauma system administrators identified two key threats to trauma system viability: funding and retaining personnel (Mann et al., 2005). TRAMAH can help to address both of these needs by optimizing service locations and optimally locating fewer facilities that provide equal or better coverage than the current system or, alternatively, better locating the same number of facilities to give more people access to life-saving trauma care.

Web-based GIS provides a powerful platform for visualizing and interacting with TRAMAH. Making the information from models like TRAMAH available through geospatially enabled Web sites greatly increases the accessibility of information that may prove valuable to planners struggling to maintain adequate population-based emergency care on limited budgets. Although the model has been developed for trauma care, the importance of rapid access to specialty medical treatment has been demonstrated for many other time-sensitive conditions including cardiac arrest, myocardial infarction, stroke, burns, and severe infection. The potential to adopt principles of TRAMAH to population-based health planning for other conditions is compelling.

Timely access to a trauma center hospital can mean the difference between life and death for severely injured patients. State trauma systems act as a safety net to provide that urgently needed care. TRAMAH can play a valuable role in assisting trauma system planners and researchers to assess the level of access provided by current systems and serve as a planning tool for future resource allocations.

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Chapter 8

Healthcare Facility Disaster Planning: Using GIS to Identify Alternate Care Sites

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Contents

Introduction

The early twenty-first century finds many healthcare facilities operating at or near full capacity. These facilities have little elasticity in their ability to handle a rapid increase in demand resulting from a major catastrophic incident. An incident could consist of the outbreak of a new highly virulent contagion, such as the H1N1 or H5N1 viruses, or the occurrence of a natural disaster or manmade calamity. To address this identified inelasticity, planners are now beginning to incorporate "surge" planning and the establishment of temporary surge facilities into their forward-thinking models.

The Joint Commission, the American organization that certifies and accredits hospitals, defines surge facilities as "facilities designed to supplement existing hospitals in the case of an emergency" (Joint Commission, 2006). These surge, or secondary care, facilities present the best option for rapidly increasing care capacity and/or providing large-scale, rapid care to a population. Forward planning should identify the best local facilities to expand capacity. Facilities best suited for a surge in demand include but are not limited to the use of secondary community hospitals or clinical care sites (e.g., downgraded facilities operating in pure outpatient modes), gymnasiums, local schools, or any area where patients can be safely housed. These facilities will require a rapid turnaround for activation.

Operating an effective surge facility requires key resources including staffing, security, equipment, supplies, and patient transport. Certain legal and regulatory issues will apply and planners should address these matters when advising the best methods for managing the secondary facility. Currently, the Joint Commission is developing a set of standards to ensure that surge facilities provide safe, high quality care (Joint Commission, 2006). Planners can look to these "working" standards when developing a situation plan. As such, the best opportunities center upon facilities with preexisting access to medical infrastructure or to the medical supply chain (e.g., deliveries of medications, linens, and oxygen) (Barbisch and Koenig, 2006; Phillips, 2006; Schultz and Koenig, 2006).

Additionally, health industry experts are looking to Geographic Information Systems (GIS), to help them perform the types of analyses and mapping useful in the planning and management of secondary facilities. GIS is a computer-based system that utilizes location information to enhance analysis and mapping and support decision making. Whereas nonspatial databases can hold classification information about things, such as type and capacity of surge facilities, it may be extremely useful knowledge also for planners to know:

- Location of these facilities
- Spatial context or what else is around them
- Systems they are related to (linear as well as geopolitical)
- Distance between each facility (and from various other facilities)
- How they are connected
- What the facility can provide

Staff, Stuff, Structure, and Systems (4 Ss)

America's healthcare facilities in both the urban and rural settings are operating at or near full capacity with little elasticity to expand capacity in response to a mass casualty event. Most facilities lack the preparation needed to effectively manage surge capacity beyond the initial response phases (Hassol and Zane, 2006a). Healthcare facilities, therefore, should create plans for increasing capacity that include the establishment of temporary secondary care sites. The Joint Commission defines these secondary care or surge hospitals as "facilities designed to supplement existing hospitals in the case of an emergency" (Joint Commission, 2006). The use of surge facilities enables the hospital to quickly augment its facilities in order to meet increased demand. Moreover, the planning for and use of surge facilities would cost little to nothing if the planning is orchestrated properly, as the hospital would only incur expenses in the event of the secondary facility's activation.

The ideal surge facility candidate would be a secondary care site with affiliations to a primary hospital that could open within three to seven days of a mass casualty incident. It is important to note that surge facilities are purely relocation facilities for stable, ambulatory patients. Secondary or "surge" facilities should never serve as the initial destination for disaster scene victims as the facility will require activation and often these facilities lack the appropriate emergency resources. Any community contemplating the use of a secondary care facility to serve as a surge facility must thoroughly assess the appropriateness of the facility and conduct advance planning to make this an option should a situation with a surge in demand present itself. This includes assessing local resources to identify optimal sites as well as identifying additional surge locations in the event of failure at a predefined secondary care facility. A fully closed hospital should only be reopened as a surge facility during a mass casualty event or communicable disease epidemic in which an isolation facility is needed. Closed hospitals should *never* be classified as primary surge sites, as a closed facility will fail to pass the 4 Ss criteria required for a surge facility.

Though no single definition or measurement standard for surge or a secondary care facility exists, there is general agreement as to the key components of a surge/secondary care site. These components include the 4 Ss of *staff* (personnel), *stuff* (supplies and equipment), *structure* (facilities), and *systems* (integrated management policies and processes) (Barbisch and Koenig, 2006; Phillips, 2006; Schultz and Koenig, 2006). Mass casualty events place additional burden on the 4 Ss and leave hospitals that are already operating at or near capacity with few additional resources to effectively address an overload to their facility. Due to the tremendous resource needs of a secondary care site, planners must identify these facilities in advance of a mass casualty incident.

Healthcare facilities and community planners are recognizing the need for tiered, flexible surge capacity plans to effectively provide care to a large influx of patients. These surge capacity plans should reflect the establishment of temporary secondary care sites (Hick et al., 2004). During the planning stages, healthcare facilities should prepare themselves for the possibility that their facility could also sustain permanent damage during a disaster and may require the use of a secondary facility for an indeterminate amount of time. This interval will depend upon the damage to the home facility and the duration of the repair (Joint Commission, 2006).

When incorporating planning for a potential surge, it is important to adopt a holistic all-hazards approach, that is, acknowledging the impossibility of planning for every contingency. To identify which incidents present the highest probability of occurring, planners should identify and analyze past incidents, and, from this analysis, create a hazard vulnerability analysis (HVA). This analysis can be structured to provide a percentage basis to major occurrences over a predetermined timeframe (usually the past 5 to 10 years). The identified incidents can then be weighted based on various factors, such as costs incurred, numbers of casualties, or the scale of the incident.

While a definitive model for identifying appropriate surge facilities does not exist, planners can incorporate the use of various models, including facilities of opportunity, mobile medical facilities, portable facilities, and secondary hospitals, into their plans (Joint Commission, 2006). Planners can also benefit from studying the various types of surge facilities that have been used in past emergency responses and build a plan that reflects the needs of their community and the available resources.

Examples of Surge Facilities

"Facilities of opportunity" are usually nonmedical buildings that can be quickly adapted into surge hospitals or centers due to their size or proximity to the host medical center. Facilities of opportunity should be identified during the planning phases for future incidents. Examples include veterinary hospitals, convention centers, exhibition halls, airport hangers, schools, empty warehouses, sports arenas, and hotels. There will be a need for some form of mutual aid agreement and for the contractual details to be worked out in advance to prevent delays in accessing a site when needed. Further, it is easiest to convert facilities with existing medical infrastructure, such as day surgery centers, some types of clinics, and other similar medical facilities due to their existing relationships with supply vendors (Joint Commission, 2006). A 2005 study conducted by the Trust for America's Health (TFAH) revealed that hospitals in 15 states lack adequate preparation for the care of surge patients at facilities of opportunity (Hearne et al., 2005). Thus, the potential shortcomings of the healthcare system during an event that exerts extreme pressure on the care infrastructure are staggering. Forethought and planning would potentially save lives while vastly improving the overall quality of care during an incident.

Mobile medical facilities are another type of surge/secondary care resource that can be rapidly deployed during an incident (Joint Commission, 2006). These can be as simple as tractor trailers outfitted to serve as patient care areas or the deployment of tents to house patients. In the United States, a test project known as MED-1 was developed to function as a fully mobile hospital/emergency care facility. MED-1 is the nation's first fully equipped mobile surgical hospital and consists of two 53-foot tractor trailers, one of which stores equipment and the other a fully functional patient care facility. The facility center morphs into a 1,000-square-foot workspace featuring a two-bed shock–resuscitation and surgical unit and a 12-bed critical and emergency care unit. MED-1 also includes materials for a climate-controlled tented area holding 130 additional beds (Romano, 2005). MED-1 closely resembles the military model of the Mobile Army Surgical Hospital (MASH).

MED-1's use in Hurricane Katrina proved its effectiveness as a disaster response mechanism, but its inherent cost prohibits many facilities from utilizing such a tool. It costs roughly $80,000 per year for maintenance and storage of MED-1 when not in use versus a nonmobile facility, which incurs no cost. The cost of MED-1 seems even more exorbitant in comparison to a facility of opportunity that generates a revenue support stream from its daily activities (Voelker, 2006).

Healthcare facilities can also explore the use of portable medical facilities to address their surge capacity needs. These facilities are truly "hospitals in a box" because they can be put together quickly and can provide care in just a few hours depending on the size and scope of the deployment. An up-and-coming prototype, the Advanced Surgical Suite for Trauma Casualties (ASSTC), has both military and civilian applications.

This lightweight, all-in-one facility can be put together in less than 30 minutes and is stored within a 5 × 5 × 10-foot box. The ASSTC can be outfitted with various medications and equipment depending on the nature of the incident. The functional differences between the MED-1 and the ASSTC center involve cost, scale, function, and size. The logistical challenges facing both facilities include the availability of plumbing and water and the high operating cost per bed (Hick et al., 2006). Thus, it is important for the planner to identify the appropriate facility model to accommodate the needs of the community and the incident itself.

Evaluating the Local Community

When evaluating the options for surge facilities, emergency planners should begin at the neighborhood level and work outward (Joint Commission, 2006). Planners should evaluate candidate facilities in light of specific criteria. The Agency for Healthcare Research and Quality (AHRQ) suggests that planners should eliminate as candidates those facilities that are abandoned or vacant (Hassol and Zane, 2006a; 2006b). In its opinion, a totally abandoned facility could not be safely converted to an operating facility in a reasonable timeframe. Additionally, an unused facility may not have functioning cafeterias, certified life systems, phone switchboards, and, if physical deterioration occurred, patient safety could be jeopardized. Planners should also assess location and relative real estate value to determine whether the facility will be converted to other purposes in the near future (Hassol and Zane, 2006a; 2006b; Phillips, 2006; Hearne et al., 2005). Of importance in the planning stages is the acknowledgment that fully abandoned sites should only be a consideration of last resort.

A more feasible candidate would be a partially downgraded care facility with affiliations to a primary hospital as organizational/contractual agreements would already exist. Partially downgraded facilities maintain some degree of inpatient services, such as walk-in clinics or urgent care, and are often affiliated with "primary" hospitals that provide comprehensive services across the spectrum of care. Size is a factor, as larger downgraded facilities present more options for surge capacity than smaller facilities. Location becomes a factor as ideal surge facilities would be located near major primary medical centers in an effort to minimize patient transporting times. Planners also must assess whether the facility could be active within three to seven days of a mass casualty event and sustain operations for two to eight weeks, or longer if needed. The last hurdle planners will face is obtaining permission and cooperation from the current facility owners (Hassol and Zane, 2006a; 2006b; Phillips, 2006; Hearne et al., 2005).

The AHRQ suggests two scenarios in which using a secondary care site as a surge facility is deemed appropriate. The first scenario involves a generic mass casualty event necessitating the transfer of ambulatory patients from primary facilities to secondary to alleviate the increased demand on the primary facility as a result of the incident (Hearne et al., 2005; Voelker, 2006). It is also suggested that hospitals would cancel all elective and nonurgent admissions and transfer as many patients to other facilities. Only the most stable patients would be transferred to the surge facility; critically ill patients would stay at the primary facility. The second scenario involves an infectious bioterrorism agent or epidemic in which the surge facility would serve as the isolation or quarantine hospital. Certain issues become relevant in such a scenario, including the prophylaxis of facility staff, perimeter control, and obtaining permission from facility owners. It is important to note that surge facilities are purely relocation facilities for stable, ambulatory patients. Because they lack emergency rooms, surge facilities cannot serve as the initial destination for disaster scene victims. Responsibility falls to the physicians at the primary hospitals to determine what patients can be safely transferred to the identified surge facilities (Hassol and Zane, 2006a; 2006b; Phillips, 2006; Hearne et al., 2005).

Surge facilities operate with the goal and intention of maintaining high standards of care. In reality, surge facilities may exist at only a baseline standard of care level due to the difficult circumstances surrounding facility operation. However, substandard care is not permitted (Joint Commission, 2006). In order to maintain community standards of care, certain services should not be instituted at a surge facility. These include the establishment of an intensive care unit, emergency department, operating room, or a large acute burn or trauma unit. Experts advise that certain patient populations should never be relocated to a surge facility, including acutely ill oncology patients, psychiatric inpatients, and pediatric patients.

These patients should remain at the primary hospital due to their sophisticated needs. Further, using a secondary care or downgraded hospital as a surge facility would be an inappropriate destination for victims of an airborne, infectious agent that has no vaccine because the downgraded hospital would most likely lack a sufficient quarantine unit. Surge facilities also should not serve as hospice sites for patients in acute suffering from chemical or radiation exposure as there will be less of a need for a large inpatient hospice facility and, unfortunately, a greater demand for deployment of corpse decontamination units and storage (Hassol and Zane, 2006; Phillips, 2006; Hearne et al., 2005).

Planning for Expansion

With regard to the facility's planning, certain contracts or formal arrangements should be made in advance for bulk and portable medical gas supplies and fire safety equipment. Advance contact should be established with commercial cleaning services, moving companies, refrigerated truck rentals, and medical gas mask suppliers. If the fire suppression system at the surge facility is not operational, the local fire department should be notified. Facilities workers need to conduct various activities to enhance facility structure, including water restoration, HVAC (heating, ventilation, and air conditioning) system repair, establishment of negative pressure rooms, restoration of communications systems, and partitioning off areas that will not be used. Workers should ensure adequate generator fuel supply and order additional fuel if needed. Moving companies should empty out desks or other items. Once the move out is completed, a cleaning company should conduct a thorough facility cleaning (Hassol and Zane, 2006a; 2006b).

Once the facility structure is intact, planners will need to identify sources for staffing the facility. Qualified, available healthcare providers can be obtained through federal government resources, such as disaster medical assistance teams and Public Health Service Commissioned Corps (Hassol and Zane, 2006a; 2006b). Planners can look toward the Department of Defense's Modular Emergency Medical System (MEMS) for help in determining the number of staff needed at the surge facility. MEMS utilizes the incident command system and establishes a network for accessing patient care personnel (Joint Commission, 2006). State governments can also be a viable source for qualified staffing by providing public health department staff members. Other nongovernment sources, such as mutual aid agreements, temporary staffing agencies, and health profession schools, can supply staff members as needed for the incident. Volunteer programs can be tapped as a source of both clinical and nonclinical staff. The American Red Cross, AmeriCorps, and SeniorCorps are all excellent sources for medical personnel and volunteers, if they are available. In addition to obtaining qualified staff, planners must address licensing and credentialing issues and institute a badge/ID system before staff members report to the facility (Hassol and Zane, 2006a; 2006b).

Additionally, the security taskforce will have its own staffing and equipment needs. Certain formal arrangements should be secured with a radio communications vendor for portable radio communications. A security equipment vendor can provide monitoring and access control equipment, including remote door controls, card readers, and cameras. Card readers should be placed at all entrances not staffed by security. These card readers must be programmed to identify staff photo-ID badges (Hassol and Zane, 2006a; 2006b). A contract with a satellite telephone vendor is crucial. Satellite phones can be rented if the facility lacks the funds to purchase such a system outright. Arrangements can be made with partner organizations for use of their security staff. If additional staff is needed, security firms can be contacted. Planners will need to specify in advance the appropriate timeframe for in-house and external responses in addition to the staffing level, uniform requirements, weapons, training, and security protocols. Other security concerns include the installation of temporary chain link fencing around the facility and the availability of traffic control devices. Local police and federal personnel should be aware of surge facility plans and be briefed on possible situations and appropriate responses (Hassol and Zane, 2006a; 2006b).

Procuring the appropriate equipment and supplies takes considerable advance planning. Significant decisions include whether to buy or lease critical items and if items should be preordered or placed on a standby purchase order. Inventory decisions include how much should be stored and how often items should be restocked (Hassol and Zane, 2006a; 2006b). Surge facilities can acquire medications and supplies through the Centers for Disease Control and Prevention's Strategic National Stockpile (SNS). Materials from the SNS, despite its extensive cache of medications, supplies, and surgical items, may not reach the designated area for several days following an extreme emergency (Joint Commission, 2006). According to the 2006 Trust for America's Health report, only seven states have enough preparation to efficiently distribute materials from the SNS (Young, 2006). Even more troublesome is the fact that not a single state reported knowledge of the exact process behind the arrival of SNS supplies (Hearne et al., 2005). The SNS, while an invaluable resource, lacks clear definition and distribution protocols (Hearne et al., 2005). Therefore, planners should take measures to establish relationships with local suppliers in advance to supplement supplies. Ideally, a surge facility should have enough supplies to cover each patient for a minimum of three days (Joint Commission, 2006).

Secondary care facilities identified for surge use will require their own patient transport services to receive patients from the primary medical center in addition to the discharge of patients. Once the surge facility is ready to receive patients, they will be transferred from the primary centers, mostly within the first few days. Surge hospitals have a continued need for patient transport beyond the initial days because additional patients may be transferred or discharged. Advance contracts should be established with private ambulance services. Hospitals acquiring ownership of a surge facility will most likely have existing contracts in place. Planners must take into consideration that private ambulance staff will need respiratory protection in the event of a bioterrorism/airborne pandemic incident. Planners should determine whether a particular ambulance company has contractual agreements in place with other facilities as this will affect their availability. Surge facility planners should coordinate with the transit authority and local emergency planning committee to secure bus transportation during disaster situations. Plans should also reflect the availability of wheelchair van services as acquired through advance communication (Hassol and Zane, 2006a; 2006b).

Several legal and regulatory issues surround the operation of an offsite surge facility. Public health regulations may be applicable depending on the operator of the facility, especially if the surge hospital is a satellite of the primary facility. Many issues will require guidance or coordination at the state and federal level, including liability coverage, narcotics handling, patient records, receiving reimbursement for staff time and incurred expenses, and matters concerning both licensed and unlicensed volunteers (Hick et al., 2004). During emergency situations, the Emergency Medical Treatment and Active Labor Act (EMTALA) can be waived and cooperative agreements can be honored to deliver certain patients to designated facilities. A waiver of EMTALA allows the immediate transfer of critical victims from the surge facility to a predetermined facility (Joint Commission, 2006). The Emergency Management Assistance Compact (EMAC) allows states to distribute aid across state lines in any disaster situation. Under EMAC, licensed physicians can travel across state lines to provide aid and their credentials will be honored upon arrival. EMAC covers liability and worker compensation to lessen the financial and legal issues of responding states (Joint Commission, 2006; Hassol and Zane, 2006a; Phillips, 2006; Hearne et al., 2005).

Healthcare facility response planners who incorporate the use of secondary care sites or downgraded hospitals need to coordinate with key local authorities to institute a feasible plan of action as the response will be a joint activity. Local authorities should look toward the federal government for guidance during the planning phase. In major planning, government response can be expected within 48 to 72 hours, the duration of time it would take to potentially activate a surge facility (Hassol and Zane, 2006a; 2006b). Planners should conduct in-depth facility assessment to select the appropriate facilities and determine the status of life systems at the facility. Planners also should estimate the cost of reopening a downgraded hospital and determine how these costs will be returned to the system. By determining what goods and services can be borrowed from other facilities, planners can decide what materials will need to be contracted out or outsourced or even obtained through disaster declaration (Hassol and Zane, 2006a; 2006b). Plans should designate authority over the surge facility; ideally, a major primary hospital would open the surge facility as a temporary satellite location.

In isolated areas or the developing world, it is important that a plan be in place that *focuses on the local components of resources, availability of care, standards of care,* *and need sets.* This will allow for the population to utilize existing resources and manage the interim period between the incident and the response. Surge facilities in the area represent the best case for housing large numbers of casualties and can range from a local school, church, or an area that can be cleared out to house a population for short periods. These areas will need access to a sewage disposal away from the facility, water treatment (this can be as simple as an area for boiling), and, when possible, access to food and medical supplies from within the community.

It is also advantageous to have a predefined list within the community of available facilities. It is important for the local community to identify regional hazards (e.g., tsunami, earthquakes, floods, and snowstorms) and facilities that would more than likely be unaffected by the incident. Exploring preexisting resources and allowing the community to model its plan based on local resources and incident history presents the best combination of mitigation techniques available for situations where resources are overwhelmed.

GIS Applications

GIS is instrumental in enabling dynamic forecasting, modeling, and secondary site identification. In other words, it is not necessary for the results of spatial operations (e.g., proximity or distance) to be stored discretely in the database. In considering how experts might use GIS to help plan for and manage surge facilities, it may be helpful to first discuss the basics of data, imagery, analysis, and mapping.

There are various kinds of spatial data that would be useful in planning for surge facilities. Base data, such as roads, public transit systems, streams, geopolitical districts, etc., are often publicly available through local, county, regional, or state governments. Some of these, such as roads, also are available through commercial vendors for a fee (e.g., TeleAtlas North America, Lebanon, NH). Aerial imagery, either vertical or "straight down" as well as oblique or angular, are often available through government sources (e.g., digital orthophotography from the USGS, state, or local) or private contractors (e.g., Pictometry, Rochester, NY; http://www.pictometry.com/ home/home.shtml).

Thematic data specific to surge facility locations will likely be "best effort," since there are no up-to-date, standards-based national databases of surge facilities or facilities of opportunity. Therefore, planners and leaders need to be aware of "metadata," or data about data, to determine usefulness and reliability of various spatial data. Examples of spatial data useful to health industry experts planning surge facilities may include:

- Approved surge facilities
  - Recently closed hospitals
- Facilities of opportunity
  - Veterinary hospitals

- Convention centers
- Exhibition halls
- Schools
- Airport hangers
- Empty warehouses
- Sports arenas
- Hotels

■ Related facilities
- Hotels (to house staff during events)
- Ambulance service providers
- Medical equipment and supplies providers

■ Reference data and imagery (e.g., base map data)
- Ortho imagery (vertical imagery, such as the "satellite view" in Google)
- Transportation and routable networks (roads, rail, transit, evacuation routes, etc.)
- Land use and zoning (institution, commercial, industrial, residential, etc.)
- Streams and other natural features
- Elevation data (e.g., topography and digital elevation model)
- Political divisions (e.g., jurisdictions and other boundaries)
- Place names and geographic names

■ Physical infrastructure (buildings, bridges, utilities, etc.)

Issues often surrounding spatial data include:

■ Ownership: Who are the data "owners" and are they maintaining their data as part of a regular business process?

■ Metadata: Is there current and accurate information about data, such as status, source, contact/ownership, keywords, resolution, spatial reference, etc.?

■ Access: Are data and imagery readily accessible and freely distributed?

■ Cost: Is there a cost, such as acquisition, construction, maintenance, or licensing, associated with data and imagery?

Typically, planners use spatial data to perform analysis and mapping. Data and imagery are used to make a decision or draw a conclusion and the results are reported or mapped (Figure 8.1).

Spatial analytical operations that may be useful to planners of surge facilities include:

■ Proximity analyses
- Where are the closest surge facilities to active hospitals?
- Which surge facilities are associated with each hospital?

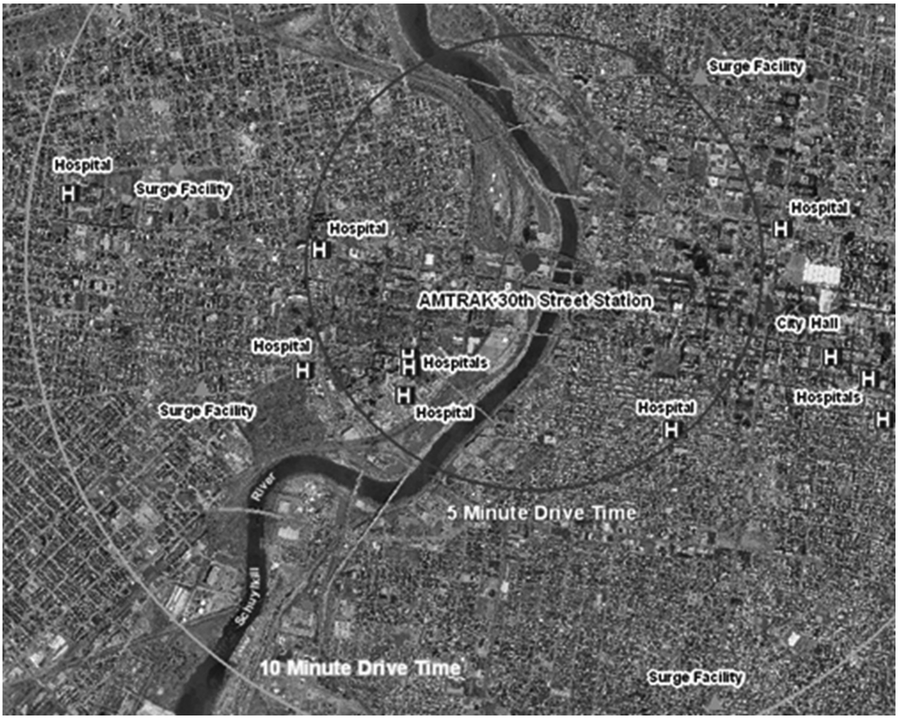

Figure 8.1 Example of spatial analysis for "surge" planning in the City of Philadelphia, Pennsylvania.

- Network analyses
  - How many ambulance services providers are within a 30-minute drive of designated surge facilities?
  - How many surge facilities are with a 10-minute walk of a public transit system?
  - How do I get from my hospital to the nearest surge facility?
- Overlay analyses
  - Within what jurisdictional districts are surge facilities of opportunity located?
- Within which 911 district is my facility?

Mapping is often thought to be a static process created with sophisticated (e.g., hard to use) desktop software used to simply report the result of spatial operations or portray a situation or relationship. Interactive mapping, or the ability to quickly change parameters and instantly see the result, is often more useful and suitable for these purposes. This is often done in a Web-enabled fashion consumable through a Web browser rather than a "heavy" desktop GIS client.

When technologically feasible, the utilization of GIS can bring together various services and data sources across the Internet (or intranet) and relies more on server-side processes rather than the desktop. Cloud computing will often lower upfront costs and allow planners to pull together data from disparate sources in a "best effort" fashion. Conversely, there can be ongoing costs related to data licensing (from commercial vendors, for example, for spatial data, such as routable commercial street centerlines). These Web services and "mash ups" are useful in situations where data and imagery are not affordable, sources are variable, spatial operations are narrowly defined, and "best effort" indicator-level results are acceptable or often the only alternative in the absence of more reliable data. This should be particularly interesting to planners and leaders working with surge facilities because there are no national data sources or standards and there is likely a narrowly defined scope of spatial operations and mapping. Generally, base data will be useful and supplemented with best-available information about surge facilities, facilities of opportunity, and support facilities. Spatial operations will likely be limited to data discovery and collection, basic proximity analysis, basic network analysis, and interactive Web mapping to report results and enable planning and situational awareness.

It is important to note that for GIS data to be accurate or "best effort" and useful in planning, a significant degree of advance forethought is required. This must occur before a downgraded hospital can be reopened as a surge facility in the immediate aftermath of a disaster and that facility can be incorporated into the GIS model (Hassol and Zane, 2006a; 2006b).

Conclusion

Effective operation of surge facilities requires advance planning, coordination of resources, efficient communications, and clear leadership. Surge hospitals carry inherent operational challenges and cannot be opened without detailed, thorough planning. The Joint Commission recognizes the need for a set of standards to ensure the safety and quality of surge facility operation and plans on working with facilities to institute these standards with minimal cost (Joint Commission, 2006; Hassol and Zane, 2006a; Phillips, 2006; Hearne et al., 2005). Healthcare facilities need to work together with community planners to develop a single, organized response to increase system-wide surge capacity. Those facilities that fail to plan in advance will find themselves without options for surge hospital use. Nothing will truly test surge facility planning more so than the mass casualty event itself. Plans may look thorough and detailed on paper, but the developing situation will most likely present a different reality with unanticipated stressors. Thus, it is crucial that facilities assess surge facility resources in advance and perhaps incorporate surge facility use into disaster drills.

This combination of forethought, identification, and ultimate quantification in the plan itself and the modeling of the plan through utilization of GIS presents a paradigm shift in decision making. The GIS-incorporated planning allows for the planner to visually identify available resources, roads, potential hazards, and a range of other data sets, which were previously relegated to specialists. Other concepts for developing more useful and reliable data and planning tools for surge facilities and facilities of opportunity include:

- Surge Sheds: Determine in advance which hospitals feed into which surge facilities and which surge facilities are related to facilities of opportunity.
- Surge Facility Wiki Map: Develop an online, collaborative effort to catalog and map surge facilities and facilities of opportunity by various registered editors and overseen by registered or approved reviewers.
- Surge Facility Map Service: Publish a map service that can be consumed on a standard Web site.

The additional information sets available to the planner (e.g., water shed information, topographical analysis, historical data) through GIS-based systems present a wide range of opportunities by which the modern planner can determine what is best for his or her facility. Therefore, decision-making changes from a mere art form into a rigor-based science dependent on clear data provided by the GIS system. The ultimate planning model would combine GIS with business intelligence, data mining, and "what if" analysis, both of geographical data and inventory data. This would provide an incredible tool for developing infrastructure and response plans at all levels.

The combination of thorough planning, identification of community resources, hazard vulnerability analysis, local resources, and need sets when filtered through the lenses of GIS creates a unique opportunity for planners. That is, the visualization of all aspects of the surge plan and the community itself will create new paradigms in optimizing response to mass casualty incidents and the ability to improve the overall quality of care during a disaster. This will result in lives saved and, through optimal planning, a way to minimize costs to the host facility. Therefore, we cannot underscore the importance of forward thinking in its ability to benefit both the community and the host facility.

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Chapter 9

Multiscale Enterprise GIS for Healthcare Preparedness in South Carolina

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Contents

Introduction

Healthcare facility preparedness for rapid response to a disaster relies on extensive planning, sharing of information, and effective coordination of resources. In recent years, much attention has been paid to the implementation of systems that integrate information to provide situational awareness across regions and states. The U.S. Federal Hospital Preparedness Program has promoted widespread use of information systems for tracking bed availability and hospital resources for medical surge during a mass casualty event. Other systems support prehospital emergency medical services, disease surveillance and reporting, rapid communication of health alerts, and management of emergency operations. Geographic Information Systems (GIS) provide a framework for integrating information from multiple sources and converting data into useful information for planning and response.

This chapter will focus on practical ways that GIS has been implemented by the South Carolina Department of Health and Environmental Control to increase capabilities for conducting routine surveillance and meeting emergency preparedness and response requirements both internally and externally for facilities, emergency responders, and public health professionals.

Overview of GIS at the South Carolina Department of Health and Environmental Control

The South Carolina Department of Health and Environmental Control (SCDHEC; http://www.scdhec.gov) is a large and complex state agency that is responsible for the "*promotion and protection of the health of the public and environment*" throughout the state (SCDHEC, 2006). This agency has regulatory, licensing, surveillance, preparedness, analysis, and intervention responsibilities that are managed through multiple program areas and executed through numerous bureaus, offices, divisions, and sections. DHEC encompasses both the primary health and environmental regulatory branches of the South Carolina state government and has over 4,500 full-time staff distributed throughout 8 health regions located within 46 counties. In South Carolina, all county health departments are part of DHEC and carry out state public health priorities while addressing local needs.

Most of the agency's primary information technology and information systems (IT/IS) are housed in the DHEC central office with centralized databases built on constantly evolving agency standards and program area requirements. These requirements come from varied state, federal, and other sources as well as specific national priorities, standards, and trends. This has led to a variety of systems being developed at different times with different programming languages, databases, data models, and end-user functionality. To address this reality, DHEC has created an agency data model and standards to guide development efforts. In an ideal IT/IS setting, all systems should be developed on the same platform with data and functionality uniform across all systems. This would allow all data to be linked and integrated to perform comprehensive analysis and integration with other information collected and maintained within the organization. Additionally, organization data should be shared with partners and linked to other available data sources via standard unique identifiers. In reality, this is not practical for a number of reasons. For example, lack of standardization and difficulty in addressing security and privacy issues have hindered data sharing both internally and externally. To address issues such as this, organizations have to find alternate methods to integrate information. Information needed to support enterprise level decisions in public health typically comes from a diverse set of both internal and external systems that contain data collected at different spatial and temporal scales with program specific constraints and intended uses (National Research Council, 1997).

All of these variations and nuanced aspects of available data have to be reconciled, or at least addressed and understood, to ensure that decisions are well informed. Beyond this common organizational dilemma, DHEC has to find a way to provide information to a diverse set of internal program areas that often are not aware of the existence of ancillary datasets that could be used to more effectively make decisions, accomplish goals, and fulfill mandates. DHEC has found that a feasible way to provide this type of agency data discovery and integration tool is to leverage one common aspect of most data in all these systems: "geography." GIS is a tool well positioned to leverage this common aspect and provide agency-wide system integration (Figure 9.1).

While Figure 9.1 is a complicated diagram of the existing SCDHEC Enterprise System Integration Architecture. While it may be difficult to understand every acronym or system listed, what is important to understand is that most governmental agencies, along with many healthcare facilities face the same challenges that might be illustrated with a similar diagram. In many instances, this complexity is not fully understood within an organization due to compartmentalized structure and fragmented management. This does not change the underlying need for data and systems integration. The process of integration is a daunting task, but the complexity can be readily managed with existing GIS tools that leverage the inherent geographic component of varied datasets. For regulated entities in DHEC systems, that geographic component could be the physical location of a facility, endpoint, or service area. For nonfixed entities such as patients or clients, that geographic component could be either the residential address, occurrence location of a given event, suspected exposure location, or even their network of contacts.

In the context of hospital and healthcare preparedness, DHEC needs to be able to look at the location of each healthcare facility and the demographics it serves. GIS applications can show where related events occur, map the confirmed and suspected cause of events, identify what risks and hazards these facilities need to prepare for and mitigate against, and address a variety of other contextual issues with inherent spatial components. DHEC has spent a lot of time and effort to standardize the way GIS is implemented in the agency. The end result is hundreds of

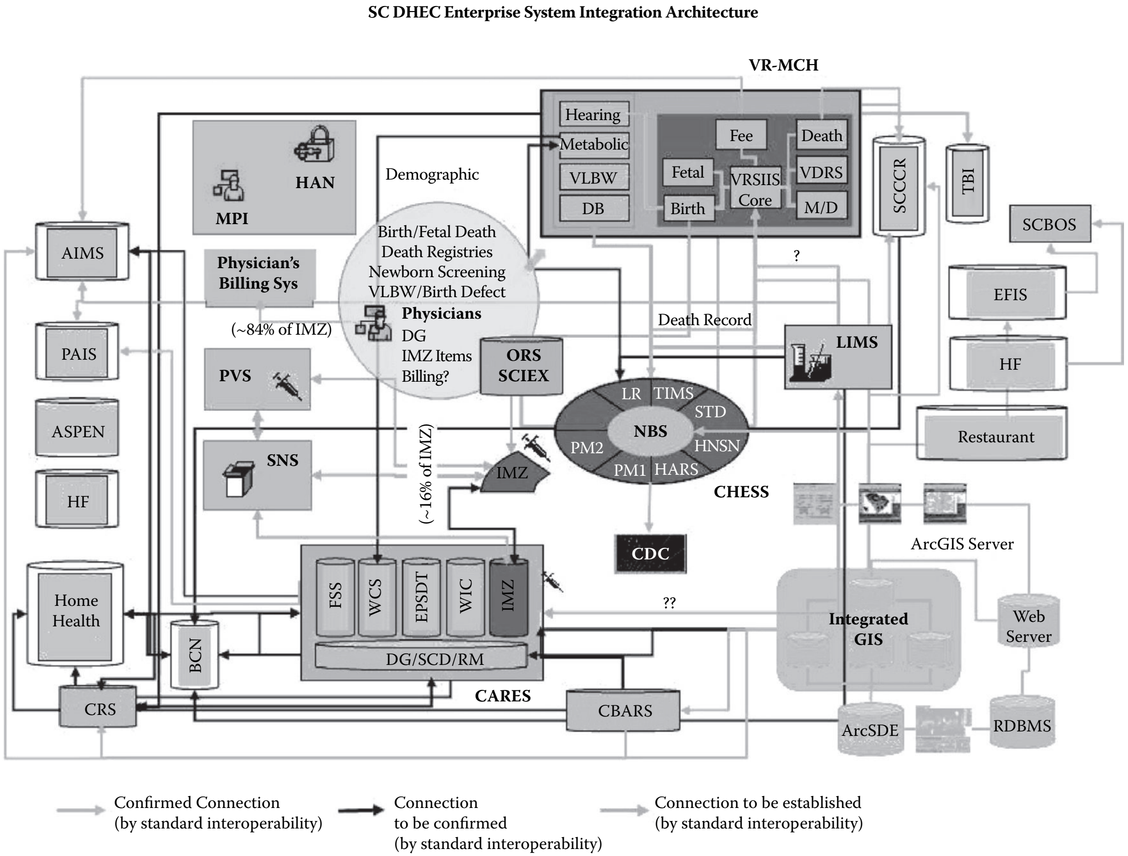

Figure 9.1 South Carolina DHEC Enterprise System Integration Architecture.

layers of spatial information, both health and environmental, produced and maintained by GIS staff and made available to both internal and external partners with standardized metadata and methods. The GIS standards at DHEC were developed by a voluntary GIS technical advisory group called the Shared and Integrated GIS (SIGIS; http://www.scdhec.gov/gis) committee. This committee is comprised of GIS staff from the major program areas in DHEC and is open to anyone with an interest in GIS.

With this coordination structure and spatial standards in place, diverse program areas can integrate various internal and external data sources by consulting metadata and relying on existing GIS infrastructure. These data sources include existing DHEC spatial data along with other socio-economic, contextual, and baseline information maintained by diverse federal, state, and local organizations. External data sources include, among others, layers maintained by the U.S. Census Bureau, Federal Emergency Management Agency (FEMA), United States Geologic Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), county GIS programs, South Carolina state agencies, and border state agencies.

GIS Integration of Hospital Preparedness Data

The first example of GIS enabled statewide integration for hospital and healthcare preparedness revolves around the location of licensed healthcare facilities. DHEC licenses healthcare facilities and services, including hospitals, nursing homes, ambulatory surgery centers, home healthcare, hospice care, dialysis centers, and others. The agency is responsible for ensuring that facilities have appropriate emergency plans in place and are prepared for natural and manmade disasters, evacuations, patient surge, and potential disease outbreaks. In order to properly carry out these responsibilities, DHEC maintains a spatially and temporally accurate health facilities layer. GIS staff, within the Division of Public Health Informatics, worked with the Division of Health Licensing to create a near real-time GIS layer that is linked directly to the main licensing database. As new facilities are licensed or existing licenses change, attributes maintained in the licensing database are synchronized with a GIS layer that is then displayed on numerous internal and external ArcIMS and ArcGIS Server Web sites (http://www.scdhec.gov/co/phsis/biostatistics/index.asp?page=oldbio) and desktop applications. These applications display the latest spatial and nonspatial information to allow end users the capability to make informed timely decisions. When changes occur in the license database, a sequence of automated events is triggered that results in either a new facility being geocoded or an existing facility record being modified to match the underlying program area information. The composite geocoding service used for this purpose was developed by DHEC working with external consultants to engineer knowledge and experience gained from years of geocoding public health data manually. This service uses county and municipal level address points, enhanced 911 centerlines, and a nationwide street network database to produce the best possible spatial match and additional attributes that explain the quality and type of match. This service is an example of service-oriented architecture (SOA) and is constantly evolving and being utilized in new and creative ways throughout DHEC.

The process of geocoding healthcare facility data occurs automatically, but it is only the first step in a complex value-added process. After georeferencing the data either via geocoding or Global Positioning System (GPS) data collection, GIS staff use geoprocessing models to add spatial information to this data, such as the normal and fast hurricane storm surge zones, special flood hazard areas, state evacuation areas, census units, and related information. In the healthcare facilities layer example, the spatial layer and program area attribute information are synchronized eliminating the need to maintain data elements in two separate locations while providing the most current information to end users. While geocoded data are valuable spatial assets, GPS locations for these facilities are much more reliable for emergency response and planning purposes, thus field collection is a vital part of the layer maintenance process. DHEC prioritizes the facility types for field GPS data collection with a customized ArcPad mobile GIS application. Facilities and other spatial data are prioritized for GPS data collection based on a number of different factors to ensure field data collection is both cost effective and based on perceived risk and the consequences of decisions made from this data. For the health facilities layer, hospitals and nursing homes are given priority due to their high numbers of licensed beds and inpatients as well as their crucial role related to disasters, evacuations, and statewide public health capacity. Within the categories of hospitals and nursing homes, additional prioritization and weight is given to those facilities near the coast that could be affected by hurricanes, flooding, and evacuation orders. Subsets of facilities are versioned and "checked out" from the central spatial database, so field data collection staff can collect updated coordinates and merge them back into the central database with no interruption to existing end users.

Critical Data Sheet Application

This healthcare facilities base layer is made ubiquitously available throughout DHEC and South Carolina through the SIGIS download server. It serves as the basis for external and internal planning efforts centered on public health capacity and all-hazards preparedness. Internally, this layer is leveraged through server-based Web sites, applications, and as a stand-alone GIS layer that can be added to an existing project or analysis effort. It also serves as the basis for the Critical Data Sheet (CDS) application that will be covered extensively in Chapter 10.

The CDS application was designed to fulfill the DHEC mandate to review emergency response, evacuation, and shelter-in-place plans for each hospital, nursing home, or hospice facility in any of eight designated South Carolina counties. These eight counties have areas with flooding predicted in the normal and/or fast surge zones produced by the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) models (NOAA, 2007). If an official evacuation order is issued in preparation for a hurricane with a predicted intensity of category 3 or less on the Saffir–Simpson scale, designated healthcare facilities have the option to request permission to shelter-in-place due to the inherent risk of moving patients balanced against a facility's ability to withstand the coming storm. Each potential hurricane landfall and shelter-in-place request is evaluated on a case-by-case basis with information that each facility provides online to DHEC detailing the plans they have put in place and their capacity to successfully protect the health and safety of their patients and staff.

The CDS application was created and made available to DHEC staff and healthcare facilities to provide a standardized set of questions and answers related to their capacity and plans as well as to provide summary reports and Web-based interactive GIS mapping capabilities. Important spatial information, such as surge zones, evacuation areas, evacuation routes, and the locations of other facilities, is provided to DHEC staff and healthcare facilities that have limited GIS capabilities. This application provides transparency in the decision-making process by providing a window into many of the variables considered, and the ability to make informed decisions and plans. It was designed at the request of the DHEC Office of Public Health Preparedness (OPHP) for primary use by the Division of Health Licensing staff that review facility plans and coordinate with emergency management officials and the governor to approve or deny requests to shelter-in-place. The system is built on a server and technical infrastructure that was already in place to serve out other routine public health analysis, visualization, and reporting applications. DHEC experiences economies of scale by using shared resources such as this for rarely accessed emergency response and planning applications. This dual-use strategy allows the agency to more fully utilize the available resources of hardware, software, data, and technical staff time while providing a buffer against the uncertain futures of different funding sources outside of those allocated for routine public health surveillance and reporting activities. Additionally, because other nonemergency-related GIS applications that are accessed daily are housed on these servers and utilize the same software and data, technical staff are notified of any system outages long before these emergency-related systems are needed.

Vital Records and Carolina Health Electronic Surveillance System (CHESS)

The same healthcare facilities layer is also used throughout the agency in conjunction with registries, such as Vital Records, that contain the coordinates for birth and death events that occur in the state. This integration allows emergency responders and planners to understand the distribution of healthcare facilities and their relative importance in handling routine public health events, such as births and deaths along with possible surges related to outbreaks and disasters. The location of these facilities is also integrated, via server-based GIS, with the South Carolina implementation of the National Electronic Disease Surveillance System (NEDSS), which is a national network of standardized infectious disease surveillance systems that promotes integrated surveillance at federal, state, and local levels (Centers for Disease Control and Prevention, 2009). The South Carolina implementation of NEDSS is called the Carolina Health Electronic Surveillance System (CHESS). CHESS submits every new incident registered, along with every address tied to that incident, to the same composite geocoding Web service that is used to map other agency datasets. A number of different fields with spatial data and standardized address elements are then inserted back into the CHESS database. These data are leveraged through an ArcGIS server spatial data viewer that allows the overlay of case data with public health infrastructure, socio-economic information, other DHEC licensed/permitted facilities, aerial imagery, and transportation infrastructure to help identify the possible cause of an outbreak and the potential disproportionate impact on the public health infrastructure (Figure 9.2). The virtual design of this system allows all case data to remain only in the CHESS registry and

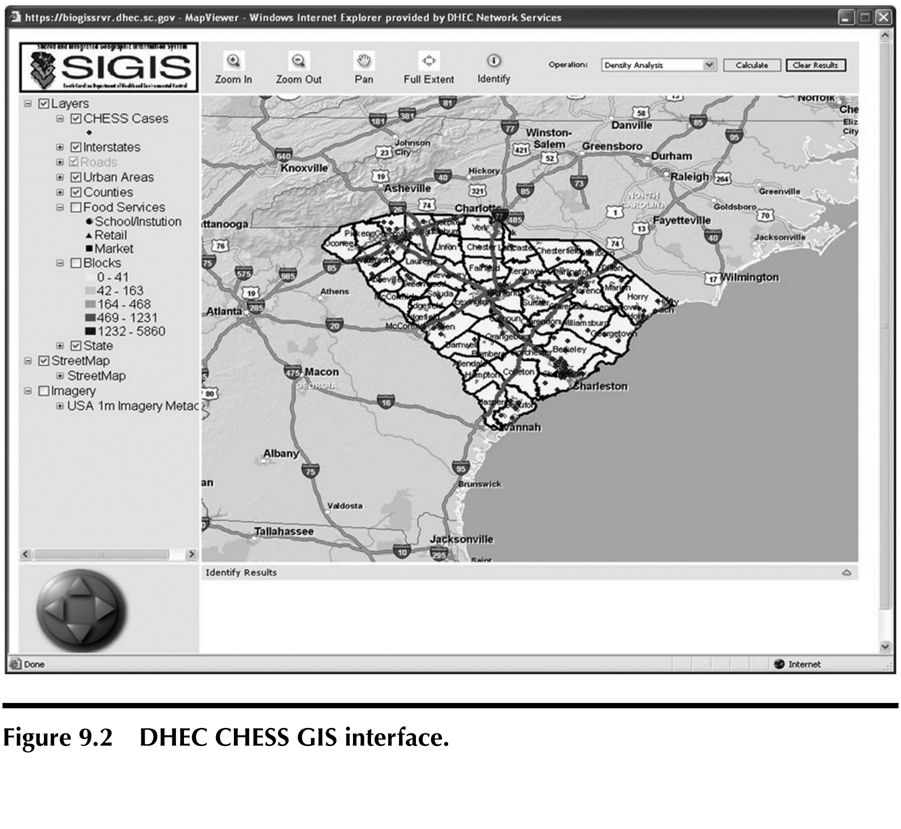

Figure 9.2 DHEC CHESS GIS interface.

be rendered "on-the-fly" over an internal encrypted connection to limit concerns related to patient confidentially and system security.

REACH

GIS also plays a crucial role in the way DHEC can deliver both informative and emergency messages to licensed healthcare facilities, public health professionals, and emergency responders. There is a national requirement through the Center for Disease Control and Prevention (CDC) for a Health Alert Network (HAN) system to be created and maintained in each state to distribute messages to a network of public health professionals and facilities when alerts, advisories, or notifications are sent out from the CDC (CDC, 2002). This approach is called a "cascading and direct alerting system." DHEC has implemented such a system locally called *REACH* (http://www.reachsc.com) to fulfill the federal HAN requirements. There are many different levels of users and components in this system. The notification system has the ability to contact anybody registered by cell phone, office phone, home phone, fax, pager, and e-mail via routine user and group selection options. This is the standard nonspatial HAN notification approach employed across the United States.

DHEC, working with developers and the South Carolina Emergency Management Division (EMD), incorporated a GIS-based spatial notification component directly into REACH that utilizes the extensive amount of spatial data available to provide another avenue to get messages out to facilities, and other geographic entities, that may not be registered REACH users. When originally designed, the REACH system could add remote ArcIMS map services to the system that is housed in the EMD's State Emergency Operations Center (SEOC). This approach provided spatial onscreen selection options, buffering, and ArcIMS-based attribute selections to generate a callout list from data that was physically housed on remote GIS servers. With recent system revisions and updates, the ability to link to remote Web services was replaced with a requirement that any GIS layer that is needed for notification be physically loaded on EMD servers. While this broke the "real time" ability to update these notifications layers, it added the benefit of keeping a current copy of the healthcare facilities and other critical layers onsite at the SEOC for use in emergency planning and response activities in the event of a DHEC or state data network or application failure. This health facilities layer has been used inside of the REACH system to notify designated coastal healthcare facilities of informational calls related to possible voluntary and mandatory evacuation orders and to provide statewide reminders of proper procedures related to the recent novel influenza A (H1N1) outbreak. DHEC staff with the proper credentials can log into this secure system and use standard GIS functions to create healthcare facility notification lists from buffering and proximity tools, user defined areas, or both spatial and nonspatial attribute queries. REACH's GIS notification capabilities are restricted, based on the current system design, to phone calls to the primary number listed for the facility in the licensing database. This provides an automated and standardized way to contact these facilities while also providing an audit trail and report of which facilities received the message as well as contact information that needs to be updated in the licensing database.

Emergency Operations Center Drills (EOC Drills)

One of the most crucial roles of GIS in hospital and healthcare emergency preparedness is the ability to overlay the locations of healthcare facilities through desktop GIS software and server-based GIS with other static and dynamic layers. This may include such information as evolving natural disasters and model output related to hurricanes, earthquakes, storm surge, flooding, and wild fires, along with the location of evacuation zones, demographics, official shelters, nuclear power plants, air monitoring stations, and related health and environmental infrastructure. To address this need, DHEC has implemented a system called EOC Drills that was originally designed to host all publicly available and secured access GIS data in a Web-based environment for use in state drills and exercises when staff did not have access to the DHEC network or their desktop GIS (Figure 9.3). This system evolved into a tool to

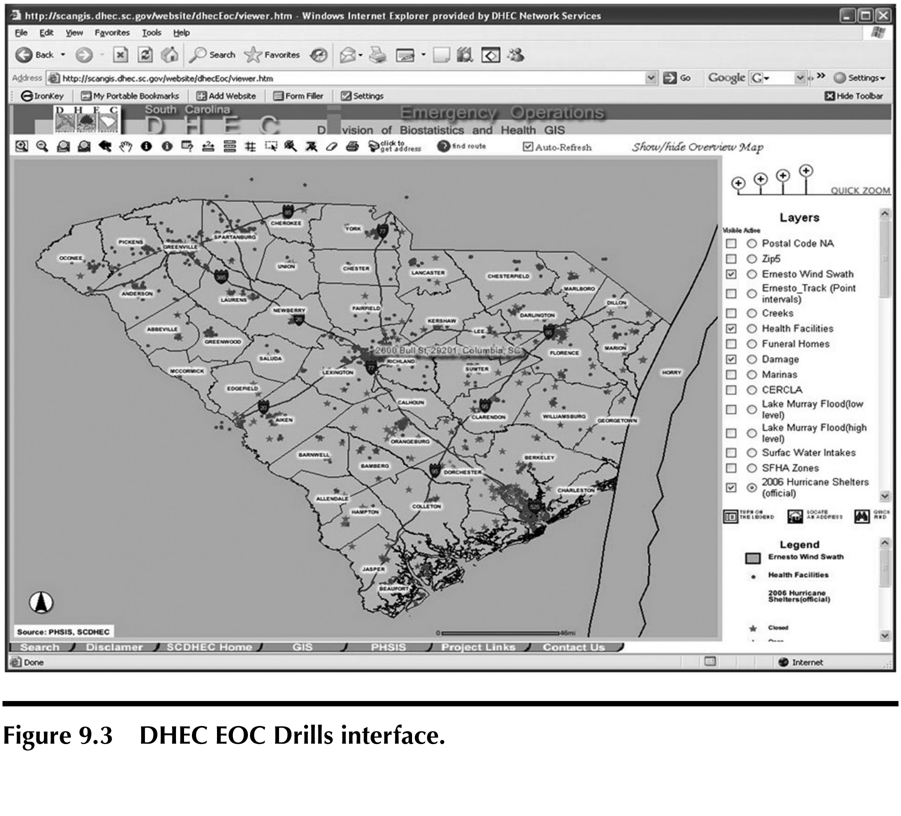

Figure 9.3 DHEC EOC Drills interface.

provide situational awareness to assist in the management of emergency situations. For example, during the Graniteville train wreck and subsequent chlorine leak on January 5, 2005 (http://chronicle.augusta.com/train/), DHEC used desktop GIS to generate possible plume models, based on the best information available, that were then overlaid with healthcare facility and shelter information via EOC Drills to determine possible impacts on existing infrastructure and to plan for possible evacuations.

At times, field staff do not have access to an Internet connection, but still need the situational awareness that GIS provides. To address this need, DHEC took all the GIS data served out through the EOC Drills, and which was available on the network as a desktop emergency mapping project, and used ArcPublisher to package all the data onto DVDs that were distributed to field emergency response staff to install on their laptops. ArcReader, a free GIS data viewer software package, or ArcGIS desktop can be used to view the GIS data on these DVDs in the field. These DVDs are updated on a regular basis and provide an alternative for DHEC staff without access to the DHEC network or Internet. The drawback is that the data is not real time, but it still allows emergency responders to understand where the public health infrastructure is located in relation to an unfolding and rapidly evolving emergency.

Community Assessment for Public Health Emergency Response (CASPER)

The same GIS technology, methods, and expertise used to develop all previously mentioned applications and data are also employed to assess the public health needs in affected communities after significant natural or manmade disasters. While public health professionals generally understand overall healthcare needs in a given area, in some instances after a significant event, teams must be deployed to the affected communities to evaluate and prioritize exactly what intervention or assistance is required and what impact that will have on existing healthcare resources. The CDC has suggested a methodology and tool set for this purpose called Community Assessment for Public Health Emergency Response (CASPER) that relies heavily on spatial statistical analysis, sampling, and field surveys (Department of Health and Human Services, 2009). DHEC has adopted this methodology and enhanced and customized existing field GIS tools for data collection in South Carolina communities. Together these tools provide public health officials and emergency responders with additional information to respond effectively and advise healthcare staff on mass casualties and public health priorities. While there are ways to produce the sample points, collect field data, and analyze results without GIS, the application of GIS technology has streamlined, expedited, and standardized the process making the results available in a graphical format easily presented and understood by public health professionals.

Emergency Hurricane Sheltering System

Assessing on-the-ground needs after a disaster is critical to an effective recovery operation. Equally important is the need to provide adequate shelter and medical care before, during, and after incidents. DHEC has worked with state and local partners to provide mass sheltering and special medical needs sheltering in the event of a hurricane evacuation or landfall by relying heavily on the use of GIS. DHEC worked with the American Red Cross, South Carolina Department of Social Services, and the South Carolina EMD to develop the Emergency Hurricane Sheltering System (http://scangis.dhec.sc.gov/dhecshelters) that allows state agencies and the public to see different amounts of information, based on user roles and emergency support functions, as events unfold. The general public can access this Web application to determine the location of the closest shelter to their home and receive driving directions. An alternate version of the Web application allows users to find open shelters during an evacuation. Emergency response and public health officials can log into this system and edit any spatial or nonspatial information for which they are responsible and either open an existing shelter or designate alternate shelters to official status instantly making them available to the public. While policy decisions are not made with this tool, it is used to make the results of those decisions available quickly and provides the level of unified situational awareness that is required. The application can be used to route nurses when staffing special medical needs shelters or American Red Cross mass shelters. Geographic reports can be generated to show the number of people and staff in each shelter along with food and security requirements. Law enforcement officials can use the tool to determine how to best serve the public, and geographic patterns can be analyzed during and after an evacuation or sheltering operation to better plan for future incidents.

The Emergency Hurricane Sheltering System relies on GIS in every step of the process of providing sheltering information. An official hurricane shelter list and corresponding special medical needs shelter list are produced each year based on different spatial and nonspatial criteria specified by a number of different organizations tasked with this responsibility. These lists are then provided to DHEC GIS staff for comparison with old lists, geocoding, and subsequent GPS data collection with customized field tools. The resulting data layer is maintained in a spatial database and leveraged through the Emergency Hurricane Sheltering System where authorized staff can enter and maintain other required information about the facility, such as Memoranda of Agreement (MOA) dates, contact information, capacity, and available resources. Additionally, the information on these facilities is also available through other agency GIS applications that display the shelter layer. This means that when a shelter is opened in one system, it is then marked as opened in other systems (such as EOC Drills), so it can be visualized and analyzed in relation to other emergency response efforts and events. This process of updating information in one location and having that information cascade to other related systems facilitates compliance with the National Incident Management System (NIMS) and the

Incident Command Structure (ICS) directives (Federal Emergency Management Agency, 2009) by providing situational awareness and unified command tools.

Other GIS Support Applications

Another critical use of GIS by DHEC is to aid in the process of hospital and healthcare preparedness by evaluating key locations for the Strategic National Stockpile (SNS) locations in South Carolina. GIS is used, in conjunction with extensive staff expertise, to evaluate the distribution of healthcare facilities, population, transportation infrastructure, and various other contributing factors to locate primary SNS distribution locations and dispensing sites. Some other DHEC GIS tools and information available to internal staff and authorized emergency response and public health professionals throughout the state include facility vulnerability and assessment information. In addition, GIS models are used to predict possible air and water contamination that could have adverse impact on the general population and specific healthcare operations.

There are many other GIS applications and layers currently being developed by DHEC that continue to increase the capacity to prepare for and respond to emergencies by providing the required level of detail to public health professionals. DHEC has recently received a National Spatial Data Infrastructure (NSDI) stewardship grant to collect data and evaluate the feasibility of collecting layers, such as Emergency Medical Services (EMS) providers, churches, and urgent care centers. Coupled with existing data layers and GIS tools, this information will be leveraged to more fully prepare for, respond to, and recovery from a variety of possible future events. DHEC is also redesigning its Emergency System for the Advanced Registration of Volunteer Health Professionals (ESAR-VHP) application with plans to embed the ability to call up registered and credentialed volunteers, not only based on their professional expertise and willingness to assist with an incident response, but also by their geographic location. If, for example, a certain hospital or health department was overwhelmed during an incident and needed to request possible volunteer doctors and nurses to supplement existing staff, DHEC will be able to conduct geographic searches inside the ESAR-VHP application (SC-SERV) for professionals in the area that could be onsite in the least possible amount of time.

Another tool being developed that centers on hospital preparedness and planning is called the South Carolina Hospital Assessment Reporting Program (SCHARP). The purpose of this tool is to provide a standardized tool and method, available 24/7 from any location with Internet access, to gather required resource and asset information from hospitals to allow these facilities and DHEC staff to evaluate facility and state-level all-hazards response capabilities. The current version of this tool has been focused on collecting required program reporting information, but the next release will include geographic reporting and analysis tools to aid the planning and gap analysis process.

Conclusion

Geographic Information Systems provide integrated and enhanced analysis, visualization, and reporting capabilities with both spatial and nonspatial data that could not be provided through any other medium. While traditional tools, methods, and staff expertise are invaluable to effectively respond to an emergency situation, the ability to interactively query and overlay multiple sources of data in a geographic context can make a significant difference. The robust and integrated enterprise GIS at a state-level public health agency has made possible enhanced planning, preparedness, response, and recovery capabilities on both a macro and micro scale providing greatly enhanced benefits for emergency management and response professionals.

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Chapter 10

Hospital Preparedness Planning for Evacuation and Sheltering with GIS in South Carolina

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Contents

Introduction

Every healthcare facility in the United States has a specific set of risks that it must address in its emergency plans. Each facility must consider the potential manmade and natural disasters that it could face and how best to protect patients and staff while adhering to all pertinent state and federal statutes and regulations and continuing to provide the best possible service to all patients in a very competitive healthcare industry. Hospital preparedness and planning is a complicated multifaceted process where the pros and cons of every aspect of emergency plans must be carefully weighed. Planning for evacuation and sheltering is a critical feature of emergency plans, particularly for facilities in areas with geologic or severe weather hazards. In many locations, hospitals must prepare for tornadoes, earthquakes, wildfires, floods, or landslides. Healthcare facilities located in coastal areas must prepare extensive plans for many of these possible events along with the occurrence of hurricanes and associated storm surge, flooding, wind, and other related extreme weather conditions.

Critical Data Sheet System Background

In South Carolina, hospitals, nursing homes, and hospice facilities located in any of eight potentially affected counties may file a Critical Data Sheet (CDS) with the South Carolina Department of Health and Environmental Control (DHEC) to provide operational information to assist in hurricane evacuation planning. This CDS, administered through an online application, must be filed with DHEC in order for the department to recommend that any of these facilities be allowed to shelter-in-place (process of staying put and taking shelter rather than trying to evacuate in an emergency situation) preceding the landfall of a hurricane with a projected intensity of a category 3 or less on the Saffir–Simpson scale of hurricane intensity. Facilities are not permitted to shelter-in-place if the hurricane has a projected intensity greater than a category 3 at landfall due to calculated risk to the infrastructure, staff, patients, and state emergency responses and evacuation personnel unless there are unusual circumstances that would have to be factored in on a case-by-case basis. South Carolina has six coastal counties, but there are eight total counties that have areas that could flood under normal or fast surge conditions as predicted by multiple iterations, with averaged output, of the South Carolina specific Sea, Lake and Overland Surges from Hurricanes (SLOSH) models (NOAA, 2007). The normal and fast distinction in these model results for potential flooding considers multiple factors, with the most important difference being the forward speed of the hurricane. The eight counties with storm surge-related flooding potential include Jasper, Beaufort, Colleton, Charleston, Dorchester, Berkeley, Georgetown, and Horry.

There are 62 licensed healthcare facilities in South Carolina located in these eight counties and the three license categories previously defined. Many of them are not shown to be within the storm surge zone under normal or fast surge conditions and would not be included in state-defined voluntary or mandatory evacuation areas. These evacuation areas are defined based on estimated risk and past experience with hurricanes. While these facilities fit the criteria to file a CDS, DHEC does not expect facilities to file one if they have no plans to shelter-in-place or will not be impacted by hurricane evacuation orders. Many facilities subject to the CDS option have clearly stated that after weighing all their existing options, they have no intention of ever sheltering-in-place because it is much safer and more effective for them to evacuate their facility when an evacuation order is issued. Beyond the CDS option addressed in this chapter, every facility in specific state license categories must file an Emergency Evacuation Plan with DHEC that contains additional facility-specific evacuation and preparedness procedures when they obtain a facility license.

Critical Data Sheet System Technical Information

To address the state CDS option, DHEC developed an integrated preparedness and planning online application with both spatial and nonspatial functions called the CDS System. The system was designed based on an existing CDS paper form at the request of the DHEC Office of Public Health Preparedness (OPHP). OPHP staff is required to evaluate shelter-in-place requests and coordinate decision making on evacuation and sheltering issues with the DHEC Division of Health Licensing, the State Emergency Management Division, and the Governor's Office. Designed and built internally, the system is driven from the DHEC health facilities GIS layer, which is synchronized with the state health licensing database to ensure accurate and current information on all healthcare facilities. Licensing information is updated in the GIS layer on a weekly basis via an automated procedure where existing GIS healthcare facility locations and attributes are compared with existing facility data and any new facilities are added and closed facilities are removed. In order to keep all information current, any licensing attribute that has changed is also updated in the underlying GIS layer during this process. The Division of Health Licensing maintains nonspatial attributes in the primary licensing database and the Division of Public Health Informatics maintains the GIS layer with all derived spatial information. When new facilities are detected or existing facility locations change, they are geocoded against a composite geocoding Web service. This Web service runs on county and municipal address points (generated from a number of different methods), the state enhanced 911 centerline file, and a nationwide street network database. The best possible spatial match is obtained, based on the address information in the licensing database, and a point is generated and flagged with required information to define how accurate that point is based on the method and dataset used to generate it. If the best address information available produces a low-level match, such as a zip code centroid, Informatics staff will contact the Division of Health Licensing to obtain better address information that will be entered in the underlying licensing database and propagate to the health facilities GIS layer. Once all points are generated, and all nonspatial licensing and spatial layer attributes have been synchronized, a number of additional spatial fields are geoprocessed via existing models and overlays to append the current normal and fast surge zones, evacuation zones, coordinates, special flood hazard areas (100-year flood zones), and related information. This information is used agency-wide, and by partner organizations, for hospital preparedness and planning efforts. Depending on the results of the geocoding and geoprocessing procedures and efforts to obtain more accurate address information, some points may be put in a queue for GPS field data collection to replace less accurate geocoded points.

Once all these routine underlying procedures are complete, the CDS System executes a query on that GIS layer for all facilities that have the option to file a CDS. This is a very simple query looking for all hospitals, nursing homes, and hospice facilities in any of the eight potentially affected counties. The result of this query then populates a view that contains all information from the licensing database that can be used in the system so that hospital end users don't have to key this information manually. This view includes basic facility license information, such as contact information, license number, address, name, and a few other data elements. DHEC understands that there are many state data entry and reporting requirements for these licensed facilities and supports the process of integrating systems to cut down on the need for dual keying of data elements by the facility. This integration not only cuts down on the workload for facility-based staff, it also serves as a quality control method to ensure base level information on facilities is the same in all DHEC systems. Once the CDS system has updated information, a login account is created for new facilities and updated information for existing facilities is displayed. As new facilities are licensed, the appropriate DHEC staff will inform these facilities of the option to fill out a CDS and provide them with their facility-specific user name and password. Facilities then designate a point of contact that logs into the system and begins the process of gathering all the required information to complete the sheet.

Critical Data System Interface

The CDS system contains seven pages, corresponding to six steps and an output page, that are accessible from either a tabbed interface or a "wizard"-style approach that takes the user to the next page upon submission. The default facility page that users are taken to after they log in is the "Main Data Sheet" that contains 13 different distinct question groupings (Figure 10.1). The first four groupings on the main page of the system include the primary contact information section for the person responsible for filling out the form as a well as all emergency contact information. The next two groupings deal with questions related to surge and generator capacity as well as the facility's ability to withstand hurricane force winds.

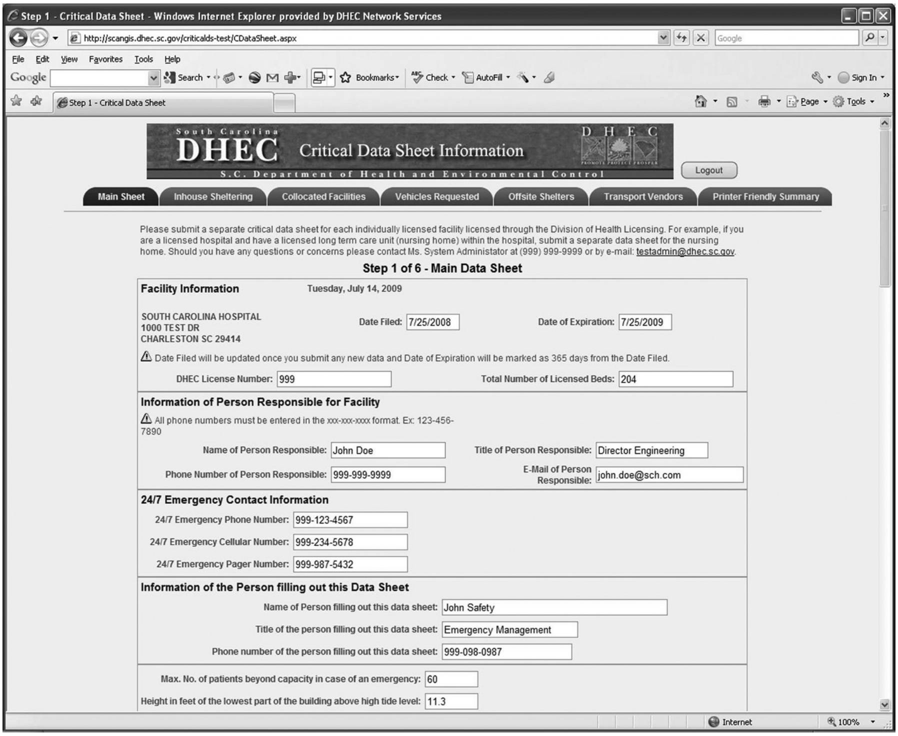


Figure 10.1 Critical Data Sheets facility homepage.

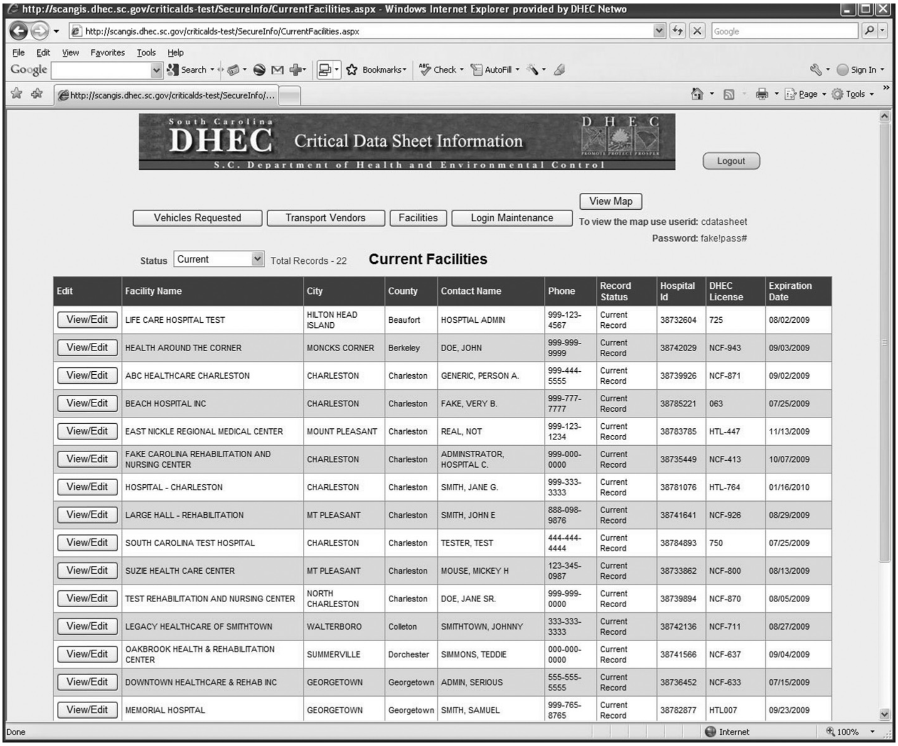
The remaining groupings on the main section include information regarding onsite medical supplies and services, emergency arrangements and equipment, communications plans, evacuation plans, and emergency response and preparedness officials who review the facility plans.

The second tab of the CDS System is the "In-house Sheltering (Emergency Facilities) Information" page, which contains the names and all required information for any CDS facility that has an agreement in place with other healthcare facilities to shelter their patients in the event of an evacuation or emergency. The third tab of the system is the "Collocated Facilities Information" page and contains information on any collocated facility. In some circumstances, a medical center may be located in the same building or on the same campus with other licensed facilities, such as rehabilitation facilities, ambulatory surgery center, or specialty clinics. This information is essential to understand the impact of potential evacuation and shelter-in-place plans. The fourth tab of the system is the "Vehicles Requested" page and contains information on the number and type of vehicles that would be required to successfully evacuate the facility in the time frame indicated on the submitted CDS. This information, coupled with the information on the "Transport Vendors" page, is essential to evaluate all facility plans together against known state resources and healthcare facility evacuation capacity. The fifth tab is the "Offsite (Relocation) Shelter Arrangements" page and contains information within agreements the CDS facility has with other facilities to shelter their patients in the event of an evacuation or emergency. The sixth tab of the system is the "Transport Vendors" page and contains all required information on any transport vendors that have entered into an agreement with the CDS facility to transport patients in the event of an evacuation. In addition to the standard data entry screens, the user has the ability to upload supporting documentation including signed wind load reports and signed agreements and statements from officials that have reviewed their plans. While these signed documents are not required to complete a CDS, users have the ability to upload information from emergency preparedness officials, fire service, law enforcement, and their insurance carrier. DHEC encourages this practice because it helps to ensure these documents are available when needed and can be factored into any DHEC preparedness and planning decision and/or recommendation. The seventh tab is the "Printer Friendly Summary" page, which allows facility users and DHEC staff to generate and print a summary report of all questions and answers to be shared with others and used when Internet access is not available. All system users also can launch an interactive map service from inside the CDS application.

Critical Data Sheet System Spatial and Nonspatial Benefits

The standardized Web-based CDS application provides numerous benefits for both DHEC and the facility outside of the spatial capabilities that will be the focus of the rest of this chapter. Since this system is Web-based and offsite from the facilities, it serves as a backup location for all information and agreements related to facility specific evacuation and sheltering plans. It also provides a way for facilities to submit current information to DHEC, and other emergency responders and public health professionals, whether they are physically at the facility or offsite. Because the CDS is required to be completed and submitted to DHEC annually, and because most information does not change from year to year, facilities often simply open up their existing sheet, review and/or update the information, and resubmit it with minimal effort. The system is designed to track user access and captures the date when changes are made by the facility, which is the date DHEC uses to ensure the sheet is current. A sheet is valid for a full calendar year from the date it was last saved, so the CDS system was designed to correspond to the annual filing of an updated sheet every calendar year prior to the hurricane season. Even though a sheet may be current, this does not mean it is complete or that a request to shelter-in-place will be approved.

For DHEC, the nonspatial benefits of the system stem from its standardized design that allows reporting across all facilities to determine whether facility



Edit	Facility Name	City	County	Contact Name	Phone	Record Status	Hospital Id	DHEC License	Expiration Date
View/Edit	LIFE CARE HOSPITAL TEST	HILTON HEAD ISLAND	Beaufort	HOSPTIAL ADMIN	999-123-4567	Current Record	38732604	725	08/02/2009
View/Edit	HEALTH AROUND THE CORNER	MONCKS CORNER	Berkeley	DOE, JOHN	999-999-9999	Current Record	38742029	NCF-943	09/03/2009
View/Edit	ABC HEALTHCARE CHARLESTON	CHARLESTON	Charleston	GENERIC, PERSON A.	999-444-5555	Current Record	38739926	NCF-871	09/02/2009
View/Edit	BEACH HOSPITAL INC	CHARLESTON	Charleston	FAKE, VERY B.	999-777-7777	Current Record	38785221	063	07/25/2009
View/Edit	EAST NICKLE REGIONAL MEDICAL CENTER	MOUNT PLEASANT	Charleston	REAL, NOT	999-123-1234	Current Record	38783785	HTL-447	11/13/2009
View/Edit	FAKE CAROLINA REHABILITATION AND NURSING CENTER	CHARLESTON	Charleston	ADMINSTRATOR, HOSPITAL C.	999-000-0000	Current Record	38735449	NCF-413	10/07/2009
View/Edit	HOSPITAL - CHARLESTON	CHARLESTON	Charleston	SMITH, JANE G.	999-333-3333	Current Record	38781076	HTL-764	01/16/2010
View/Edit	LARGE HALL - REHABILITATION	MT PLEASANT	Charleston	SMITH, JOHN E	888-098-9876	Current Record	38741641	NCF-926	08/29/2009
View/Edit	SOUTH CAROLINA TEST HOSPITAL	CHARLESTON	Charleston	TESTER, TEST	444-444-4444	Current Record	38784893	750	07/25/2009
View/Edit	SUZIE HEALTH CARE CENTER	MT PLEASANT	Charleston	MOUSE, MICKEY H	123-345-0987	Current Record	38733862	NCF-800	08/13/2009
View/Edit	TEST REHABILITATION AND NURSING CENTER	NORTH CHARLESTON	Charleston	DOE, JANE SR.	999-999-0000	Current Record	38739894	NCF-870	08/05/2009
View/Edit	LEGACY HEALTHCARE OF SMITHTOWN	WALTERBORO	Colleton	SMITHTOWN, JOHNNY	333-333-3333	Current Record	38742136	NCF-711	08/27/2009
View/Edit	OAKBROOK HEALTH & REHABILITATION CENTER	SUMMERVILLE	Dorchester	SIMMONS, TEDDIE	000-000-0000	Current Record	38741566	NCF-637	09/04/2009
View/Edit	DOWNTOWN HEALTHCARE & REHAB INC	GEORGETOWN	Georgetown	ADMIN, SERIOUS	555-555-5555	Current Record	38736452	NCF-633	07/15/2009
View/Edit	MEMORIAL HOSPITAL	GEORGETOWN	Georgetown	SMITH, SAMUEL	999-765-8765	Current Record	38782877	HTL007	09/23/2009

Figure 10.2 Critical Data Sheets administrator console.

information is current, expired, or never entered. The system also contains essential information required for issuing and evaluating the impact of imminent evacuation orders regarding the estimated number of vehicles needed to evacuate each facility, how many vehicles have been requested, and transportation agreements that are in place with transport vendors (Figure 10.2). The ability for DHEC staff to access the system from any location with Internet access is very helpful since the Division of Health Licensing and OPHP staff may work from either the state or DHEC Emergency Operations Center (EOC) in an actual event when the information is needed the most. DHEC can also provide "read only" access to this system to preparedness partners, such as the South Carolina Hospital Association, so they can coordinate with their members to ensure all plans are filed.

From a spatial standpoint, this system offers Internet GIS tools and data to users who may not have other available GIS expertise or software. The current GIS capabilities of the system are built on a password-protected ArcIMS map service. This password restriction is required because this application is not intended for the general public and all information entered by the facility is considered confidential. Once a user is authenticated into the application, the map service user

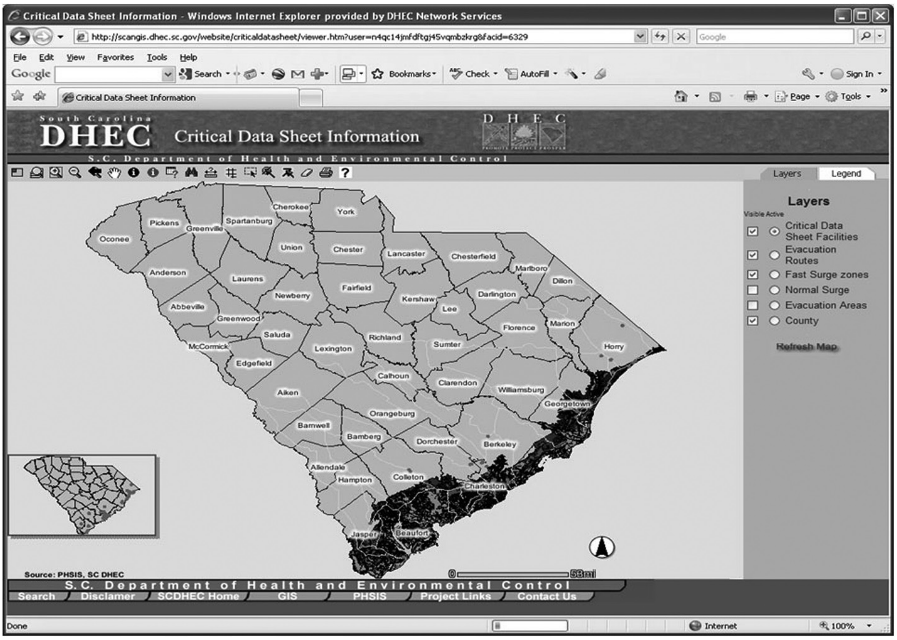


Figure 10.3 Critical Data Sheets default mapping interface.

name and password are provided onscreen to eliminate the need to remember two usernames and passwords for one system. When a user clicks the button to launch the map and enters the correct credentials, he/she sees a mapping default screen that displays the entire state along with each facility location, normal surge zones, fast surge zones, evacuation areas, evacuation routes, and base layer geographic information (Figure 10.3). As a user zooms into the location of his/her facility, he/she can see detailed transportation infrastructure. Users can turn existing layers on and off and query available layers via standard spatial and nonspatial tools. Facility users can locate their facility in relation to the normal and fast surge zones as well as their defined evacuation area and closest evacuation route (Figure 10.4). This spatial information is useful during the evacuation planning process because it will be factored into a shelter-in-place request to DHEC. In addition to the spatial and nonspatial information in the CDS System, DHEC staff include other pertinent information in the decision-making process. Additional spatial information used in this process can be posted on this map service so users from the healthcare facilities can access it as well. This fosters transparency and accountability in the decision-making process and serves as an excellent medium to provide information to healthcare providers.

DHEC makes recommendations to the State Emergency Management Division for the final decision by the governor regarding the mandatory evacuation

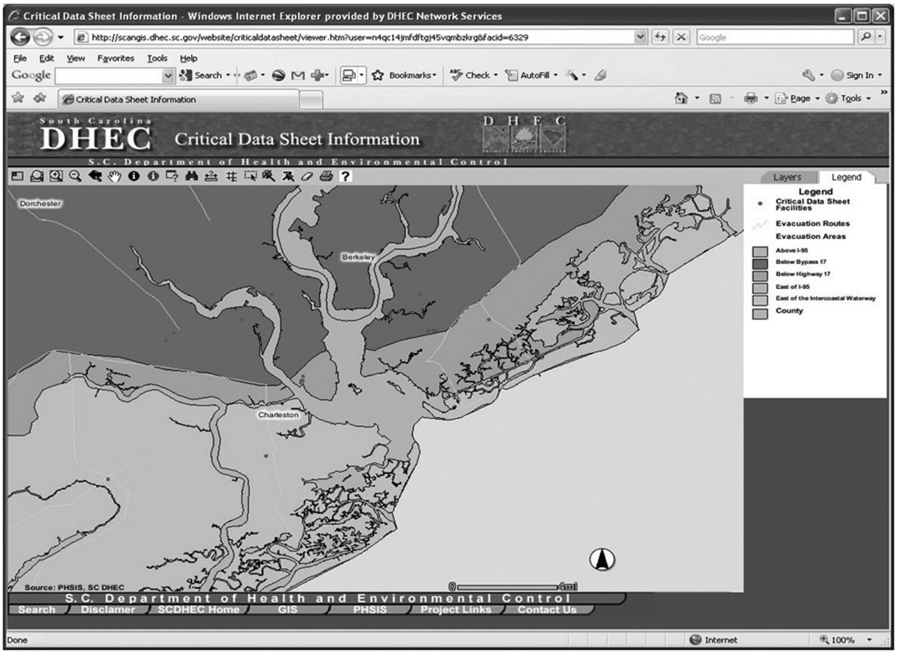


Figure 10.4 Critical Data Sheets detailed map view.

or shelter-in-place option for each healthcare facility. The approval for a facility shelter-in-place request is dependent on a number of factors. One of the primary factors DHEC considers is the projected category and severity of the hurricane as predicted at landfall. If the hurricane's intensity is predicted to be in excess of a category 3, then no facility has the option to shelter-in-place unless there are unusual circumstances that require case-by-case consideration. If the hurricane's intensity is predicted to be a category 3 or less, then the type of evacuation order that has been issued, voluntary or mandatory, must be weighed against the facility's existing plans, geographic location, risk of transporting patients, benefit to the community after the storm, and the capacity for state law enforcement, emergency management, and response personnel to assist the facility. The reasons and allowances to shelter-in-place are complicated and are not the intent of this discussion. Every facility's request and projected hurricane landfall are evaluated independently and DHEC considers various complicated factors together while consulting with appropriate internal and external resources to make an informed recommendation.

GIS plays a large role in this decision-making process because any single factor alone is not enough to make an informed decision. Multiple factors that include the intent of the existing regulations and other pertinent spatial and nonspatial data must be considered. Other GIS-enabled applications and tools are used to track the current path of the specific hurricane along with the projected wind swath, storm surge, and landfall location. Spatial overlays with elevation, topography, and Special Flood Hazard Area (SFHA), and the associated 100- and 500-year flood plains can be factored in. Hurricane-related flooding is not only confined to storm surges and is often caused by extreme precipitation and inland flooding of existing water bodies, such as lakes, rivers, and streams. SFHA data is used to predict and properly plan for this type of flooding. Other available healthcare facilities and resources in close proximity can be considered in a GIS environment along with existing state Emergency Management Division (EMD) operational areas and plans. While there is no simple method that can be used to make a decision as important as whether or not to evacuate or shelter-in-place, the more information that is available and the ease of information integration increase the likelihood that the correct decision will be made. GIS provides an ideal tool to manage complex situations and consider multiple factors in an interactive fashion with information that can be updated in real time as the event progresses.

Other GIS Tools and Planned Enhancements

Based on the current advances made in server-based GIS technology, past requests, and user input, the CDS mapping component is currently undergoing a complete redesign and upgrade. This redesign will better address the intended purpose of providing CDS facility users and DHEC response and preparedness staff with a simple tool to make decisions based on the best information available. The system is being upgraded to ArcGIS Server from ArcIMS and all facility locations will be rendered based on the current status of the CDS for each facility (current, expired, never accessed) and include additional spatial and nonspatial attribute information that will be available from within the mapping interface for spatial analysis and display. The need to enter a user name and password to access maps will be removed because the user is already authenticated once inside the system. When DHEC staff access the map service from an administrative page, they will be brought to the default state view. When DHEC or a facility user accesses the map service from a particular facility page, he/she will automatically be zoomed into a scale appropriate for that facility. Additional layers of information will be provided on the default service, such as population and aerial imagery, and the map will be enlarged with a number of “nonessential” tools and buttons removed. Other enhancement options are currently being evaluated, such as routing and the ability to display current weather conditions and hurricane information by default on the map service, so it is easier to relate current weather conditions to existing plans and shelter-in-place requests.

Conclusion

The process of maintaining a GIS-enabled application, such as the CDS System, is ongoing and requires feedback from end users. GIS staff that design and maintain the system must keep up with the current technology and attempt to employ that technology to address the needs of the system users. In the event of an evacuation, all requests to shelter-in-place must be evaluated in a timely manner and decisions made based on the best information available. GIS-enabled tools, such as the CDS System, provide a level of standardization, integration, and transparency in the decision-making process that helps end users focus on the most important aspect of hospital preparedness and planning, which is to protect the safety and well-being of patients and staff.

Acknowledgments

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Chapter 11

Making Sense Out of Chaos: Improving Prehospital and Disaster Response

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Contents

Introduction

Communities nationwide are at risk for disasters, pandemics, and terrorist incidents. Successfully responding to these incidents requires coordinating input and effort from a multitude of sources, and providing up-to-the-minute information as the situation evolves. The prehospital and disaster medical response system is a unique environment that presents several challenges to the healthcare system. Public safety, fire services, emergency medical services, hospitals, public health, and local government agencies all respond to these incidents. While the purpose of their missions may be linked, they each require unique data and tool sets for optimal response in a coordinated manner. This coordination requires current information that must be communicated to the individual responders as well as those on whom they depend for direction, within and between organizations, and in real-time (Meissner et al., 2002). Even public safety agencies accustomed to working shoulder-to-shoulder are unable (and sometimes unwilling) to share information due to multiple systems, multiple interfaces, and multiple data streams that provide each agency's information, not to mention a need for security to protect that information. Since many emergency resources are not available on a single network, interactions among agencies often occur on a personal/phone/fax basis. The resulting interaction, therefore, is limited in scope and slow in response time, in contrast to the heightened need for information access in an emergency situation (Tanasescu et al., 2006). Cutter (2003) noted that there is a disconnect between the researchers of geographic information sciences and the local responder or emergency manager. Whereas the researcher is interested in spatial data acquisition and integration, dynamic representation of physical and human processes, and cognition of geographic information, among other things, the responder wants to know what data need to be collected, who has it, how can I get it, and will my computer talk to yours?

For a Geographic Information System (GIS) to be successful in this environment, it must be interoperable, portable, accessible, and independent of infrastructure that may be damaged during the disaster. Applications must also be flexible for quick adaptation as the situation changes (Meissner et al., 2002). Designing information systems that span these operational limitations and provide pertinent information to managers and responders from these disparate disciplines is required to make sense out of chaos.

Situation Awareness

For years, we have been struggling to make data portable and accessible. And we have been successful. We now have data at our fingertips. Too much data.

More data does not equal better information. Technology has created a snowstorm of facts and figures that can be so overwhelming as to be useless. Studies have shown that as a decision maker's information load (defined as data to be processed per unit of time) is increased, the decision maker tends to "simplify" the information to make sense of it, as well as attend to fewer data dimensions during the process (Wright, 1974). Wright describes these simplification tactics as including restricting attention to certain portions of the data, excluding from consideration data about less relevant dimensions, even though they may have been considered in less taxing situations, or by focusing attention on data in certain regions of each dimension.

Providers need only that data that is relevant to their situation. They need only that data that helps them manage an incident. Decision support tools can filter and distill the data so that the user can have the right information at the right time. In critical public safety operations, providers do not need to be wading through tables, moving from application to application, or dealing with multiple databases. They want data presented in a way they can use quickly and easily.

A first responder who is multitasking at an incident needs to reserve his/her cognitive skills for the task at hand. Decision support tools have the potential to allow data processing for first responders so that useful, filtered information is made available in a manner that meets their needs and allows them to concentrate their attention on more critical problems. Decision support tools may tell providers about the status of a nearby hospital, may tell them the quickest route between two locations, may include site-specific material safety data sheets for hazardous materials, or may provide an overview of an incident.

Well-designed decision support tools can provide enhanced situation awareness for the public safety sector. The concept of "situation awareness" (also referred to as "situational awareness") has been developed and tested in the airline industry. A formal definition of situation awareness has been provided by Endsley (1988): "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future." A less formal definition is that situation awareness simply means knowing what is going on around you. Nevertheless, three elements are crucial: perceiving what is happening, understanding what it means, and being able to use this information to predict what is going to happen next.

Jones and Endsley (1995) have looked at pilot and air traffic controller errors in order to characterize examples where situation awareness was inadequate. More than 80% of errors had to do with perception. In other words, the information was not detected, not monitored, or not even available. Understanding what is going on around you in time and space is exactly where a GIS excels. A GIS can provide situation awareness for responders in the public safety sector, such as emergency medical services, hospitals, fire, law enforcement, public health, and military.

GIS and EMS Management

A GIS has the potential to "get the right resources to the right place at the right time." Imagine that a 911 call is placed. Once the dispatcher receives the call, he or she notifies the appropriate agency as quickly as possible so they can respond to the emergency. In the event of a medical incident, ambulances arrive to the scene, provide an assessment and emergency treatment, then make arrangements for the patient to be transported to definitive care. Contact with a base station that routes ambulance traffic to receiving hospitals alerts the emergency department of the impending arrival. An Emergency Medical Services (EMS) GIS could improve patient outcomes by making these processes more efficient.

EMS Case Study: A Schoolyard Accident

Emergency personnel often have to make educated guesses regarding numerous decisions that might significantly impact patient mortality and other important outcomes. For instance, several years ago, while running on the playground at her elementary school in Hesperia, California, an eight-year-old girl suddenly chased a ball into the middle of the local street. With the sound of screeching brakes and a thud, numerous teachers and students suddenly looked up just in time to see the girl thrown over the hood of a car and then lie limply on the sidewalk. Immediately, 911 was called by the teachers. A fire engine and ambulance were dispatched to the scene.

Upon arrival, the first paramedic recognized that due to the severity of her injuries, this child would be best served at a pediatric trauma center rather than the local community hospital. The local community hospital was about 10 to 15 minutes away by ground ambulance, but the pediatric trauma center was about 20 to 90 minutes by ground ambulance, depending on traffic conditions. The paramedic knew that if a helicopter was close by, it could pick up his patient and fly over the rush hour traffic and get to the pediatric hospital in about 20 minutes. The paramedic also knew that current weather conditions could prevent a helicopter from flying through the mountains to get to the pediatric trauma center in the valley. He also knew that the local community hospitals might be on ED (emergency department) diversion status due to the full utilization of their resources. Unfortunately, the paramedic was forced to make "educated guesses" regarding helicopter proximity and availability, hospital diversion status, traffic conditions, and weather conditions because there was no way to have all this information immediately available in order to make an ideal decision.

The paramedic guessed that there would be bad traffic since it was Friday afternoon and requested a helicopter to transport the girl to the hospital. Unfortunately, the closest available helicopter was 30 minutes away and took nearly an hour to land on the scene due to poor weather conditions in the mountain pass. En route the child's heart stopped and she was unable to be resuscitated at the hospital. It was later determined that the highway was wide open and that the ground ambulance may have been able to get the child to the desperately needed care within about 20 minutes. If the paramedic had been able to have the right information in real-time, the outcome might have been different for this little girl. Numerous similar scenarios like the one above have been taking place for many years because of the lack of real-time situation awareness for public safety personnel.

Now, imagine a system that answers these questions *at a glance*:

- Where is the closest airship and landing zone to the patient?
- What is the current weather in the area?
- What are traffic conditions on the possible routes available to ground crews?
- Which hospitals are available and what resources do they have?

The development of just such a system, the Advanced Emergency Geographic Information System (AEGIS), described later in the chapter, began with these seemingly obvious questions. However, nowhere in EMS was there a single tool that could provide this information. Based on a "user needs" assessment, rather than a "top-down" approach, customization of a GIS provides the best tool for real-time decision support (Zerger and Smith, 2003). Much of the information is available, but access to multiple systems is required. Although custodianship of the various data can provide a barrier to integrating the required information, emphasizing the communal benefit to the various entities resulted in successful collaborating with the principals of these other systems to bring all this information together for the first time.

GIS and Disaster Management

Elaborate disaster plans that collect dust on a shelf, except for biannual drills, are rarely of use when needed. For first responders, a major constraint to utilizing GIS is providing an understandable user interface and a willingness to adopt new technologies (Cutter, 2003). Inexperience with a system precludes them from using it to aid decision making to its full potential (Zerger and Smith, 2003). A clearly accepted rule of human work is that "practice makes perfect." Better performance can be readily expected if disaster responders are assigned tasks they already carry out on a routine basis. Even in times of low stress and excellent information availability, the individual who is familiar with his or her tasks is much more likely to perform at high levels. In disaster situations, where the level of stress and distractions makes it difficult to focus on the details of what needs to be done, a clearly defined and understood role significantly contributes to the probability of highly effective performance among rescuers and healthcare personnel (Bissell, 1996).

With this in mind, what works best in a disaster is what people are good at. And what they are good at is what they do on a daily basis. By adding additional features to the same tool that serves on a daily basis for EMS operations so that it also can be used for episodic disaster management, the advantage is that the public safety community would already be familiar with the system and additional training would not be required. Because many EMS systems experience disaster-like conditions (ambulance diversion, multiple casualty incidents, road closures, severe weather conditions, etc.) on a weekly or even daily basis, having the same system for both EMS and disaster management makes sense. A hybrid EMS/disaster management GIS will be able to adapt as needed to meet any conditions along this continuum.

A Disaster Case Study: Esperanza Fire, 2006

On October 26, 2006, Santa Ana winds were blowing across Southern California. These winds are seasonal, occurring mostly during the fall. The wind blows from the northeast to the southwest. They are strong with gusts in excess of 75 miles per hour at times. Conditions begin with high pressure systems; as the air drops to lower altitude, it picks up speed, increases in temperature, and loses humidity. The result is dry, hot, and windy conditions that increase the risk of seasonal wildfires. Arsonists also seem to appear during these weather patterns. At approximately 1 a.m., an arsonist set a blaze at the foot of the San Bernardino Mountains near Cabazon.

Six fire engines were assigned to structure protection in the mountain community of Twin Pines at 1:43 a.m. There was some difficulty reaching the structures because of fleeing residents blocking the narrow, winding dirt road that provided access to the area. They were finally able to set up their engines around several structures atop the ridge. Around 5:45 a.m., Engine 57 prepared to defend the "octagon house," which was at the end of an unnamed drainage that ran several miles down hill to a point near the origin of the fire. This drainage ran from the northeast to the southwest, in perfect alignment with the ongoing Santa Ana winds. The other five engines were staged at nearby structures. They were able to communicate amongst each other using a tactical frequency not assigned to the fire. At that point, they expressed concern about the fact that one of their exit routes had been cut off by the advancing fire.

At about 6:45 a.m., the engine crews noted that the fire was moving up toward them very rapidly, and they began to set back fires. Around 7 a.m., the firefighters took refuge in their engines and waited until the fire front passed through at about 7:15 a.m. After the front had passed, they were no longer able to contact Engine 57. Shortly thereafter they were able to make their way to the Octagon House (Figure 11.1). There they found the five-man crew of Engine 57, victims of a burnover. Three crewmembers were dead at the scene. Two firefighters were transported to a nearby burn center where they later died of their injuries.

The Esperanza Fire Accident Investigation Factual Report (Anon., 2007) noted several *contributing* factors that facilitated the accident. The alignment of the unnamed creek drainage with the Santa Ana winds combined with the high fuel load and low moisture content created dangerous conditions. Span of control was exceeded in a complex environment. There were also communication problems.

Figure 11.1 The Octagon House after the Esperanza Fire. Engine 57 is in the lower right corner. (Photo courtesy of AP's Reed Saxon.)

The engines were using a tactical frequency not assigned to the fire and their objectives were not clear. Finally, a contingency map from 2002 describes some of the structures they were defending as being "nondefensible." They also identified one *causal* factor "that if corrected, eliminated, or avoided would have prevented the fatality." That causal factor was felt to be a loss of situation awareness.

Certainly data were available. The unified incident command system organizational chart was published. Fire perimeters were created. Fire frequencies and historic fire perimeters were known. Fire threat and fuel rank were described. The contingency map showing the nondefensible structures was available. The problem was that these various pieces of data were not immediately available to the incident commanders, or at least were not available in a form that made them accessible in a practical time frame. Assembling disparate data so that critical information is available to a commander enables them to focus their cognitive skills on the demands of managing a complex wildfire rather than expending time and energy locating, reading, and interpreting data. It is exactly this type of situation awareness that a disaster GIS should provide, not only for incident commanders, but also for individual responders on a handheld smart-phone or other portable device (Figure 11.2).

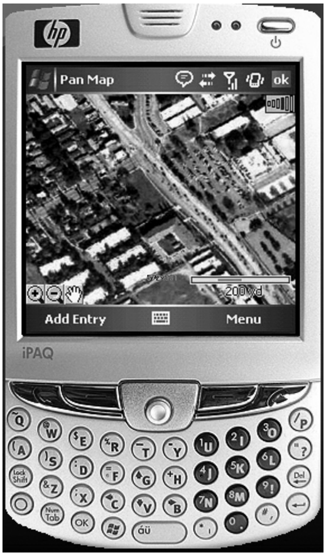

Figure 11.2 AEGIS displayed on a handheld mobile device.

Now, imagine a system that answers these questions *at a glance*:

- What is the location and extent of the disaster?
- How many are injured, and what is the extent of their injuries?
- Who is the incident commander?
- Where are personnel and resources currently deployed?

If at its most basic level, situation awareness is knowing what is going on around you, then a GIS can effortlessly provide this. Being able to see a fire perimeter in time and space and appreciate its relationship to a community or its relationship to public safety personnel can also be easily accomplished (Figure 11.3). Additional information may be added, such as the locations of schools, staging areas, traffic conditions, weather, camera inputs, etc.

Making Sense Out of Chaos: One Solution

GIS can be, and has been, used in all phases of the disaster cycle: preparedness, response, recovery, and mitigation. Risk assessment and preparedness efforts can be enhanced by use of tools such as the Federal Emergency Management Agency's (FEMA's) HAZUS (http://www.fema.gov/plan/prevent/hazus/) and National Oceanic and Atmospheric Administration's (NOAA) weather forecasting (http://www.nws.noaa.gov/). GIS is particularly useful for integrating modeling results

Figure 11.3 Fire perimeter mapped showing proximity to structures and location of resources.

in time and space, and for assessing exposure (Von Braun, 1993). And national databases, such as HSIP-Gold (National States Geographic Information Council, 2006), providing information about vital infrastructure and available to government entities, can aid in hazard vulnerability identification as well as resource capabilities for a given area.

However, real-time disaster applications of GIS have very specific requirements, which are significantly different from long-term decision making for disaster planning (Zerger and Smith, 2003). To understand how a GIS can be used during crisis situations, we can examine one solution: AEGIS.

AEGIS

AEGIS was designed to address many of the inadequacies seen in our daily EMS operations. Loma Linda University Medical Center is the only Level I trauma center and pediatric hospital in a vast area of Southern California, about 25% of the state. This region is geographically diverse, including urban and rural communities, desert, lake, and mountain terrain (including the highest and lowest points in the continental United States, Mount Whitney at 14,505 feet and Death Valley at 282 feet below sea level), and extremes in temperatures. The resources available also vary a great deal from locale to locale, and, as a result, emergency services are parochial and fragmented. As a tertiary referral center and a base station for ambulance runs, our Mobile Intensive Care Nurses (MICNs) take about 3,000 ambulance calls every month. As medical providers in the field, the authors understood the challenges faced not only by paramedics, but also by emergency dispatchers and the nurses in the radio room trying to route ambulances for the best patient care. As part of a Department of Defense-sponsored project focused on getting medical care to the site of injury, we worked to develop a system we felt would provide a solution to many of the barriers encountered in the prehospital setting.

First, it was understood that the system must be available to all who would need to use it for emergency management. This meant a Web-accessible system that could be accessed securely from any number of locations. Second, the information would need to be able to transmit a great deal of information in an easily understood interface, making a visual system most desirable (i.e., the old adage: "a picture is worth a thousand words"). And, it was apparent that many of the challenges were geographic in nature. This led us to consider GIS as the only viable platform on which to base such a system.

We also realized that "old" information would be useless in the dynamic setting of emergencies and disasters and sought to include real-time information necessary for efficient operations. Most of this information was already accessible in a variety of forms. For example, information regarding hospital diversion status and other alerts is transmitted in tabular form to all local hospitals and updated frequently via radio and phone communications. One can look at current traffic conditions from live streaming cameras as well as determine highway speeds from sensors located along the freeways. Current incidents being worked by the California Highway Patrol are also available on the Web, showing where incidents are located and their status. This information can be used to avoid certain areas as well as to estimate how long resources may be deployed to an incident. However, none of this information was available without having to access multiple resources.

Working with ESRI (Environmental Systems Research Institute, Inc.), Redlands, California, we were able to develop a GIS that incorporates both static and dynamic information in a single, user-designed, user-friendly interactive map. Static information includes a variety of maps with the location and attributes of key facilities and resources, including hospitals, fire/EMS/police stations, major venues, schools, airports, and numerous additional overlay options that can be toggled on or off by the operator (Figure 11.4).

Dynamic information includes color-coded hospital diversion status, real-time traffic information, current weather conditions, and updated major incident information and location from Emergency Dispatch (Figure 11.5 and Figure 11.6).

One feature we felt would be helpful to users of the system would be the ability to know where ground and air assets were located. Several incidents, including the one in our schoolyard case study, had shown that having this information might have prompted a different resource to be dispatched to an accident, resulting in a shorter response time and subsequent arrival of the patient to definitive care. Through the use of automatic vehicle locators (AVLs), AEGIS is able to visualize

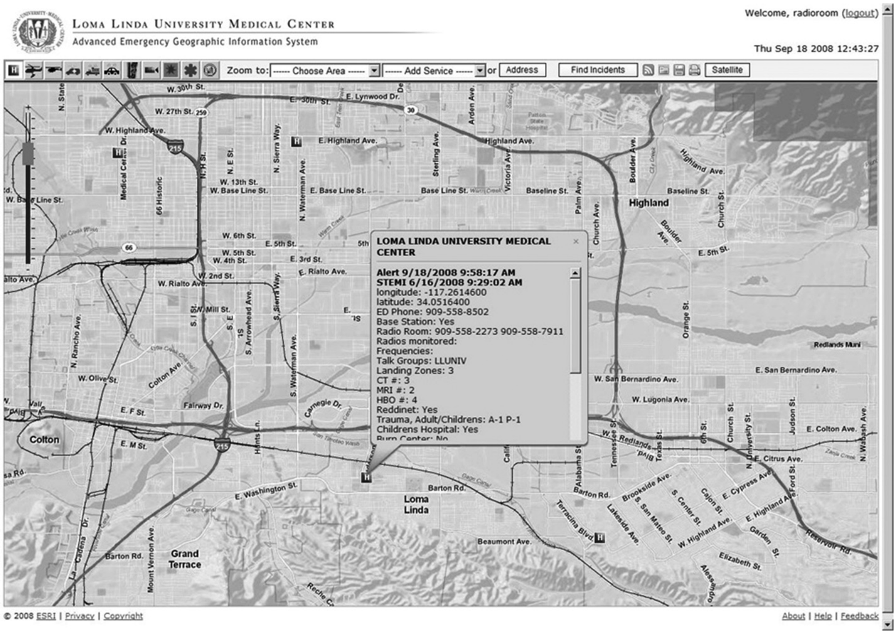

Figure 11.4 Map showing location of hospital, fire, and sheriff stations.

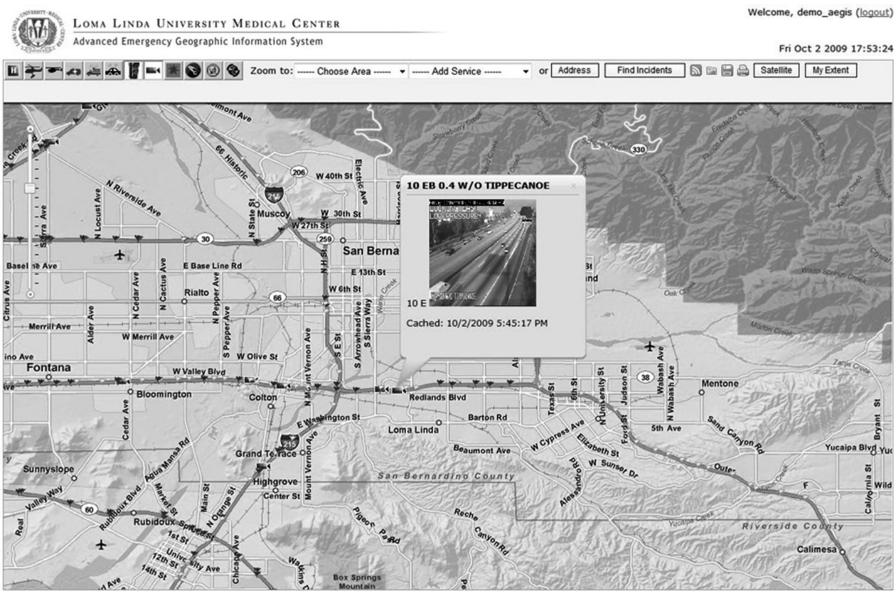

Figure 11.5 Current traffic conditions from speed sensors and highway Web cams.

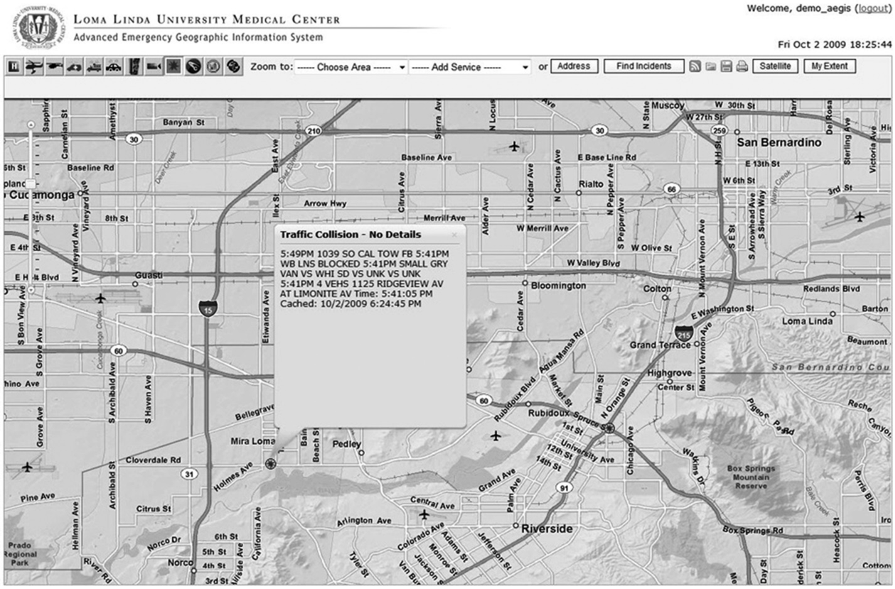

Figure 11.6 Active incidents from the California Highway Patrol, updated every minute.

fire apparatus, air transport helicopters, and other support vehicles in real-time (Figure 11.7 and Figure 11.8). Along the same idea, GPS-enabled phones and other personal devices could show the location of key personnel and other resources. Now emergency managers, as well as responders, have an up-to-date awareness of where their resources are in relation to the incident, and in relation to others who are or will be deployed.

AEGIS began as a means to improve prehospital operations. As the system has evolved, we saw the advantages of using it for disaster operations as well. The system is scalable and can expand to meet the requirements for managing a large regional disaster, or shrink to meet the requirement for routine EMS activity. It is designed to allow secure access to a variety of information sources. For example, information regarding mutual aid agreements cached in the system beforehand can facilitate requisition and deployment of resources. Critical information, such as that needed during the Esperanza Fire, can be included as attributes of structures and locales so that it is available quickly and visually to the incident commander. Through the inclusion of community contacts, "reverse 911" systems, automatic paging, and phone tree activations, AEGIS can alert individuals or communities with updated information, requests, and directives.

We also understood that some disasters would require use of available predictive tools that describe wildfire activities, toxic plume behavior, hazardous material incidents, flooding, and earthquakes. These can be integrated into the system for

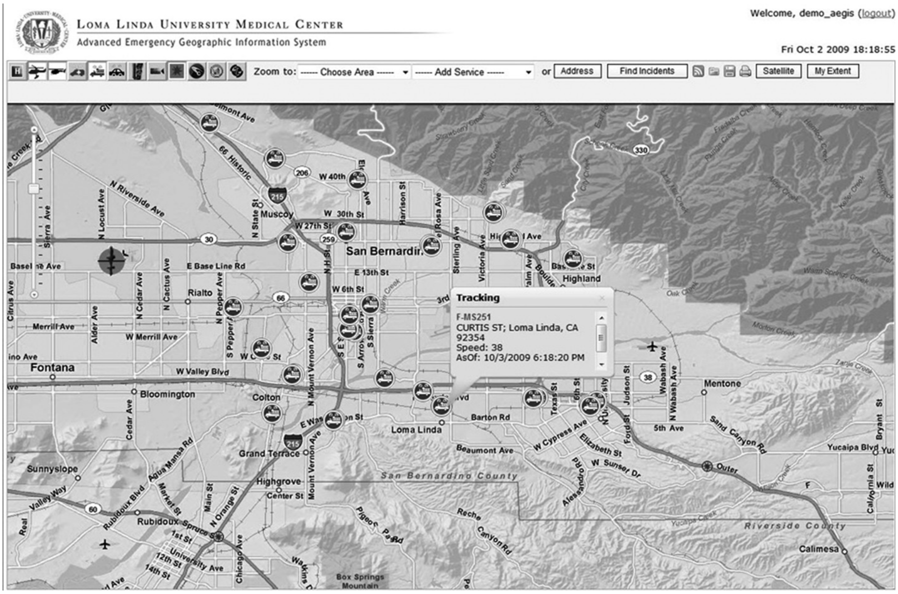

Figure 11.7 Real-time tracking of ground assets.

Figure 11.8 Location, direction, and airspeed of medical transport helicopter.

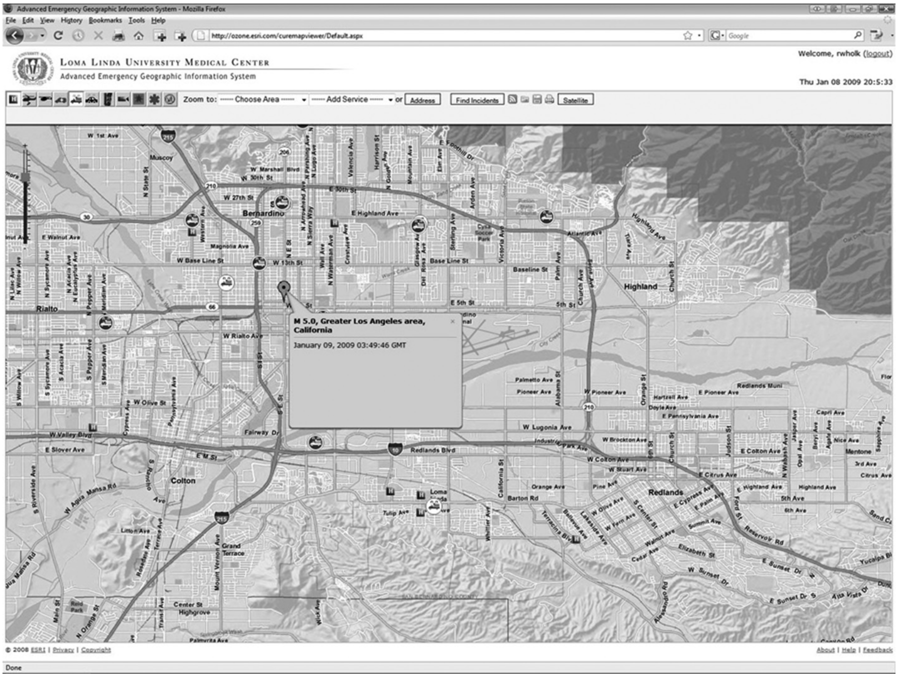

Figure 11.9 An RSS feed incorporated into an AEGIS map.

immediate use by emergency managers. Additionally, any geospatial information that is needed by a particular agency, jurisdiction, or responder can be incorporated via RSS (rich site summary) feed, resulting in a customizable map specific to the user's needs and/or incident (Figure 11.9). Conversely, information displayed on the AEGIS system can be exported to other mapping systems via RSS feed, making it universally available. This idea of being "technology agnostic," which we feel allows integration of data from multiple disparate sources into a common interface, has been paramount in the development of the system.

As we began to see that the system could be used in emergency incidents of all types and sizes, we felt that some additional attributes would make it even more effective. By incorporating the fundamentals of the Incident Command System, emergency managers could see at a glance who the incident commander is, and who is responsible for operations, planning, finance, and logistics. Personnel in critical positions or locations can be identified and given specific instructions, and personnel or assets in other locations can be redeployed to more strategic positions. This is accomplished by allowing interoperable communications among a variety of devices via text messaging to an individual or group participating through the system.

It was also critical to provide the system to portable devices so that everyone working on the incident, whether remotely or in the field, will have access to the information. Field responders can provide accurate, timely, on-scene information to the system with "on-the-fly" editing of the map, adding incident-specific information, such as roadblocks, photographs, location of command posts, and incident perimeters. Information published to the map is available to all authorized viewers instantly and simultaneously. From Web or mesh access points, field responders can access all pertinent data, update scene specifics, or communicate with other responders. It also allows mobile users to run sophisticated analysis provided by a remote server using the field data input. This increases their ability to perform their duties expediently and safely, and convey timely information through to their command structure and to others who require an understanding of the nature of their response.

Additionally, AEGIS can handle multiple incidents. During an extended disaster, such as a wildfire or flood, there is a possibility of other emergency incidents occurring, such as hazardous material events, multiple vehicle accidents, or train wrecks. Resources and drawdown levels affected by local incidents could impact management decisions at more remote sites. This information would be readily available to the incident manager.

AEGIS was first deployed using the Esperanza Fire as a prototype. While its use in that incident was mostly in conjunction with communications, the authors were able to demonstrate its features to many emergency responders, including incident command personnel, who provided positive feedback and suggestions. Through its deployments during numerous drills and exercises, as well as its daily use in the emergency department, AEGIS continues to undergo this iterative evaluation process by those who will potentially use the system.

AEGIS is an example of a GIS that can overcome the barriers that occur during a disaster, allowing an integrated, efficient, and secure response by establishing a common operating platform for all agencies involved in the response. Improved situation awareness enhances planning and increases personnel safety. The spatial representation of the incident, the extensive scope of information for decision support contained in the data layers, visualization of adjacent critical structures, and the understanding of resources available with current asset allocations, will allow managers to make well informed decisions, decrease uncertainty, and improve time to action. Understanding the operational conditions at all levels and across agencies is necessary for prompt response, proper allocation of resources, and responder safety. This information can be provided seamlessly to all authorized users via Web-enabled desktop or mobile computing devices.

Conclusions

Disasters often require immediate action with very little information. Systems that allow emergency managers to access real-time information, receive updates instantly, communicate with field responders and other personnel, and provide decision support can be invaluable in making these decisions. A successful GIS-based EMS and disaster management system also will be flexible, portable, and interoperable. A system that can be used on a daily basis avoids a barrier to its use during emergency incidents and aids the user in critical decision making. Communications should occur instantly among users of the system, circumventing the barriers often seen when various agencies, jurisdictions, and technologies are involved in the response. Those using the system should have access to the information that they require to manage the incident, but it should also safeguard sensitive information. We have described above one example of an EMS/disaster management tool that can bring together a variety of information resources into a single access point.

Acknowledgments

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CASE STORIES III

Chapter 12

Disaster Preparedness for Influenza at a Community Hospital Network: A Case Study Using GIS

Edward M. Rafalski, PhD, Vincent J. Gallagher, MBA, Matthew M. Wakely, BS, and Armand Turceanu, MHA

Contents

Introduction

Geographic Information Systems (GIS) and data analytics techniques can be effectively applied by hospital operations, quality, planning, and public relations staff to better prepare for outbreaks of disease within hospital, hospital network, and health system service areas. The community hospital network case study that follows provides examples where corporate and hospital operations staff collaborated and leveraged data analytics, GIS, disaster preparedness planning, and operations/logistics management skills. Techniques developed in this example led to improved preparedness in advance of the next potential outbreak of disease and can be applied to other similar institutions and scenarios.

Located in the suburbs of a major metropolitan area, the "community hospital network" is comprised of two acute care hospitals located within 10 miles of each other, but each serving distinctly different populations and patient demographics. The first wave of influenza A (H1N1) virus, also commonly referred to as the swine flu, occurred in the latter half of Spring 2009. The outbreak tested the hospital network's disaster preparedness plans and provided valuable lessons as the organization planned for the next wave of H1N1 expected in the Fall of 2009. Analytical techniques presented are applicable beyond H1N1 to include the epidemiological study of the incidence of communicable disease using GIS and the response of community hospitals to disease outbreaks.

H1N1 Background

According to the Centers for Disease Control and Prevention (CDC), influenza (the flu) is a contagious respiratory disease caused by influenza viruses. Statistics show that every year in the United States approximately 5 to 20% of the population acquires the flu, more than 200,000 people are hospitalized from flu complications, and approximately 36,000 people die from flu-related causes. There are three types of influenza viruses by which humans can be infected: A, B, and C. Subtypes of influenza A that are currently circulating among people worldwide include H1N1, H1N2, and H3N2 viruses. Winter is the season for flu in the Northern Hemisphere. Although the timing and duration of influenza seasons vary and outbreaks can occur as early as October, most flu seasons peak in January or February. Figure 12.1 shows the past 26 flu seasons in the United States and the peak five months reflecting the heaviest flu activity. February was the most frequent (12 seasons), followed by January (5 seasons) (CDC, 2009a).

Of the multiple sources of flu data, one of the most comprehensive is the U.S. influenza surveillance system. The CDC joined with various partners including state and local health departments, public health and clinical laboratories, vital statistics offices, physicians, clinics and emergency departments, and the U.S.

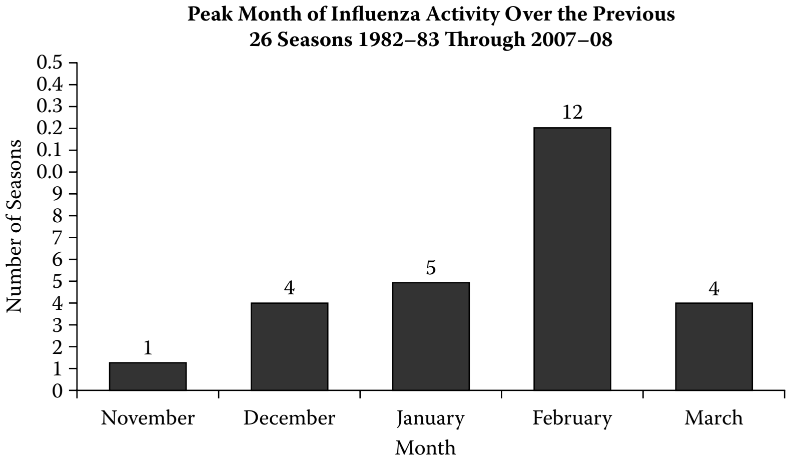

Figure 12.1 Peak month of influenza activity over the previous 26 seasons: 1982 to 1983 through 2007 and 2008.

Departments of Defense and Veteran's Affairs to establish the surveillance system (CDC, 2009b). Influenza activity for the calendar week July 12 to 18, 2009 was higher than normal for this time of year (Figure 12.2). During this period, over 99% of all subtype influenza A viruses being reported to the CDC were novel influenza A (H1N1) viruses.

The H1N1 Novel A flu virus is expected to cause a more severe flu season. According to the World Health Organization (WHO), the risk factors for serious pandemic disease are not known definitively. The WHO lists potential risk factors, such as existing cardiovascular disease, respiratory disease, diabetes, and cancer for a serious H1N1 pandemic. Asthma and other forms of respiratory disease have been consistently reported as underlying conditions associated with an augmented risk of severe pandemic disease in several countries. Obesity also may be another risk factor for severe disease and there is accumulating evidence suggesting pregnant women are at higher risk for more severe disease (World Health Organization, 2009). Given the ongoing H1N1 activity, the CDC warns that the new virus, in conjunction with regular seasonal influenza viruses, could potentially cause significant illness with associated hospitalizations and deaths during the U.S. influenza season.

An additional concern revolves around a lack of patient-oriented clinical research alongside the public health response to the pandemic (Hien et al., 2009). The recruitment of patients into clinical descriptive studies or randomized control trials is almost nonexistent. There is no comprehensive data on the disease pathogenesis and viral replication patterns of H1N1. Additionally, no qualitative research has been completed to establish the benefits of public health responses. There is a lack of assessments on combinations of antiviral drugs, intensive care interventions,

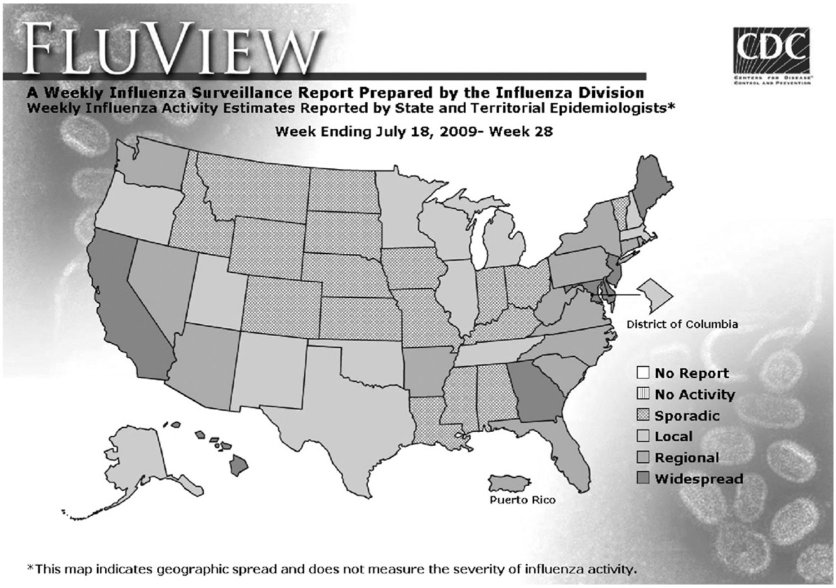

Figure 12.2 The CDC's "FluView Map."

and drug resistance. It is assumed that the novel H1N1 virus spreads in the same way that regular seasonal influenza viruses spread.

In a brief review of the Spring 2009 outbreak, the first H1N1 patient in the United States was confirmed by laboratory testing at the CDC on April 15, 2009. The U.S. government declared it a public health emergency on April 26, 2009. By June 19, 2009, all 50 states in the United States, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands reported novel H1N1 infection. While nationwide U.S. influenza surveillance systems indicated that overall influenza activity decreased during the latter summer months of 2009, H1N1 outbreaks were ongoing in various parts of the United States (Figure 12.3). Of the cases being reported, not all were positive for H1N1. Out of the 50 states and a total of 43,771 cases reported through July 24, 2009, the State of Illinois had the third largest amount of confirmed and probable cases with 3,404. The Southern Hemisphere was just beginning its influenza season and their experience was expected to provide valuable information about what may occur in the Northern Hemisphere in the following season (CDC, 2009a).

One of the most important H1N1 preparation strategies for hospitals is to review current response plans and to review staff roles and responsibilities. Hospitals should also be aware of state and regional plans. For example, if the hospital is located in a border region, the hospital should be aware of neighboring state plans. Vigilance over the summer and fall seasons is critical and quality managers play a

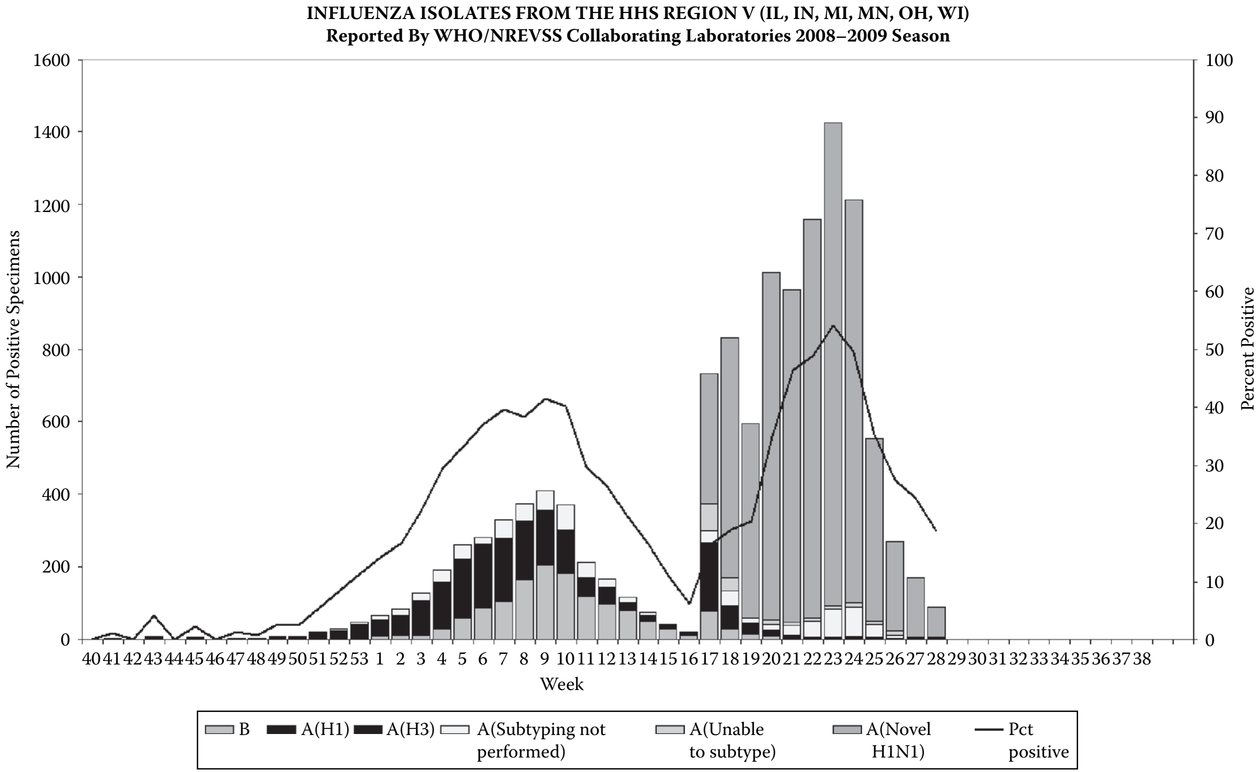

Figure 12.3 Influenza isolates from Health and Human Services (HHS) Region V (IL, IN, MI, MN, OH, WI); reported by WHO/NREVSS collaborating laboratories for the 2008–2009 season.

significant role in the preparedness process. Public health Web sites are a key source of information online (Connelly et al., 2009).

In one study, researchers reviewed the Web sites of state and local health departments in the first 24 to 30 hours after the public health emergency was declared (Ringel et al., 2009). The majority of state health departments acted appropriately by having some specific information about the H1N1 virus on their Web sites. The information was easy to access and provided content on how to protect individuals and their families. Some of these sites also provided information for healthcare providers, either using their own content or by linking to the CDC. Slightly more than half had press releases posted and some posted information in another language on their Web site. Of the local health departments observed, less than half provided specific information about the new virus within 24 hours (by linking to the CDC or their local states' departments). Additionally, less active communication was noticed on their sites relative to press releases. As a general observation, the health departments that were part of the Cities Readiness Initiative (CRI) responded more effectively. State departments acted more effectively than the local health departments, but there was no stated need to improve universal access to information by providing content in more than one language (one example being Spanish).

Flu Cases in Illinois

The application of GIS techniques to better understand the spread of disease is a valuable asset in the epidemiological process. In an effort to understand the regional variability of flu incidence, cases for three consecutive flu seasons were mapped in the State of Illinois (Figure 12.4). The incidence of flu during the period April 2006 through March 2007 was mapped by county indicating a higher concentration of cases in large population centers, namely northeastern Illinois, which includes Chicago and its surrounding suburbs.

The following year's flu season, mapping April 2007 through March 2008, exhibited a broader distribution of cases throughout the state and its counties (Figure 12.5).

Finally, the period April 2008 through March 2009, exhibited a similar distribution to that of 2007 with a higher concentration of cases in northeastern Illinois (Figure 12.6). Upon an initial review of the number of cases in the period 2008 to 2009 using GIS, no visible differences were observed at the county level year over year with the exception of the number of counties reporting cases. Upon further study, discussed in the next section, this level of analysis (county) was not sufficient for local tracking or planning local response to an influenza outbreak. A greater level of mapping granularity was needed.

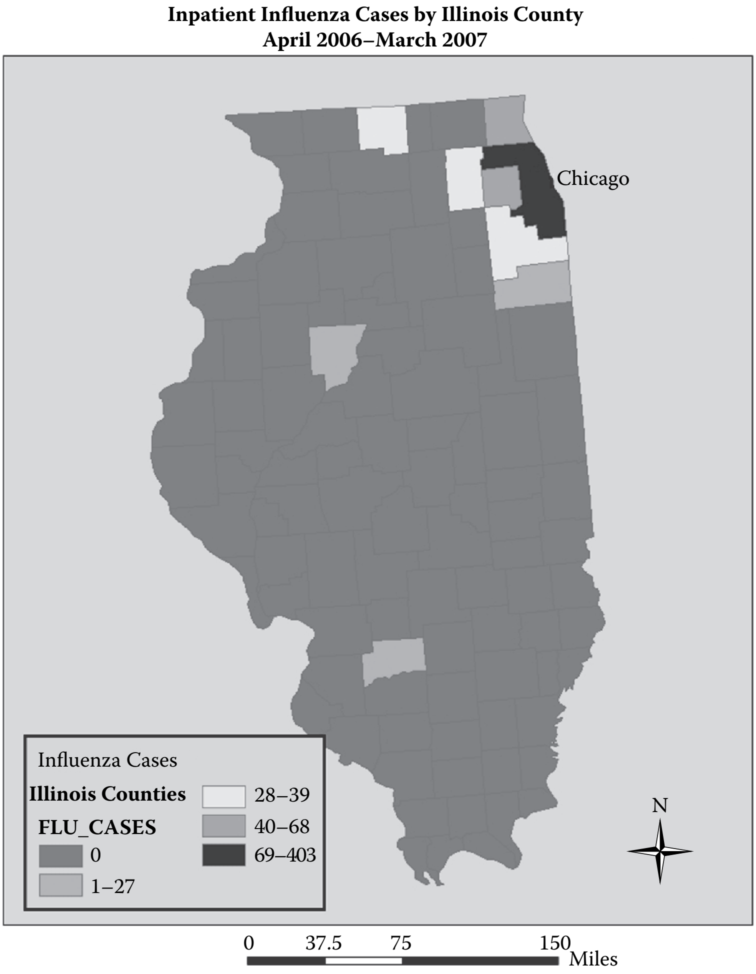

Figure 12.4 Inpatient influenza cases by Illinois county: April 2006 to March 2007.

H1N1 Case Study Background

The "XYZ" Hospital Network

As stated above, located in the suburbs of a major metropolitan area, the "community hospital network" is comprised of two acute hospitals located within 10 miles of each other, but each serving distinctly different populations and patient bases.

Hospital A is a long-established community medical center that has evolved to meet the needs of the population it serves. Modernized over the decades, Hospital A has retained a loyal patient base, has a tenured medical staff, and a strong

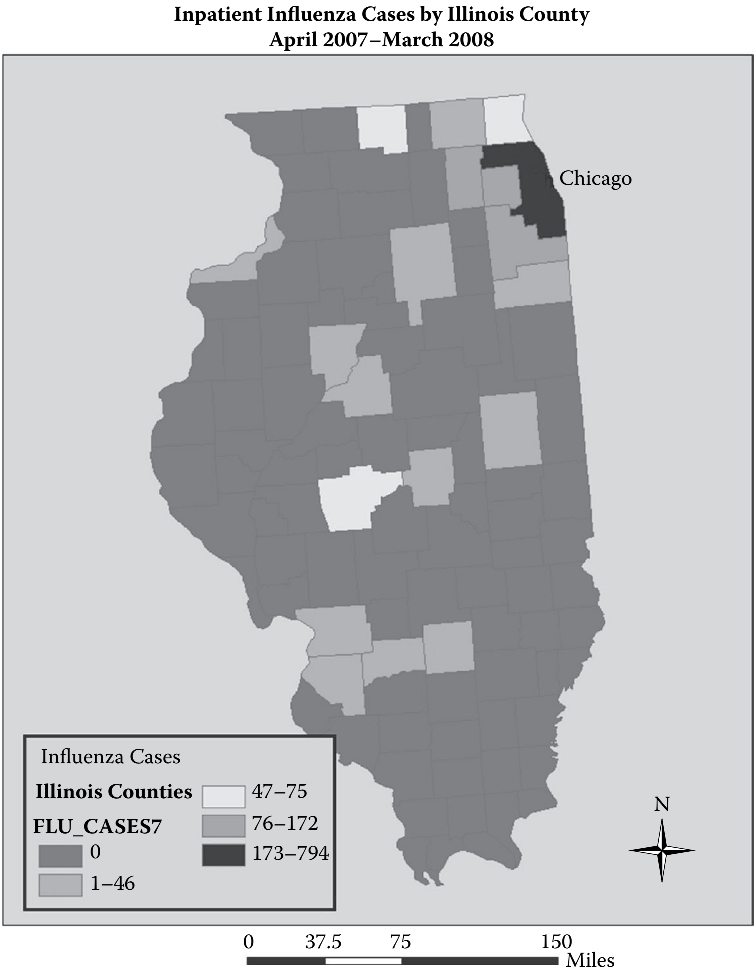

Figure 12.5 Inpatient influenza cases by Illinois county: April 2007 to March 2008.

affiliation with the community. Serving primarily middle-to-upper income, single home, older established communities, Hospital A excels in geriatric care, and disease treatment related to aging, including oncology services and orthopedics. With nearly 400 beds, Hospital A has 900 physicians on staff representing more than 80 medical and surgical specialties, and treating more than 18,000 inpatient admissions annually.

Hospital B, acquired by the hospital network in the late 1990s, is located in one of the fastest growing and most demographically diverse suburban areas in the state. Serving many ethnically mixed communities, Hospital B's primary service

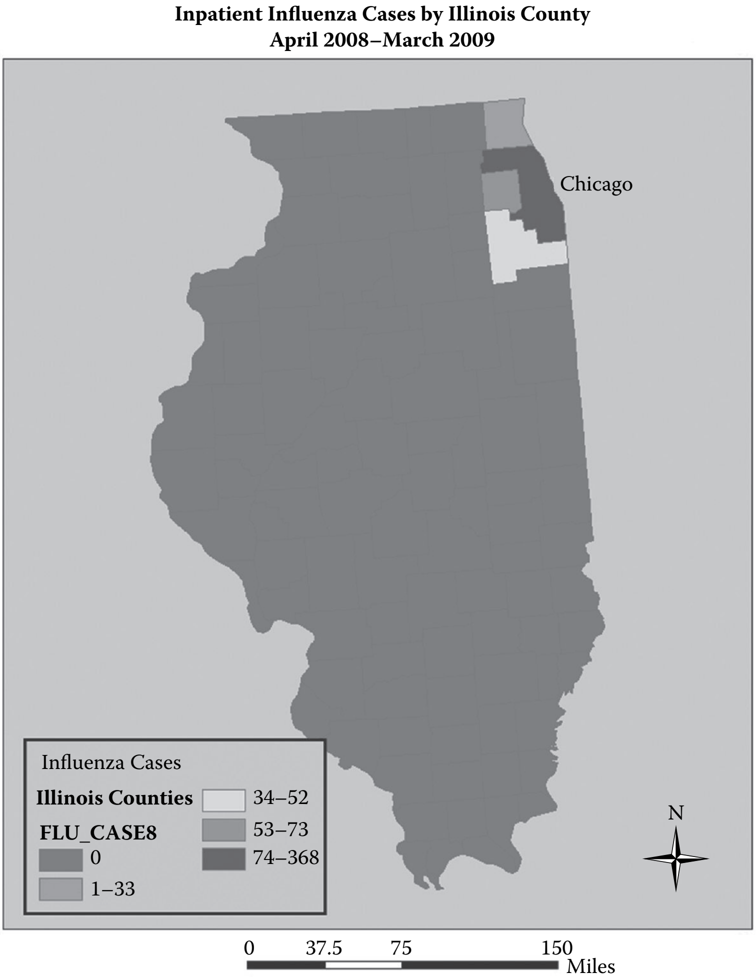

Figure 12.6 Inpatient influenza cases by Illinois county: April 2008 to March 2009.

area consists of nearly 40% Hispanic, African American, and Asian residents. With strong pediatric and obstetrics programs, Hospital B has 330 beds and more than 1,000 physicians representing 60 medical and surgical specialties, treating more than 15,000 inpatient admissions annually. Expansion of Hospital B by the hospital network has been a priority in a race to keep pace with its growing and diverse patient population's healthcare needs. Recent years have seen the acquisition of new medical technologies at Hospital B, significant infrastructure improvements, and a major expansion of its emergency department (ED), including specialized child-focused emergency room (ER) care.

The hospital network also operates several immediate-care, nonurgent, ambulatory centers located throughout both hospitals' primary and secondary service areas. The centers were opened as part of a larger strategy to extend local presence within new communities and decompress both emergency rooms and inpatient units to limit growing occurrences of ambulance bypass due to growing patient volumes and resulting capacity constraints.

Despite the geographic proximity of Hospitals A and B, their differing patient needs and medical staff specialties have tested the full integration and allocation of many services, including information technology (IT), materials, communications, and other operational support. This impact of not fully integrating became most apparent in April 2009 with the onset of Influenza A (H1N1) virus in the region.

Pandemic Preparedness

As initial reports of the H1N1 Virus were received in mid-April, Hospitals A and B implemented independent preparedness plans.

Note: Although both hospitals are part of a larger regional hospital disaster response council, previous conclusions made by Hospitals A and B following avian influenza and Top Officials (TOPOFF) exercises included postdrill analyses that each were able to operate independently in a disaster or pandemic scenario. TOPOFF is the nation's premier terrorism preparedness exercise, involving top officials at every level of government as well as representatives from the international community and private sector. Thousands of federal, state, territorial, and local officials engage in various activities as part of a robust, full-scale, simulated response to a multifaceted threat. During a disaster that may include the need for patient or healthcare worker isolation (for disease containment purposes) or a situation that results in the inability to communicate between hospitals (due to a natural disaster or act of terrorism), functioning autonomously of each other seemed advantageous at the time in the event of an individual failure.

Notices of the first confirmed H1N1 cases in Mexico, along with signs and symptom updates, were transmitted via e-mail alert by various agencies in late April 2009. These alerts were received by infection control personnel, physicians, and administrators at both hospitals. They included H1N1 guidance e-mail updates on diagnoses and antiviral agents for treatment/chemoprophylaxis of the H1N1 infection. Specimen collection protocol followed from additional sources. Soon the daily updates from national, state, and county sources became hourly, as additional cases were reported and new H1N1 management guidelines were identified. By the time the WHO announced its decision to raise the Pandemic Alert Level to Phase 4 on April 27, 2009, staff at both hospitals were receiving hundreds of updates daily from various sources, including the CDC. Because of the rapid flow of information and the evolving nature of the virus, many of the updates were obsolete shortly after being issued because new H1N1 clinical protocols were being established almost hourly.

Information Glut

With no central clearinghouse for information or an established singular disaster preparedness communication channel between Hospitals A and B, the glut of information (heightened by excessive media coverage and use of social media platforms) led to a series of frenzied exchanges consisting of the continual forwarding of e-mail bulletins, alerts, and updates between hospital counterparts in an attempt to keep each other informed. The H1N1 information shared between hospitals was often obsolete or inaccurate by the time it was opened and read by intended recipients.

What was known at the time was that the virus in the earliest U.S. cases appeared to be targeting children who were suffering only mild illnesses. Also at risk were the elderly, as well as anyone who had recently traveled to Mexico, or come in contact with someone who had traveled to Mexico, where at the time more than 150 cases and 7 H1N1-related deaths had been confirmed by the CDC.

Both hospital EDs and most of the hospital network's ambulatory sites began reporting a handful of "possible" H1N1 cases. State public health laboratories were now being inundated with specimen collections, and return confirmation of suspected influenza A virus cases was taking more than a week, adding to the uncertainty of the situation. Telephone calls and drop-ins at both hospitals' EDs jumped an estimated 300% over the three days that followed, with many individuals demanding Tamiflu™ or Relenza™ despite being asymptomatic and not having traveled—or even come in contact with anyone who had traveled—to Mexico. Confirmation of the public's confusion was evident by the nature of their requests upon presentation in the ER, with many instances of Hispanic patrons citing the need for the H1N1 antiviral due solely to their Latino ancestry.

Streamlining and Targeting Communication

One solution for streamlining internal communication was the request that all hospital personnel cease forwarding bulletins, alerts, and updates, and, instead, rely on a single source for all H1N1 clinical information. The CDC Web site was the source selected; physician and ER staff at both Hospitals A and B were urged to check the site frequently. Dedicated H1N1 computers (dubbed *H1Coms*) were set up in the hospitals' ERs with all browsers pointed at the CDC Web site, so updates could be viewed in real-time. The CCTV (closed circuit television) channels at both hospitals and immediate care facilities overrode usual programming to instead display select pages from the CDC Web site.

By the end of April 2009, all patient points of contact within the hospital network reported being incapable of handling the number of phone calls and drop-ins related to H1N1. ED personnel estimated they were spending 20 to 30 minutes with each case differentiating the "worried well" from those who may have actually been exposed to the virus and exhibiting symptoms. At Hospital A, most of the inquiries and ER visits involved their elderly population who are most at risk for annual influenza strains. At Hospital B, a large percentage of the worried well were Hispanic residents from within the community and families with young children. Together these demographic groups were the same identified by the CDC as being at the highest risk.

Communicating to the general public was now a priority. Both hospitals established a Swine Flu Hotline, accessible to callers directly from the hospitals' main switchboards. The hotline provided a list of symptoms, tips on how to prevent spreading the virus, and an appeal to "call your primary care physician if you suspect you have been exposed to the swine flu virus." Once activated, all swine flu-related calls to the ER were transferred to the hotline. In the days following the launch of the hotlines, H1N1 calls and visits dropped significantly. Along those same lines, swine flu advisory signage was placed at all patient and visitor entrances next to mobile hand sanitizing stations. The signs highlighted the symptoms and tips for preventing spread of the virus. English and Spanish versions of the signage were strategically placed at locations that served largely Hispanic patients.

Scheduled conference calls were conducted twice daily with all team members at both hospitals. The agenda included updates on medical supplies, antivirals, vaccines, antibiotics, masks, healthcare worker availability, hospital occupancy/availability, and use of alternative health facilities. Based on volumes, community demographic characteristics, and past seasonal flu patterns, decisions were made on the allocation and distribution of needed materials and sources.

Community Hospital Emergency Department/ Immediate Care Activities

Utilizing control charting methodology to test for process and environmental change, an analysis of the community hospital network's ED activities was performed. The period between April 30, 2009 and May 7, 2009 depicted an increase of activity beyond two standard deviations above the mean (Figure 12.7). This period of variance corresponded to the period in which CDC and WHO were actively communicating the progress of the virus online in their respective Web sites and e-mail distributions. The variance also reflects reports of volumes of "worried well" arriving at the network's emergency departments and immediate care centers.

Comparing the period April 15 through May 14 of 2008 versus the same period in 2009, thereby controlling for seasonality, a 159% increase in emergency department discharges with a diagnosis of upper respiratory infection (ICD9-CM, 465.9) was observed (Figure 12.8). When further analyzing the data, it was observed that the proportion of Hispanic population presenting with upper respiratory infection (URI) increased 179% during the same period from 19.2% to 53.5% of the total ED population.

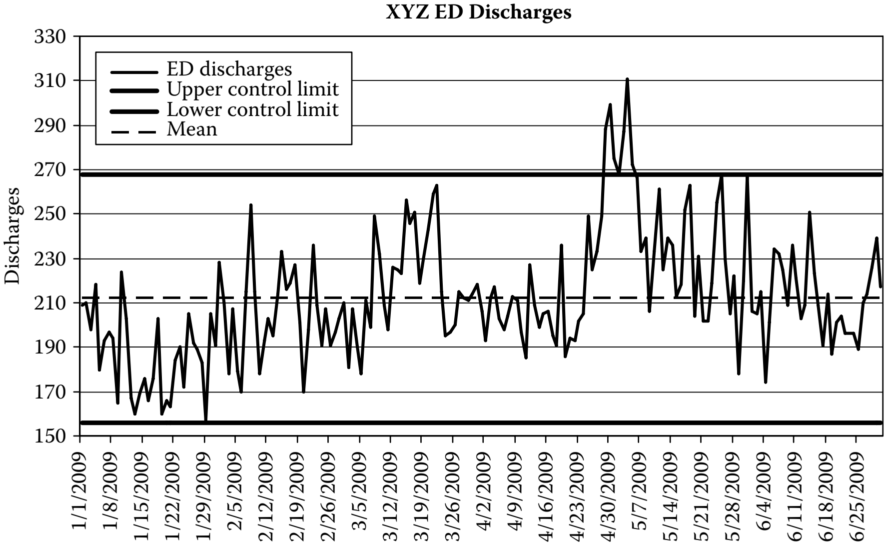

Figure 12.7 Emergency Department (ED) discharge control chart.

XYZ Hospital Network ED Discharges by Ethnicity and Diagnosis

APRIL 15, 2008–MAY 14,2008

	TOTAL D/C		TOTAL DX: URI D/C	
ETHNICITY	CASES	% CASES	CASES	% CASES
HISPANIC	628	10.0%	23	19.2%
NON-HISPANIC	5,625	90.0%	97	80.0%
TOTAL	6,253	100.0%	120	100.0%

DX: URI = UPPER RESPIRATORY INFECTION

APRIL 15, 2009–MAY 14,2009

	TOTAL D/C		TOTAL DX:URI D/C	
ETHNICITY	CASES	% CASES	CASES	% CASES
HISPANIC	1,661	23.4%	162	53.5%
NON-HISPANIC	5,447	76.6%	141	46.5%
TOTAL	7,108	100.0%	303	100.0%

Figure 12.8 Emergency Department (ED) discharges by ethnicity and diagnosis.

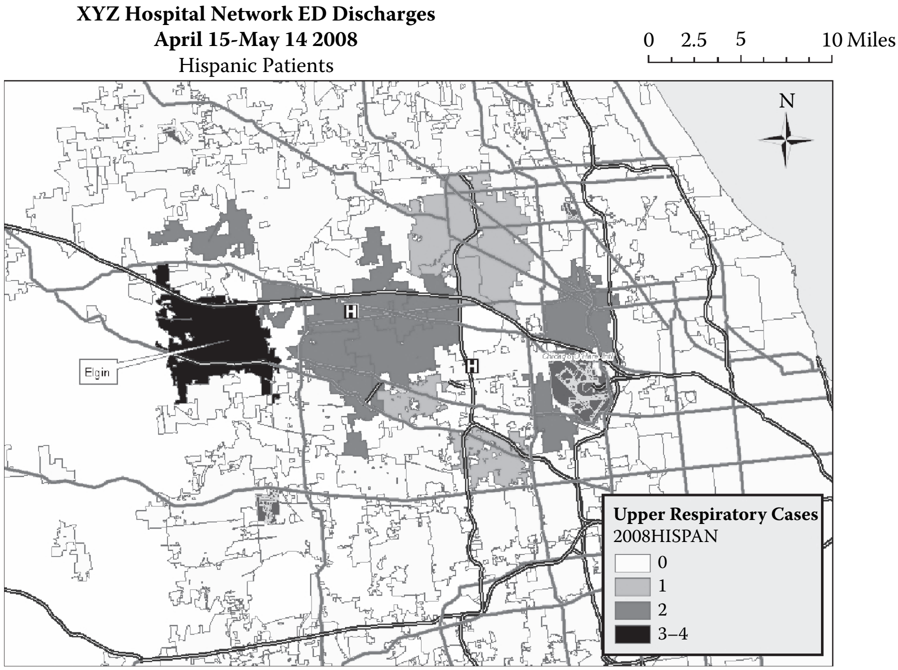

Figure 12.9 Hispanic patient discharges: April 14 to May 15, 2008.

A GIS analysis of the distribution of Hispanic cases of URI by residential community areas indicated a shift in the geographic origin of the highest quartile of cases from a community farther away from Hospital B to one much closer (Figure 12.9 and Figure 12.10). This shift corresponded to the shift in at-risk groups from non-Hispanic to Hispanic.

Discussion

The need to utilize GIS mapping by patient type for disaster preparedness is a critical step to understanding the nature of the cases presenting at a community hospital emergency department. The application of real-time analytics combining GIS and control charting by planning, data analytics, and mapping professionals is a value-added benefit to critical decision making and epidemiological analysis. The process of mapping the data concurrently with the evolution of the local epidemic allows public relations, communications, materials management, and operations staff to coordinate efforts in the midst of disaster preparedness plan activation. Further, as the crisis progresses, concurrent mapping of information allows for staff to react to conclusions drawn from the analytics in real-time.

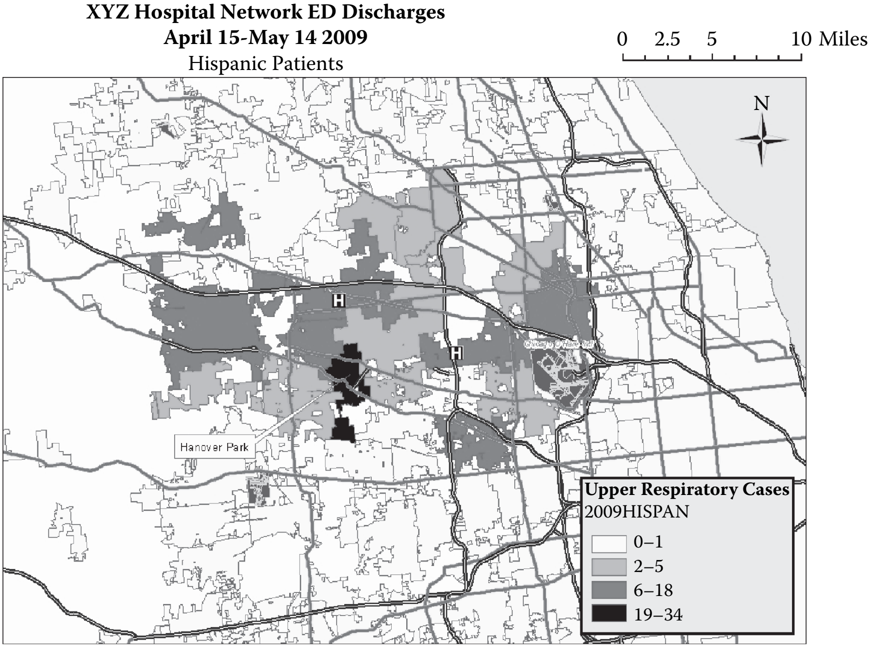

Figure 12.10 Hispanic patient discharges: April 14 to May 15, 2009.

While extremely useful for macrotrend analysis, data analytics and information provided by the WHO, the CDC, and local health department Web sites was not granular enough to inform hospital staff to effectively adjust their disaster preparedness plans at the local level. Further, information provided by these sources may have caused unnecessary alarm in local populations thereby causing microtrends that were not consistent with national trends during the crisis. It seems that in this case, the CDC, the WHO, and the resulting media reporting around H1N1 and speculation regarding the spread of H1N1 from Mexico contributed to the reaction of the Hispanic community and the subsequent arrival of this population in the hospital network's emergency departments seeking treatment or preventative therapy. Staffing adjustments to meet the demand of the Hispanic community and to triage the worried well from those who, in fact, were potentially carrying the H1N1 virus were made as a result of the surge in Hispanic cases. The overall surge of cases of both clinically ill and worried well populations required that hospital operations staff quickly adjust to the demand for supplies and staff, particularly those who spoke Spanish.

Signage (Figure 12.11) was added in Spanish and posted throughout the hospital network to alert the community to properly recognize the signs and symptoms and what to do to avoid the spread of the virus. The purpose of adding this signage was to communicate effectively to the community and manage the surge by

GRIPE PORCINA (INFLUENZA PORCINA)
AVISO DE SALUD PÚBLICA DE
LOS CENTROS PARA EL CONTROL Y LA PREVENCIÓN DE ENFERMEDADES (CDC)

Ha habido casos de gripe porcina en los Estados Unidos.
Si tiene algún síntoma parecido a los de la gripe, tal como: fiebre (calentura), tos, dolor de garganta y congestión nasal

PIÉNSELO MUY BIEN ANTES DE VISITAR A NUESTROS PACIENTES.

Como siempre:

❖ **Lávese las manos con frecuencia**
❖ **Cúbrase la boca y la nariz al toser o estornudar**
❖ **Evite tocarse la nariz, la boca o los ojos**

Figure 12.11 Spanish patient H1N1 notice.

discouraging the worried well from seeking unnecessary services as the epidemic was unfolding.

Finally, a Spanish language hotline was implemented to alleviate the amount of calls made to the emergency departments. The hotline had a listing of the most frequently asked questions being posed by the Hispanic population. The purpose of adding the line was to decompress call volume to the ED, educate the worried well, and instruct the community on basic disease prevention skills.

Conclusions

Use of community hospital clinical data systems to monitor outbreaks within the organization in conjunction with publicly reported data is critical to appropriately plan and react to local trends in real-time because they may differ from regional, county, state, or national trends. Use of GIS to quantify local trends enabled enhanced information analysis and supported management decision in the response to influenza and prepared the case study organization to better prepare for the next potential outbreak. Analyzing populations at risk for outbreak, such as patients with cardiovascular disease, respiratory disease, diabetes, cancer, asthma, respiratory disease, obesity, and pregnancy, and monitoring their access to providers during an outbreak may lead to improved service delivery and awareness during an outbreak. Effective communication between hospitals and local health departments is of significant value, particularly if local trends observed are not consistent with larger regional or national trends. The importance of hospital operations staff working collaboratively across multiple disciplines, including public relations and data analytics, cannot be overstated. It is also useful for hospitals to share their key findings postcrisis, thereby critically evaluating the state and local health departments' experience relative to the hospital network's emergency response. Finally, ensuring that hospital disaster preparedness plans comply with state and federal regulations is essential. These combined efforts will assist in improved disaster preparedness planning, which will generate an effective and well coordinated response by community hospitals in a crisis.

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Chapter 13

Disaster Preparedness and Response for Vulnerable Populations: Essential Role of GIS for Emergency Medical Services during the San Diego County 2007 Firestorm

Isabel Corcos, MPH, PhD, Holly Shipp, MPH,
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Contents

Background

San Diego is the second most populated county in the State of California with over 3.1 million residents living in 18 cities and a vast unincorporated area. San Diego County's land area of approximately 4,200 square miles contains four major microclimates including coastal, inland, mountain, and desert, and a mix of urban, suburban, rural, and remote communities. Although numerous fault lines run through San Diego County, the most likely natural disaster comes not from seismic activity, but from wildfire. The California Department of Forestry and Fire Protection developed models ranking fire probability based on factors, such as the frequency of fire weather, fuel ignition patterns, expected rate of spread, and/or past fire history. Nearly all of the land area in San Diego County is ranked as "high" to "very high" fire risk (California Department of Forestry and Fire Protection, 2008). San Diego County residents have recently experienced two major wildfires, or firestorms, in the past few years: 2003 and 2007.

Firestorms in Southern California are extremely dangerous and different than fires elsewhere in the country. Driven by strong winds gusting to 60 mph, walls of fire jump over freeways and sweep through neighborhoods and may leave residents mere minutes to evacuate. Unique conditions fuel these fires, and include high ambient temperatures, very low humidity, an ignition source (such as a downed power line or camp fire), and Santa Ana winds. These winds carry hot, dry air from the deserts in the east toward population centers closer to the western coastline (National Oceanic and Atmospheric Administration, 2008).

In October 2003, the worst firestorm in San Diego history ran rampant through the county, burning more than 375,000 acres and destroying over 2,000 homes in the course of five days (Amabile et al., 2004). Evacuation orders were delivered by public safety officials in the field and many individuals needing assistance relied on the 911 system for transportation. Since medical facility evacuation plans were not coordinated at a regional level, they also relied on the overtaxed 911 system to evacuate their medically fragile patients. Paramedics and EMTs (emergency medical technicians) were often not readily available when it came time for these facilities to move their patients.

The *After Action Report for the 2003 Firestorm* included several recommendations geared toward enhancing the safety of residents, and, in particular, care of medically fragile and vulnerable individuals who needed to be evacuated (Amabile et al., 2004). The elements put in place after 2003 included:

- Implementation of a reverse 911 system to notify residents of need to evacuate.
- Creation of pet friendly and large animal shelters to encourage compliance with evacuation orders.
- Implementation of a common electronic information system (WebEOC) among disaster service personnel.
- Development of regional disaster response plans for hospitals.
- Coordination of medical operations response in a central location, which worked with public/private partners.

As part of the response to the *2003 After Action Report*, the County of San Diego created the Emergency Medical Services Departmental Operations Center (EMS DOC) to coordinate the medical response to disasters and to begin to develop regional disaster response plans for hospitals and other healthcare facilities. During a disaster, the EMS DOC is the operational arm that oversees the entire EMS system, which consists of both prehospital and hospital resources, in order to respond to requests for assistance from individual facilities. The EMS DOC monitors the EMS system and coordinates the medical response between the 41 paramedic agencies and 20 emergency hospitals in San Diego County. A specific emphasis was to create procedures to coordinate the evacuation of residential healthcare facilities and hospitals, and other pockets of the population with special needs. Another result of the *After Action Report* was the implementation of WebEOC (ESi Acquisition, Inc., Augusta, GA). WebEOC is a Web-based communications tool used as a platform to facilitate communications between county and city operations centers, hospitals, law enforcement, and fire agencies.

The 2003 firestorm (Amabile et al., 2004), and Hurricanes Katrina and Rita in 2005, highlighted the vulnerability of certain groups with special medical care and resource needs. These "vulnerable populations" included not only individuals in medical facilities, but also adults and children in group daycare, individuals with chronic medical conditions or disabilities, non-English speaking populations, and those without private transportation. In particular, the unique transportation requirements of patients in hospitals, skilled nursing facilities, and home healthcare illustrated the critical importance for regionally coordinated evacuation plans to prepare and provide for the evacuation of medically fragile populations (Ford et al., 2006; Baggett, 2006).

The County of San Diego EMS drafted a plan to prepare for future large-scale incidents. This plan included:

- The creation of a list of current resources, including emergency response personnel and emergency care facilities
- The identification of special populations defined by characteristics, such as age, class, location, race/ethnicity, and language
- The efficient use of available tools, such as Geographic Information Systems (GIS)
- The use of operations centers to connect multiple agencies
- The preparation of multiple scenarios for the evacuation or deployment of aid to identified high-risk populations in the event of a known or probable disaster

The creation of specific mapping tools for disasters, emergency response, and mitigation was deemed essential to carry out this plan. Key to a coordinated medical response is the ability to identify, locate, and assist those in need within the context of rapidly changing conditions typical of large-scale disasters. Spatial data and GIS are integral to the ability of the EMS DOC to prepare and respond to medical emergencies during disasters.

GIS for the EMS DOC

GIS had been used for a number of years at EMS for projects involving emergency medical and injury data, and several staff epidemiologists used GIS for internal and community health projects, such as mapping the locations of motor vehicle crashes, identifying EMS resources, or analyzing different rates of injury for areas within the county. Although there was no funding or mandate to create an in-house, all-hazards GIS system, EMS leveraged existing resources to implement the plan, which supports the core function of disaster readiness. In order to maximize existing resources, all five epidemiologists on staff were trained to use GIS mapping software at least functionally, which at the time was ArcGIS 9, ArcMap 9.1 (ESRI, Redlands, CA). Most of their training was self-guided; utilizing free online tutorials and assistance from staff members who were more proficient in the use of GIS. One part-time epidemiologist specializing in GIS was hired to maintain and update the disaster preparedness spatial database (DPSD) and work on projects that focused on disaster preparedness and planning for medical response. In addition, epidemiologists worked with other GIS personnel within the County of San Diego as part of a network to develop operating procedures, protocols, and tools that addressed all aspects of emergency response and recovery.

Evolution of a Disaster Preparedness Spatial Database

The first step in creating the DPSD was to determine what data and other spatial information were most critical for disaster preparedness from a medical or public health standpoint. Consulting with first responders and other medical personnel, and drawing from experience gained during past disasters, helped to develop the initial spatial data used in the DPSD. These data fell into three general categories:

1. *Hazards*: Natural and manmade features, such as fault lines and flood zones that could trigger, or be involved in a disaster.
2. *Infrastructure and assets*: Basic structural components of the community, including roads, public transportation, medical facilities, public safety, and large venues or employers.
3. *Vulnerable populations*: Those at special risk for poor health outcomes during, or resulting from, a disaster. These populations could include community residents, such as the very young, the elderly, the homeless, those without private transportation, and non-English speaking individuals, as well as patients in medical facilities, group homes, shelters, or incarcerated.

In addition to identifying the locations of vulnerable populations and medical facilities, other critical information was collected and maintained in the database (Table 13.1). This information was used to assess not only each facility's specific evacuation needs, but also their ability to receive evacuated patients from other locations. For example, for hospitals and nursing homes, the number of licensed and staffed beds, the ambulatory status of patients, and the facility address and contact information were readily available to EMS DOC staff through the DPSD. For nonmedical facilities, such as schools and daycare facilities, building capacity, staffing, and hours and days of operation were included in the DPSD.

Initially, data included in the DPSD were found through publicly available databases, such as licensing and financial datasets accessible online through the state Web site. Over time, more recent data were included through collaboration with community partners, such as the local hospital association, skilled nursing facilities, base hospitals, council of community clinics, ambulance coordinators, and the Medical Reserve Corps (MRC). Spatial data were continually added as EMS epidemiologists promoted the availability of the DPSD through conversations with paramedics, duty officers, and other emergency personnel. Table 13.2 shows an example of key nonspatial information included in the EMS DPSD.

San Diego County EMS epidemiology staff presented the DPSD at the NACCHO (National Association of County and City Health Officials) Public Health Preparedness Summit in July 2007 and at the ESRI (Environmental Systems Research Institute) Health GIS conference in October 2007. At that point, its usefulness and effectiveness was untested in a disaster.

Table 13.1 A Sample List of Spatial Data Contained within the EMS DPSD

Category	*Layer*
Hazards	Earthquake fault lines, fire hazard severity zones Dams/dam inundation, flood plains Nuclear generating facilities Military; unexploded ordnance
Infrastructure and assets	Transportation Roads, rail, public transit Airports, heliports Ports, bridges Fuel stations
	Medical resources Hospitals Mobile medical assets Clinics, pharmacies
	Public safety Law enforcement, fire stations Fire/rescue helicopters Ambulance service stations Emergency operations centers HazMat
	Geographical features and data Canyons Water bodies/coastline features Reserves/protected lands
	Boundary/jurisdictional Municipalities, reservations, military Zip code, Thomas guide, census tracts
	Adjacent counties Roads, medical resources
Vulnerable populations	Medically fragile populations Hospitals Home health/hospices, skilled nursing facilities Intermediate care facilities

Table 13.1 A Sample List of Spatial Data Contained within the EMS DPSD (Continued)

Category	*Layer*
	Other vulnerable populations Adult day care, single room occupants Schools, child care, group homes Major employers, tourist attractions Detention facilities
	Census and current census estimates

Table 13.2 Key (Nonspatial) Data Included in Vulnerable Population Layers in the Emergency Medical Services Disaster Preparedness Spatial Database

Category	*Key Data*
Population demographics (census)	Age distributions (minors, elderly) Average household size Poverty level Availability of vehicle Non-English speaking, other languages
Medical facilities	Number of patients Age, disposition (bedridden, disabled) Special needs (oxygen, IV, infant car seats) Number of staff (contact name/phone/e-mail)
Other medically fragile	Bedridden: due to age or disability Wheelchair bound: unable to walk and self-transport Special needs: medical equipment (e.g., IV, oxygen) Chronic conditions (kidney failure, diabetes, etc.)
Adult and child daycare Schools	Facility capacity, staffing, days/hours of operation Age, special needs K-12 traditional, year-round

The Incident: Firestorm, October 2007

On the evening of October 21, 2007, the San Diego County Emergency Operations Center (EOC) and EMS DOC were activated in response to two rapidly spreading fires propelled by strong Santa Ana winds. A GIS-trained EMS epidemiologist was requested to report to the EMS DOC. The Harris fire, located in southeast San Diego County, was spreading quickly toward heavily populated neighborhoods. Evacuations of local residents were underway, and the evacuation of medically fragile individuals from local healthcare facilities was anticipated. The epidemiologist used the DPSD to create a base map of San Diego County containing basic infrastructure and geographic details, as well as locations of hospitals, skilled nursing facilities, elderly residential care facilities, and other vulnerable populations.

Initially, the fire perimeters and movement were known only by word-of-mouth, primarily from radio traffic of firefighting personnel (Figure 13.1). This information was roughly sketched into the map to identify facilities that might be in the path of the fire and to plan for evacuations. Reports of a second major fire came in just before midnight. This fire, dubbed the Witch Creek fire, had the potential to move westward through the valleys toward the Pacific Ocean. This placed

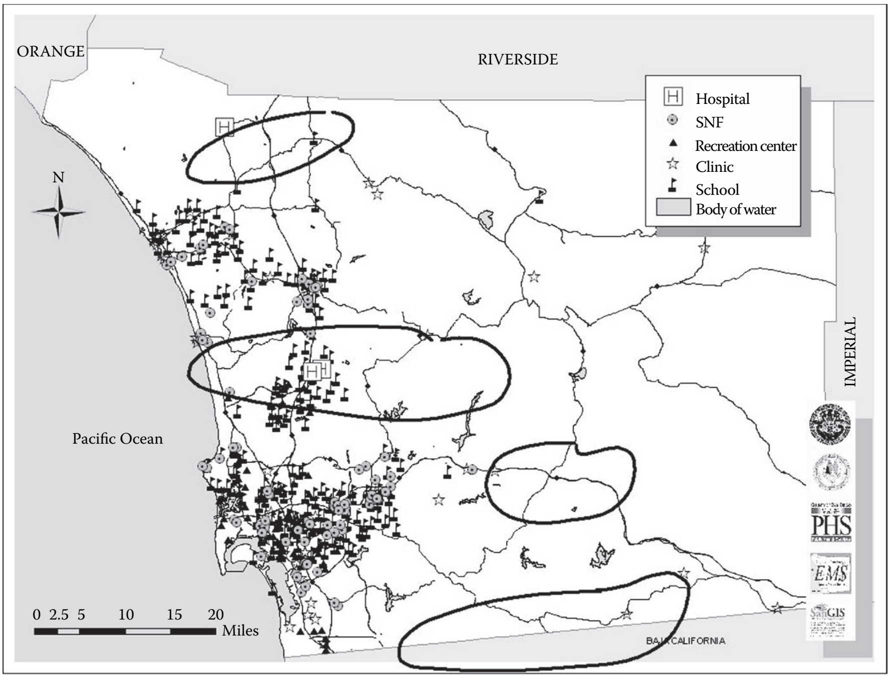

Figure 13.1 Approximate fire perimeters, threatened medical facilities, and possible evacuation sites in San Diego County, October 21, 2007. Fire perimeters were hand-drawn using descriptions from first responder radio traffic (October 21, 2007).

several hospitals and densely populated urban areas in danger. By early morning on October 22, nine total fires had been reported. However, the fire locations were still not well defined due to the inability to conduct aerial reconnaissance in the darkness, and because the Santa Ana winds were gusting at more than 60 mph, which precluded aerial overview.

Planning for Evacuations

The goal of the EMS DOC on the first night of the fires was to preplan for the evacuation of medical facilities in danger to ensure that each patient went to a receiving facility able to provide comparable medical care. Because fire is highly unpredictable, several scenarios were considered. The GIS epidemiologist created and printed large-scale wall maps describing the approximate fire perimeters and the possible fire paths based on communication from responders in the field. Included on the maps were all facilities housing medically fragile individuals, as well as possible shelter locations, such as schools, community clinics, and recreation centers (Figure 13.1). Coordinators in the EMS DOC used these maps to identify medical facilities in the predicted fire paths, and the GIS epidemiologist extracted their contact information, bed count, and other pertinent details from the DPSD. EMS DOC staff then called each endangered facility to notify them of possible evacuation, and to determine what resources would be needed, such as transportation, type of receiving facility, and personnel. Staff also collected the current patient and staff census from each facility, and the GIS epidemiologist updated the DPSD medical facility data with this information. In addition to preplanning for the evacuation of medical facilities, the maps were used to identify and contact sites not in fire danger and assess whether they could receive patients. Each receiving facility had to have not only capacity for intake, but the resources and personnel needed to administer equivalent care. Using all of this information, evacuation plans were developed for each endangered facility. Staff members at the endangered medical facilities were told to prepare for probable evacuation by collecting medical records and three-day supplies of medication for each individual patient to take with them to the receiving facility.

By the second day of the fires, fire perimeter layers were created via satellite and evacuation layers based on reverse 911 call areas were created by GIS staff in the EOC and shared by GIS personnel across agencies. These data allowed for more thorough preplanning for the evacuation and eventual repopulation of threatened medical facilities. Due to the massive extent of the fires, many roads were closed, leaving some potential receiving shelters inaccessible. GIS epidemiologists created maps displaying the available transportation routes away from evacuated facilities. EMS DOC staff used these maps to consider the feasibility of transport to facilities in the adjacent counties of Orange and Riverside. GIS epidemiologists contacted Orange County GIS staff to obtain spatial data for medical facilities and roads in order to plan for evacuations to receiving facilities that might cross county lines.

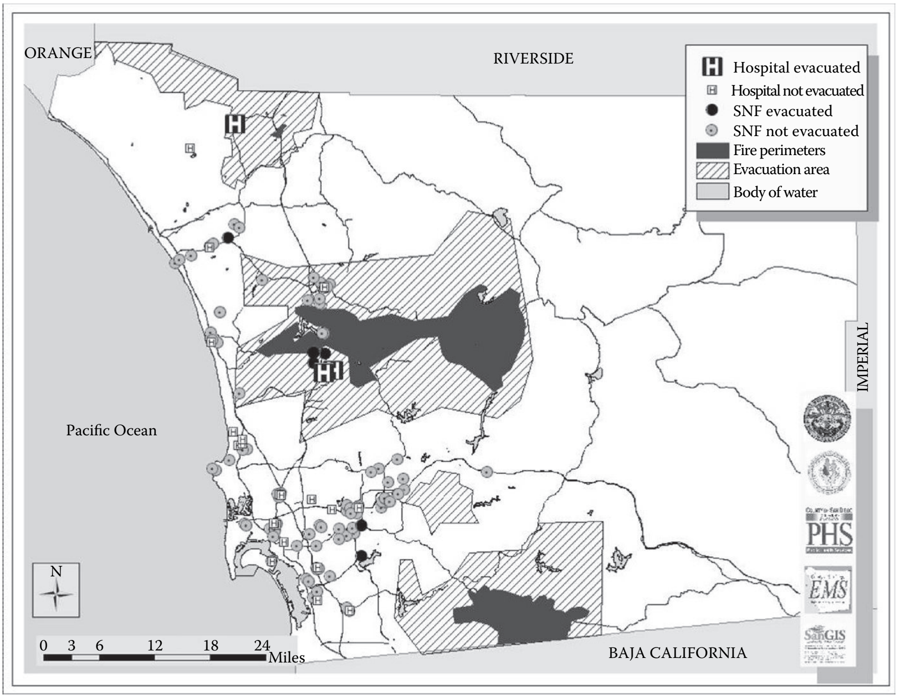

Figure 13.2 Location of medical facilities in relation to fire perimeters and evacuation areas (October 22, 2007). County overview of all fire perimeters.

Figure 13.2 shows an overview of the fire perimeters, the mandatory evacuation areas, and threatened medical facilities. Figure 13.3 shows a proximity view of the Witch fire that was threatening to overtake a hospital in north San Diego County. Seventy-four patients needed to be evacuated to comparable level care facilities. To minimize stress and maximize care, the goal was to move patients only once, with their medical records and a three-day supply of medication, and to send appropriate medical staff with them to the receiving facility. Using the plans developed in the EMS DOC based on information from the DPSD, the entire hospital was evacuated and shut down within eight hours.

All patients were safely moved to comparable receiving facilities, with staff and supplies. That same night, the EMS DOC received a call from a large skilled nursing facility (SNF), housing approximately 500 patients. Staff from this SNF reported seeing fire over the ridge, approaching their facility. As a result of the preplanning that had occurred using the DPSD during the previous day, the EMS DOC was prepared to evacuate the facility using ambulance strike teams and other transport vehicles to move residents to a safe location. Four hundred ambulatory residents at this SNF were moved via bus to a high school gym, and 100 nonambulatory

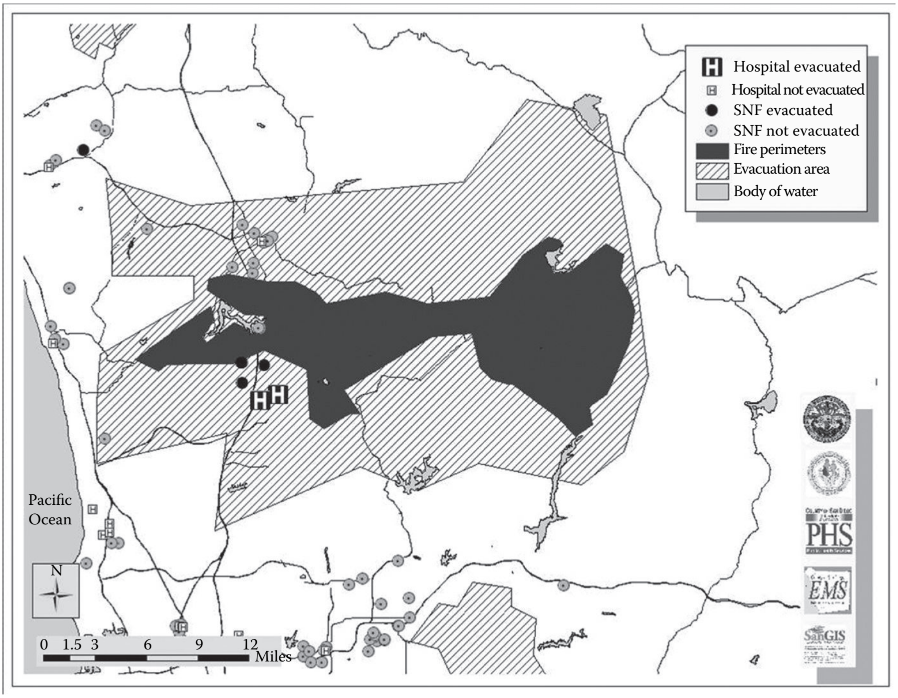

Figure 13.3 Proximity view of large fire perimeter threatening two hospitals and multiple skilled nursing facilities (SNFs).

patients were moved via ambulance to appropriate care facilities. All were safely placed within two hours.

All patients who were evacuated from medical facilities were tracked through the EMS DOC. A formal mechanism was not in place at the time, so by EMS DOC request, the facilities would fax or call and report all patients who were evacuated from their facility and the location to where they were evacuated. This information was compiled in the EMS DOC and used to monitor patient movement during the evacuation and repatriation. Table 13.3 lists the type of facility evacuated, the type of receiving facility, and the number and disposition of patients in care.

The Aftermath

During the course of the firestorm, as many as 12 fires burned, eventually becoming 7 major fires that burned nearly 400,000 acres, or about 15% of the total county land area (Figure 13.4). By the time the last fire was fully contained on November 7, 2007, more than 515,000 individuals had been evacuated from fire-threatened areas, a scale that had never before been seen in California.

Table 13.3 Medical Evacuations of 1,429 Patients in San Diego County Firestorm, October 2007

Facility (Total no. of patients)	*Patient Disposition (No. of patients)*	*Receiving Facilities*
Hospital A (74)	Intensive care (10) Telemedicine (10) Medical/surgical (30) Labor and delivery (6) Emergency department (7) Neonatal intensive care (2) Behavioral health (7) Other (2)	Thirteen hospitals
Hospital B (75)	Acute care (14 Ambulatory (61)	Five hospitals One skilled nursing facility
Hospital C (40)	Psychiatric (40)	One psychiatric hospital
SNF 1 (121)	Basic Life Support (BLS) (77) Advanced Life Support (ALS) (9) Ambulatory (35)	Multiple SNFs
SNF 2 (279)	BLS (27) Ambulatory (252)	One shelter
SNF 3 (129)	EMS DOC provided transport from nonmedically staffed shelter to receiving SNFs (129)	Three SNFs
SNF 4 (47)	EMS DOC provided return transport to repatriate patient in original SNF after evacuation order lifted (47)	One SNF
SNF 5 (60)	Transport assistance (60)	One SNF
SNF 6 (81)	Wheelchair-bound (73) Ambulatory (8)	Four SNFs
SNF 7 (15)	Transport assistance (15)	One SNF
SNF 8 (500)	Transport assistance (500)	Multiple shelters

Note: Patients were sent to comparable care in other medical facilities or medically staffed shelters.

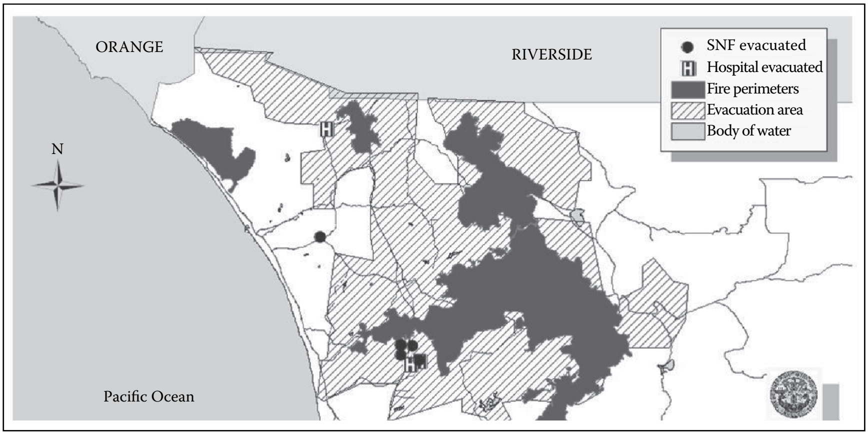

Figure 13.4 Final extent of fire perimeters, mandatory evacuation areas, and evacuated medical facilities in San Diego County, October, 2007.

Approximately 1,600 homes and more than 1,200 other structures and vehicles were destroyed, and the projected damages were expected to exceed $1.5 billion. (Ekard et al., 2008). Despite massive destruction, there were only 10 civilian deaths, 23 civilian injuries, and 89 firefighter injuries attributed directly to the fires.

More than 1,400 medically fragile individuals were evacuated in a cooperative effort with various medical transport and mass transit agencies, along with ambulance strike teams from outside of the area (Table 13.3). Two acute care hospitals with 149 patients were safely evacuated during this emergency, one of which evacuated and shut down in less than eight hours and the other in less than two hours. All patients were safely transported with their medical records and necessary prescription medications to an appropriately staffed medical receiving facility. During the course of the evacuations, several facilities housing medically fragile patients self-evacuated and showed up at a local shelter. As a result, another medically staffed shelter was opened nearby as a holding station to care for these individuals until appropriate receiving facilities could be located. In other cases, SNFs who initially self-evacuated were given assistance with repatriation after the fire danger passed.

The 2007 wildfires began almost exactly four years after the catastrophic wildfires of October 2003. The 2007 fires were almost as large (Figure 13.3), and destroyed nearly as much property as the 2003 fires, but injury and death surveillance suggests that far fewer people were injured or killed during the 2007 fires. This success was due to a combination of factors, including rapid and aggressive population evacuation using the reverse-911 system within a population that was familiar with the destructive potential of wildfires. The successful evacuation of medical facilities could not have been possible without the extensive cooperation between the EMS DOC and the medical facilities and without the use of the DPSD for preplanning and evacuation efforts. In particular, the biggest impact from using GIS and the DPSD was the ability to preplan such that patients went from their beds to a comparable bed without staging at a shelter first. Because information on facilities was already available, there was time to preorder the appropriate number of ambulances and get them into position at the facilities well in advance of need. Finally, maps facilitated staff ability to model and prepare alternate plans based on changes in the direction and intensity of the fires.

Enhancements Since the 2007 Firestorm

A set of prepared "Ready Maps" were developed and made available in PDF form for the EMS DOC. Maps of medical resources and vulnerable populations have been prepared and are updated routinely (Figure 13.5). General maps showing geohazards (earthquake fault lines, dam inundation areas, and other hazards) are available for quick reference (Figure 13.6). In addition, map books and facility directories have been created enabling responding personnel to quickly see and contact facilities at risk in a threatened area. Map atlases have been created using a developers' utility available from ESRI (Price, 2008). Resources and other information are mapped on a smaller scale for easy reference. Directories organized by grids are especially useful for identifying resources or vulnerable populations in relationship to hazards.

Replicating the Disaster Preparedness Spatial Database

There are significant advantages for local agencies in creating a similar GIS-based data system, including coordinated disaster response, efficient resource allocation, spatial identification of at risk groups or facilities, and evacuation planning. In addition, the database can become a valuable resource for community information for grant writing, policy development, and coalition building. The most important benefit is the protection of the health and safety of the general public.

Conduct a Needs Assessment

The first step in developing a DPSD is to conduct a needs assessment. This will help define the purpose and structure of the GIS system. Critical questions to answer include: What is the purpose of the data system, what data are available, who keeps it, how is it maintained or updated, are there metadata, is it understandable? This process should also help identify local data resources to provide guidance and support in the development of the GIS system.

Once the necessary data sources have been identified, work out exchanges and cooperative agreements to share information. It is important to have a clear

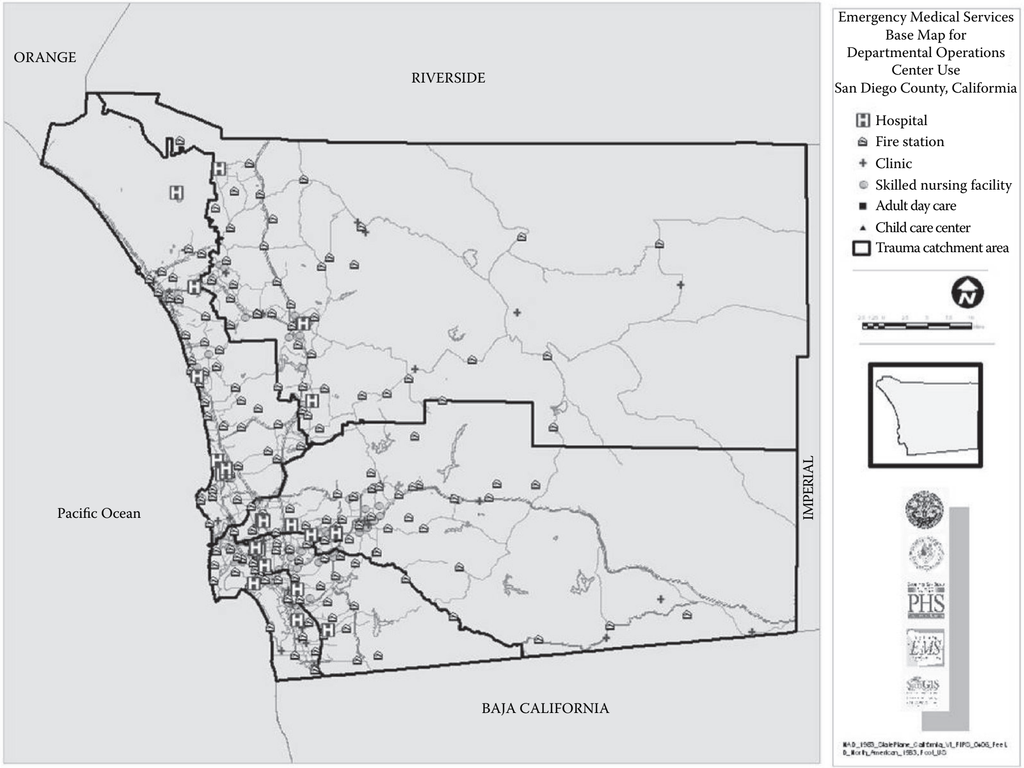

Figure 13.5 "Ready Map" of selected medical and fire resources, hospital trauma catchment areas, and vulnerable populations for use in the Emergency Medical Services Departmental Operations Center (EMS DOC).

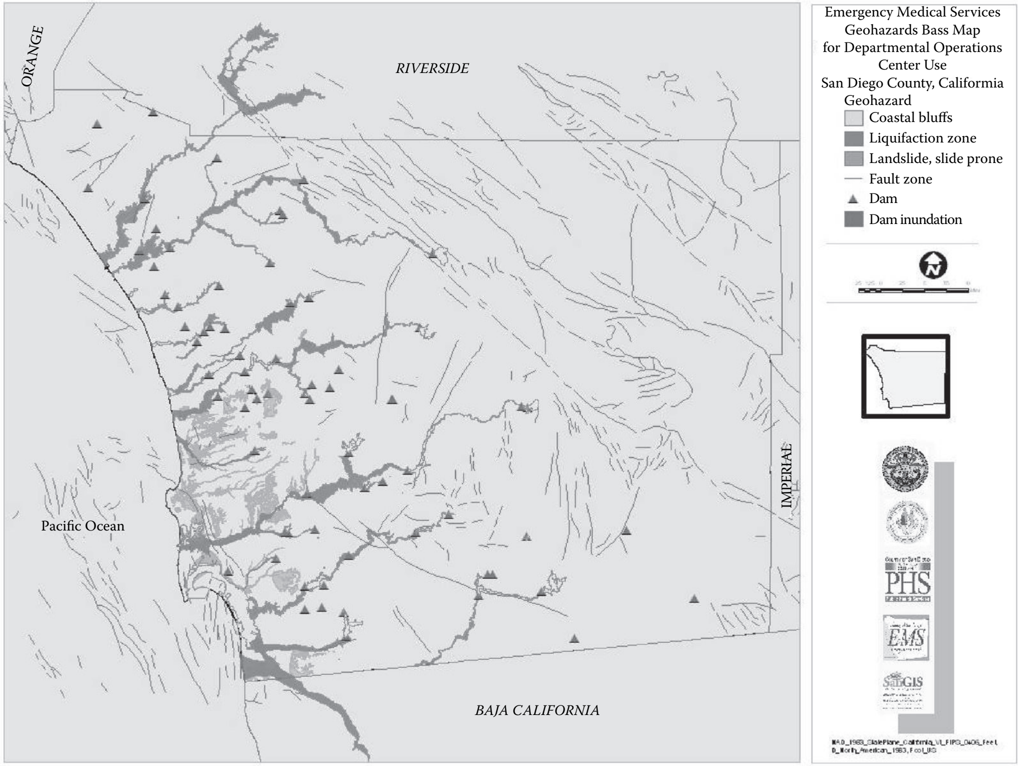

Figure 13.6 "Ready Map" of location of selected geohazards in, or near, San Diego County for use in the Emergency Medical Services Departmental Operations Center (EMS DOC).

understanding of what information is confidential and how to protect the data from unintentional disclosure. Confidentiality issues are of particular concern with geographic data.

Identify and Train Sufficient Staff

As with any new system, implementation of a DPSD requires an ongoing commitment of personnel to maintain, update, and expand the data. Personnel must also be trained in the software and use it frequently to retain their skill.

GIS software and expertise are often already available. Most county and city governments employ GIS technicians in traffic engineering, land use, or planning departments in order to produce maps and conduct spatial analyses. Local universities that have geography departments can be a source of both technical expertise from faculty and a pool of students who need GIS-related projects, such as developing base maps and researching data sources. Many schools of public health also have GIS courses and/or faculty with GIS expertise.

A disaster, such as a firestorm, requires a minimum of two trained staff each working a 12-hour shift. A disaster continuing more than five or six days may require additional staff to replace and refresh the original responding staff. Train extra staff under the assumption that in a local disaster, some staff will be personally impacted and unable to report for work.

Prepackage and Preplan Data and Information Needs

Once the data system is in place and staff has been trained, develop data and maps that reflect the information that will be needed immediately in a disaster. Talk with disaster coordinators and participate in disaster drills to develop an understanding of what is needed. Develop a series of base maps or Ready Maps as well as some basic information tables.

Data prepared for non-GIS staff should be in Excel® or spreadsheet format, which is familiar to a wider audience than other formats. Sharing data is critical during a disaster, so discuss and reach agreement on formats for sharing information before the disaster hits.

Create Procedures to Update and Check Critical Information

Complete, accurate, and timely data are essential to the development of a spatial database. For example, a state-generated list of licensed hospitals may include the address of the administrative complex for a hospital system, but not the location of the emergency room or inpatient facility. If not reviewed and updated regularly, the DPSD will become outdated, and much of the GIS system rapidly will become obsolete.

Develop a data maintenance procedure for every database that identifies the owner of the data, how often they update the database, and any restrictions or limitations. This information forms a basic update schedule that keeps the GIS system current.

Evaluate Every GIS Request as an Opportunity for Future Disaster Planning

GIS is used for a variety of nondisaster planning needs by EMS staff and other agencies who request assistance with health, medical, or public health mapping projects. Most of these requests involve the creation of new shapefiles, which can be used to enhance mapping capability during emergencies.

For example, a request for a map of school locations can also be used to establish the sites for emergency shelters, which are often set up in schools. Demographic data concerned with immigrant (non-English-speaking) populations, or populations without private transportation for health outreach programs, are also valuable for identifying groups who will need assistance during an evacuation or public health emergency. This information can also be added to the database of spatial information used in emergency planning.

Conclusions

Due to the nature of the weather patterns and geography of Southern California, it is inevitable that another large-scale disaster will occur. In preparation for future events, EMS staff is using the lessons learned from the most recent firestorm to further improve and coordinate efforts to evacuate and care for medically fragile persons and other vulnerable populations. GIS layers are added continuously as new information or facilities are found. New ideas are constantly emerging and new methods of locating vulnerable populations and medically fragile individuals are constantly being tested. Finally, though the system is far from perfect, a well-known, comprehensive plan to identify vulnerable populations prompts people to think about disaster and locating vulnerable populations, who are normally not involved in disaster planning.

Acknowledgments

The authors gratefully acknowledge the tremendous contributions of the San Diego Geographic Information Source (SANGIS), and from the County of San Diego: Julie Cooke, Public Health Services, Community Health Statistics; Ross Paul Martin, GIS Manager; Adrienne Perry, Health and Human Services Agency, Strategic Planning and Operational Support Division; the Office of Emergency Services; and the Emergency GIS group.

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Chapter 14

Natural Disasters and the Role of GIS in Assessing Need

Omar Ha-Redeye, JD

Contents

Introduction

Disasters are characterized by decision making under high stress. Information can be scarce or overwhelming and confusing with conflicting data. Geographic Information Systems (GIS) provide assistance by facilitating information transfer, assisting decision making, and depicting information that can be easily evaluated and understood. GIS has the potential to bring order out of the chaos emerging from a disaster.

The use of GIS in natural disasters differs from other medical applications because of the possibility of complete damage to healthcare infrastructure. Medical responses in disasters range from acute medical care to long-term mental health and trauma services. GIS proves useful beyond the response phase of a natural disaster, and should be considered for all stages of the emergency management cycle. Risks and hazards can be plotted on maps before a disaster occurs to mitigate pending damage. When developing preparedness and training exercises, GIS can be used to coordinate all elements of an organization. GIS can even be used during the recovery phase, not only to plan for restoration of infrastructure and medical services, but also to provide a detailed account of the disaster and its aftermath. Sharing research establishes benchmarks, and can then help mitigate future risks. This chapter addresses all stages of the emergency management cycle, illustrating the use of GIS in natural disasters for each stage.

What Is "the" Problem in Disaster Management?

Mitigation is increasingly becoming the central focus in disaster management. Advance allocation of resources can help avert damage and casualties. GIS is a cost-effective way to graphically organize vast amounts of data, which are then stored using minimal physical space and duplicated on multiple servers for redundancy and rapid distribution when necessary.

Earth observation data created through satellite image analysis is the most common mitigation GIS method. Maps are integrated with information and communication technology to improve early warning methods.

New commercial solutions will aid in addressing the challenge of harmonization and transfer of information across different systems and software. Louhisou et al. (2007) summarize this saying: "The problem in the disaster management is not lack of technology or existence of the relevant information, but often the lack of accessibility of the information."

Real-Time Decision Support Is Really Happening

Real-time decision-making support may become standard procedure in the near future. Louhisou et al. (2007) combined satellite data from ESA (European

Space Agency) mission ENVISAT with data from environment monitoring Earth observation (Envimon) software. This method could be applied to a variety of environmental hazards and automated to create real-time operation. To further enhance interoperability, the system functioned as an open and flexible platform upon which other application systems could be built, to establish an infrastructure connecting satellite information to end users, including responders and victims.

Some technical limitations do still exist for implementing real-time decision support. Zergera and Smith (2003) examined the use of a simple local-scale hazard map as part of an interactive decision support system for cyclone risks in a rural community and found that the scale of spatial data and its appropriateness for decision making on a regional scale fell short. Computer processing can be inefficient by slowing down questions queried to a GIS system, and each disaster risk has its own unique parameters. Emergency managers are also more interested in temporal resolution than spatial resolution: the movement of people, resources, and risks rather than the exact location within a fraction of a meter. The "when" is more important than the "where."

The key to real-time monitoring appears to be frequent data acquisition and rapid delivery (Louhisou et al., 2007). If GIS access is too slow, disaster managers will prefer printed maps. Print also has the added advantage of resilience against power failures. High detail is often more suitable for planning and preparedness than the actual response, when many managers are accustomed to discussions and meetings around print maps spread on a table. Encouraging transition to software response programs can be met with stiff opposition, and a lack of coordination between agencies using GIS and those using traditional print maps. Training in GIS to overcome these barriers also is an important step in mitigation.

Despite resistance, technical barriers to real-time decision support appear to be on the verge of being resolved, and GIS is experiencing greater acceptance. Krike (2005) suggests that real-time simulations might be available for tsunami modeling even before waves reach affected coastlines, pointing to detailed computer animations of wave generation, displacement, and run-up produced after the 2004 Southeast Asian tsunami. Anderson (2009) used the tsunami in Sri Lanka to develop modeling on the western coast of Canada. However, the wide level of variability of coastal features makes accurate prediction of disaster impacts and localization difficult, and extensive and expensive mapping of the ocean floor is needed. Managers should at least plan for worst-case scenarios, even if produced in real-time.

Disasters Cost Lives and Money

Although GIS is becoming more accepted, the cost involved in risk assessment can make it less attractive for developing countries. However, Dewan et al. (2006)

consider remote sensing information ideal for the developing nations because of greater effectiveness over ground observation. Hong et al. (2007) developed a proposed global prediction system displaying both “when” and “where” for landslides created by heavy rain, a development possible only due to advances in satellite remote sensing technology and high-resolution geospatial products.

High-resolution inventories can develop susceptibility maps for mitigation of debris flow risks after hurricanes by combining preexisting data sets collected for other purposes (Guinau et al., 2005), which helps minimize data acquisition costs. Validation often occurs by nonspecialists through training exercise and test zones, further reducing costs.

Accurate risk assessment can also bring considerable economic, social, and ecological benefits (Kang et al., 2005; Mu-yi et al., 2005). Developing countries can save considerable money in the long term with minimal GIS, and, therefore, should be considered a prudent investment.

GIS information can even be linked with specific sensitive species in a flood plain to estimate exposure to pollutants (Kooistra et al., 2001). Linking disaster mitigation with ecological conservation efforts can make an effective case for resource allocation. Climate change is also high on the public agenda in many developed nations. Coastal flood risk analysis can be used in response to concerns of sea level rising, inundation risks, and soil erosion (Demirkesin et al., 2007; Dewan et al., 2006; El-Nahry and Saleh, 2005). Each flood-related risk has corresponding health issues, making their identification and mitigation beneficial to health responders.

Even preservation of ecotourism has been cited as an effective strategy for resource allocation where mitigation efforts have been insufficient (Roman-Cuesta and Martinez-Vilalta, 2006). Since socio-economic factors can play a central role in long-term recovery, a holistic disaster management approach can effectively incorporate GIS into both physical and mental rehabilitation efforts.

Getting on the GIS Training

Connecting disaster simulations to live monitoring systems or field information can help disaster managers make decisions in real-time (Takeuchi et al., 2003), particularly when it comes to estimating damage to infrastructure and buildings. The Katrina response used small aircraft with high-resolution cameras to obtain over 8,000 images of flooded areas. Over 5 million photos were downloaded in the first week of response alone (Nourbaksh et al., 2006). However, modeling behavior and effect on human populations is more challenging due to lack of predictability of human responses.

One approach by Uno and Kashima (2008) utilized a numerical evacuation analysis to estimate damage to human beings during a flood, and identified individual circumstances, age, and gender as crucial criteria. The model assumed people were initially indoors and then moved along the centerline of the road. This model predicted the best route of evacuation, congestion points, and bottlenecks, and areas where the largest number of victims would be located (Takeuchi et al., 2003).

Self-evacuation continues to be one of the most fundamental principles for emergency preparedness, but existing building codes still rely on travel distance and exit width that appear too restrictive to account for emergency evacuation scenarios. Evacuation plans can better predict walking speed flow patterns and crowd density in enclosure dimensions when spatial layout of buildings is plotted as a network of nodes representing the geometry and shape of buildings. This method allows for accurate evacuation prediction for even complicated tall and large structures (Yuan et al., 2009).

Models are not perfectly accurate and cannot account for variables like safe zone misinformation, so print maps with directions to the nearest health facility should ideally be produced in advance to help with crowd control (Auf der Heide, 2006). Graphic models can be three-dimensional, and the building weighting approach doesn't necessarily take into account internal architectural people flows, including multiple levels and emergency exits (Takeuchi et al., 2003).

Increased computer power will allow for even greater detail management in the future, even in-field augmented reality using head-mounted displays. However, this is currently limited by communication infrastructure and time needed for environmental models. Computer generated images can depict findings using a virtual image technique, helping responders understand a three-dimensional depiction of what a response would look like before a disaster even occurs. Images linked with panoramic video frames to communicate complex information can create realistic landscape visualization. Video technology cannot currently remove or change objects placed on the terrain, rendering it more useful for offline preparedness training exercises and public communication than a response communication tool (Ghadirian and Bishop, 2008).

Conducting multiple simulations with training exercises allows algorithms to be continually refined and updated to enhance operability. Simulations should consider long-term rehabilitation issues of larger logistics, relief delivery, shelter management, debris and garbage disposal, urgent repair of infrastructure, postdisaster reconstruction, and restoration of normal medical services (Takeuchi et al., 2003). Still, there are limits to the amount of optimal information in any simulation.

Turkey intended to minimize future loss from earthquakes through adequate preparation by developing a GIS loss-estimation system. The most important step was identifying and processing appropriate data, which comprised of 70% of the project's budget. Optimal data was defined as the bare minimum information needed for the system that did not create excess complexity on the screen (Bilgi et al., 2008). Some systems do allow toggled information sets, so that users can simplify or enhance the display as necessary.

Remember Your Users Are the Public

Bacon et al. (2008) suggest that proper responses require a common operational picture (COP) consisting of the roles, responsibilities, and capacities of other participants, and a common basis for action. With adequate preparation, asset allocation, and personnel training, the COP can help rapidly deploy responders. However, the largest user of GIS information during a natural disaster is the public, especially those in affected areas. The public may be initially alerted through traditional siren systems or messages on television or radio, but also can receive GIS information through mobile phones, car navigation systems, fax machines, and Web-based information systems.

Public users can be divided into three groups, each requiring different types of information. High-priority information for those in the immediate vicinity of the disaster can include the initial disaster information, nature of the alert, evacuation orders, nearest evacuation area, and appropriate routes to those areas. This communication should not be disrupted by service use of other members of the public. The second group is preregistered users who have indicated a preference for receiving this type of information, usually members of the media or institutional representatives. This group also includes disaster analysts who utilize external data and information provided to them to help identify high-risk areas or produce high-risk maps. They may request specific data and information from disaster managers, and a restricted site can be created to help provide dedicated and uninterrupted information. The final group includes members of the general public who may have relatives or friends in the area. A public Web site on a reliable server depicting GIS and other related information is usually sufficient to meet their needs (Louhisou et al., 2007).

How Natural Is Any Disaster?

At the center of any disaster are people. Responders to a natural disaster should be aware of more than just the physical characteristics of an area, such as the social and economic features like poverty levels and rural populations. Disaster managers should keep in mind that some inner-city populations may be computer illiterate or non-English-speaking. They may require a special approach to response efforts if they are unable to obtain vital information or use GIS maps for evacuation (Zarcadoolas et al., 2007). Cultural and language barriers can also present unique communication challenges (Cutter et al., 2003).

Effective risk management and vulnerability assessment is accomplished by shifting from planning *for* and communicating *to* communities, to planning and communicating *with* communities. Poverty is one of the factors indicating greatest vulnerability in a population because it is characterized by unsustainable dependencies on natural resources for basic sustenance. These communities will invariably lack adequate information (Aldunce and León, 2007). This was most acutely obvious with Hurricane Katrina in 2005. The economically disadvantaged and ethnic or racial minorities were affected disproportionately. Katrina also largely shaped the general public's perspectives of shortcomings in emergency medical response.

One starting assumption in vulnerability research is that vulnerability is a social condition resulting from social inequalities that govern the ability of people to respond (Cutter et al., 2003). The social and economic costs of a disaster unevenly fall on these vulnerable groups, and affect their ability to cope with a disaster, including the ability to evacuate (Curtis et al., 2007).

Curtis et al. (2007) used a site approach—looking at proximity of a neighborhood to a hazard with the social context of a neighborhood to determine its situation—to help predict where counseling resources should be allocated to address posttraumatic stress after Katrina. Areas of urban sprawl create vulnerabilities from dependency on vehicles and a more fragmented community support. However, it is the high-density areas that typically incur greater casualties, and have higher numbers of minorities and low-income homes (Hall and Ashley, 2008). Social vulnerability factors identified in Katrina included: type of household, age, minorities, income levels, home construction and ownership, political voice, financial constraints, and choices made by individuals.

Showalter and Myers (1994) debate the logic behind separating natural from technological hazards. Chakraborty et al. (2005) take it further, stating that vulnerability is a human-induced situation resulting from public policy and resource distribution, and is itself the root cause of disaster impacts. Proper mitigation of these risks therefore includes bridging natural and technological boundaries through social and economic development to develop greater resiliency within communities (Showalter and Myers, 1994).

Social: The Real Final Frontier

Vulnerable populations can face elevated stress levels even before disasters occur, predisposing them to posttraumatic stress. Despite higher risks, indigent or minority populations are also less likely to seek help for disaster-related depression, and have higher incidents of chronic or untreated medical problems that can complicate their medical presentation (Bergrren and Curriel, 2006).

Pre-Katrina social stress mapping was combined with disaster impact and damage mapping to predict stress loads in neighborhoods. Different variables will prove more important than others depending on the nature of the disaster, and methodological problems become even worse when combining vulnerability with spatial risk. Some approaches used include combining the socioeconomic characteristics, use of absolute or relative numbers, or weighing through quantitative indices (Curtis et al., 2007). Although specific hazard risk-validated processes have not yet been developed, vulnerability mapping has been proven effective for resource allocation during response, particularly in determining need for evacuation assistance (Chakroborty et al., 2005; Guidry and Margolis, 2005). This is crucial because human and economic losses are incurred from the delay and inadequacy of response and rehabilitation (Casciati et al., 1997).

Nongovernmental organizations (NGOs) and community-based agencies are championing the transition from traditional, top-down disaster response models characterized by compliance, standardization, and protocols, to a more comprehensive approach. Traditional response agencies use a "survival of the fittest" approach, providing mass care ("one size fits all"), have short-term resource commitments, and focus on response and disaster-caused needs alone. Community-based operations during Katrina used a "we are only as strong as our weakest link" approach, providing specialized custom care, long-term resource commitments, and focused on ongoing community needs (Jones, 2006). Curtis et al. (2007) conclude:

> … all people are not equal in the United States [or elsewhere], and … there is both geography and a social character to vulnerability. … it is easy to see how spatially and socially complex vulnerability is. It is not enough to map poverty, we have to understand the social dimensions within our maps.

Positive outcomes are best achieved though good governance, by equipping people to establish their own priorities while taking into consideration cultural and socioeconomic circumstances. Increased participation of marginalized victims creates higher feelings of responsibility through empowerment and capacity building. A sense of control enhances the self-perception of a community, thereby increasing the effectiveness of collective problem-solving. Feelings of isolation during a disaster are often the main reason for reluctance in utilizing services or complying with directions (Aldunce and León, 2007). Participation at the local decision-making level, therefore, is essential, and all stakeholder groups should be engaged before a disaster (Ha-Redeye, 2009).

Despite considerable literature about this approach, there continues to be resistance toward a more client-centered approach to disaster management. Some still continue to blame minorities for the inability of standardized plans to meet their individual needs (Powers et al., 2009). Poor representation of vulnerable groups in disaster management could explain this resistance in part (Cutter et al., 2003). Emergency management is a sector particularly resistant to institutional change, but it is happening slowly (Ha-Redeye, 2007). Without greater emphasis on the needs of victims during a disaster, there will be little interest in mapping and identifying vulnerabilities, and GIS applications for these purposes will be unable to achieve their full potential.

They're Not Lessons Unless They're Actually Learned

GIS can give meaning to disasters by helping to understand what actually occurred. Retroactive analysis, or "groundtruthing," is a crucial part of developing benchmarks (Krike, 2005). Engineers visually interpret aerial images and compare them to images to ensure accuracy of findings (Schwarz et al., 2002). When scientists learn about disasters, disaster managers can evaluate which response techniques worked better than others. Existing tactics can be challenged on their efficacy and revised.

Lessons are ideally incorporated into mitigation strategies, but one of the most common complaints in disaster management is that the same mistakes are repeated. Recall bias poses a special challenge because most postdisaster reports are conducted following a significant lag after operations, and recordkeeping is often abandoned in favor of critical patient care (Auf der Heide, 2006). GIS information, therefore, can be an important part of the storytelling process to help demonstrate what actually happened and the lessons learned.

The importance of online data managers grew in importance in the aftermath of both Katrina and the Pakistan earthquake (Nourbaksh et al., 2006). When information is shared, it allows for identification of salvageable areas that can be targeted for aid. However, Curtis et al. (2006) turned body recovery images of New Orleans into a GIS map layer and could identify the exact house where some bodies were found, demonstrating the privacy issues that can arise. In contrast, geolocating in Pakistan was often off by 100 miles, which could be corrected by authenticated users on online public maps. But copy transparency is not always as high a priority in developing nations where some GIS information is too sensitive for public distribution. Initial maps in Pakistan were withdrawn over security concerns in Kashmir, released by the United Nations only after peace talks were conducted (Nourbaksh et al., 2006). Governments can be especially resistant to sharing in the context of co-existing civil conflicts or secret military installations.

GIS is considered particularly suitable for research when integrating multiple data sources plotting several variables. Graphic representation of complex map data makes findings easier to understand, especially if using buffering and overlay techniques to summarize vulnerabilities and risks (Chakroborty et al., 2005). Auf der Heide (2006) states, "Disaster planning is only as good as the assumptions on which it is based." A bird's-eye view provides a bigger picture for situations that may initially appear localized. However, before any analysis of recovery after disasters can occur, researchers need to know where to look to find the information.

Showalter (2001) looked at 26 years of disaster management literature and found nearly half of all remote sensing hazard and disaster research appeared in journal articles. Another 30% were in conference materials and proceedings. Reports, books, and other sources comprised the rest of the literature. As access to imagery and processing software increases, so does the percentage of journal articles. However, most research can be found in specialized remote sensing publications that can be difficult for disaster managers to access and review.

Most GIS literature focuses on floods, the most prevalent natural hazards in the world. There are also some practical reasons for an abundance of flood literature. The typically larger areas affected produce better spatial resolution, and images are more easily obtained than with other hazards. GIS research is different with natural disasters because of the greater emphasis on the applied nature of saving lives, rather than strictly theoretical applications. The perfect time for GIS-based research, therefore, is the recovery stage, but this is limited in its ability to foreshadow creative or innovative developments, or discuss unforeseen and uncommon hazards.

The best way to advance remote sensing research, according to Showalter (2001), is the incorporation of research into disaster management strategies and into the emergency services framework of mitigation, preparedness, response, and recovery. The following case studies demonstrate how the emergency cycle can be used to highlight best principles.

Case Study: Vancouver Island Health Authority

The Vancouver Island Health Authority (VIHA) (http://www.viha.ca/) provides healthcare to over 752,000 residents of Vancouver Island in British Columbia on the west coast of Canada. VIHA has a network of health facilities with about 17,000 employees and an annual budget of approximately $1.6 billion per year. In 2005, VIHA began developing a Web-based GIS application for emergency planners called VIHA's Emergency Management GIS (VEMGIS).

Researchers in Canada have attempted to learn from the events of the December 26, 2004, tsunami in Southeast Asia. Geographic similarities between the two areas meant that many of the previous predictions of tsunami effects had to be revised. Although the extreme run-ups found off Sumatra Island in the Pacific are unique, researchers expect that a British Columbia tsunami would be comparable or worse (Krike, 2005).

The current warning system in British Columbia is intended for far-field and telegenic tsunamis, not disasters originating off the coast (Figure 14.1). Terrain can be rugged and mountainous, and there are remote communities without broadcast radio, off-air television, or cellular coverage. Coast guard VHF (very high frequency), amateur, and ECO (emergency operations center) coastal radios do cover most of the island, and warning systems for remote communities include landline (dial-down) notification system, cellular and satellite phones, facsimile, and e-mail. Other community warning methods, such as sirens, speakers, horns, and signs, are used, but no single method will be able to reach all communities, and multiple methods need to be integrated. MSAT-G2 satellite dispatch radio initiatives provide more uniform coverage, and cellular coverage is also being expanded. Improvements to the warning system will require all stakeholders, including public

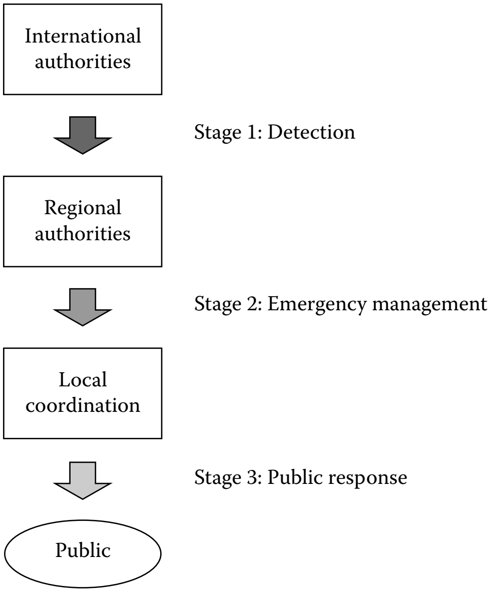

Figure 14.1 Tsunami warnings in British Columbia were designed for disasters originating on the other side of the Pacific Ocean. (From Anderson, P. 2009. *19th World Conference on Disaster Management,* Toronto, Canada. With permission.)

providers and private distributors, to develop standards and tools mutually beneficial to all (Anderson, 2009).

VEMGIS was developed as a pilot project for emergency management, sharing information only with preregistered users. Local governments are required by law to establish emergency programs under the Emergency Program Act, [RSBC 1996] CHAPTER 111, sec. 6(3). Legislation also mandates sharing information with regional governments, fire departments, and public emergency programs. Other preregistered users include agencies providing disaster management services, the Ministry of Transportation, the Victoria Airport Authority, a local radio station, and educational institutions in the area.

VEMGIS provides a centralized access to community-specific information on the Internet for emergency planning, providing a dedicated data set including standardized data and key contact information. Members of the Regional Emergency Coordinators Committee provided information for their respective organizations that was imported into a GIS, allowing a location-based application for disaster coordination across agencies (Figure 14.2).

VEMGIS focuses on providing community characteristics and resources and facilitating communication. The system includes topographic information such as aerial photos, infrastructure and transportation, and natural terrain as

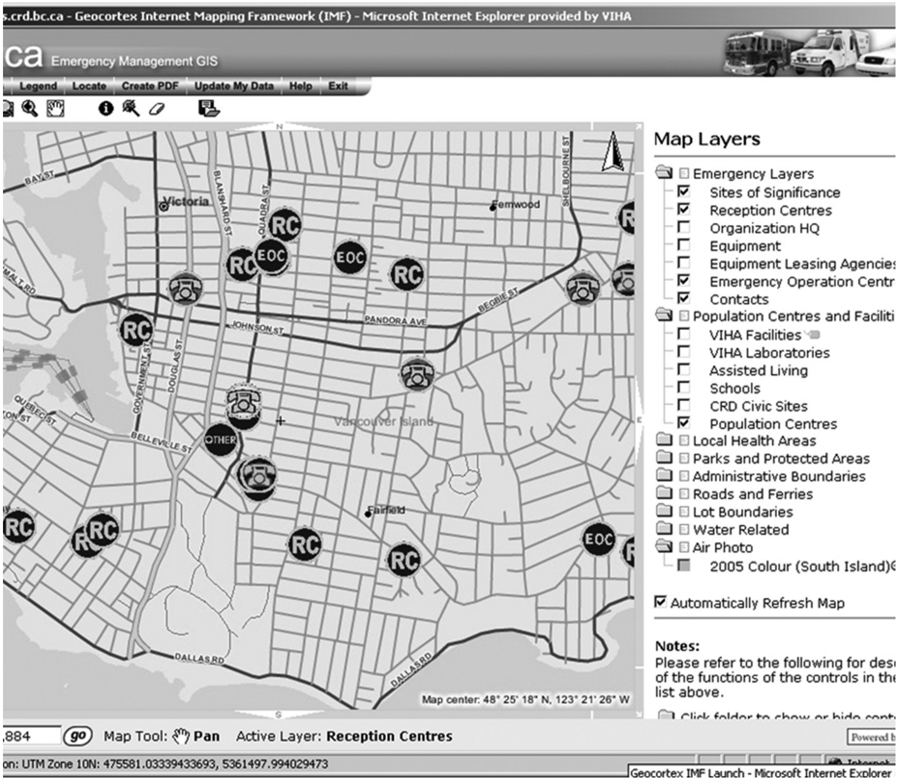

Figure 14.2 The VEMGIS display allows for multiple layers of information to be toggled off and on, which makes it easier for users to read.

well as key centers. Vulnerable areas and populations identified include: tourism facilities, correctional facilities, low-income housing and transition houses, home dialysis clients and other medically dependent populations, persons on disability assistance, and children. Specific disaster hazards also will be included to enhance planning activity. Contact information for each agency and organization involved is listed as well as a description about them, their operational capacity, and potential resources.

Key stakeholders piloted the program in the southern part Vancouver Island to identify shortcomings in the system before being extended to the other parts of the island. More information still needs to be added, including the home locations of people receiving home support services who may require specialized health services and additional assistance with evacuation as well as further vulnerable populations, hazardous materials, and disposal sites.

If governmental funding recognizes the utility of this system, VEMGIS may be expanded throughout the province. As with many projects, acquiring funding before a major disaster actually hits can be challenging.

Case Study: 2009 Manitoba Flood

The City of Winnipeg, Manitoba, Canada, is located on the Red River, a strategic waterway located in a flat and low-lying flood plain. The city is susceptible to multiple floods, causing considerable damage over the years. The government constructed the Red River Floodway in 1969, an artificial waterway used to divert melted snow and ice away from the city. Other mitigation strategies included dyke construction, a diversion channel emptying into Lake Winnipeg, and an artificial dam and reservoir (Simonovic, 1993).

Additional rain and snow storms in the spring of 2009 created critical conditions in Winnipeg. Potentially damaging ice in the river initially prevented the Red River Floodway from being opened. Water crests rose to 22.6 feet, considered one of the worst on record.

The Office of Disaster Management (ODM) was responsible for ensuring that health services and emergency operations continued uninterrupted during the flood, and needed a tool to analyze the situation, predict future outcomes, and make critical decisions. Limited resources and time for training and tool development necessitated something simple. Most importantly, the tool would have to guide users through the four stages of the emergency management cycle.

Mitigation and preparedness priorities involved reviewing similar historic floods to identify recurring patterns and determine impact (Figure 14.3). Decisions needed to be communicated quickly and effectively to managers and key stakeholders. If ice jams blocked the Red River Floodway or it failed to divert enough water from the river, ODM would have to prioritize evacuation. Response issues included impact of environmental factors, such as heavy rainfall and peaking, road closures, and evacuation routes for specific areas (Figure 14.4). Recovery phase analysis focused on obtaining RadarSAT data from Earth observation satellites to identify flood locations and establish how it differed from previous floods.

ODM worked with ESRI Canada to create a COP that would serve as an effective visualization tool, allowing real-time situational awareness through ESRI's ArcGIS online services. Base maps were combined with imagery and real-time data to create an accurate depiction of the natural disaster as it occurred. Information was obtained from a variety of different sources, including satellite imagery, cartographic data from Natural Resources Canada, geospatial data from the Manitoba Land Initiative (MLI), road closures from the Medical Transportation Coordination Centre (MTCC), and regular weather

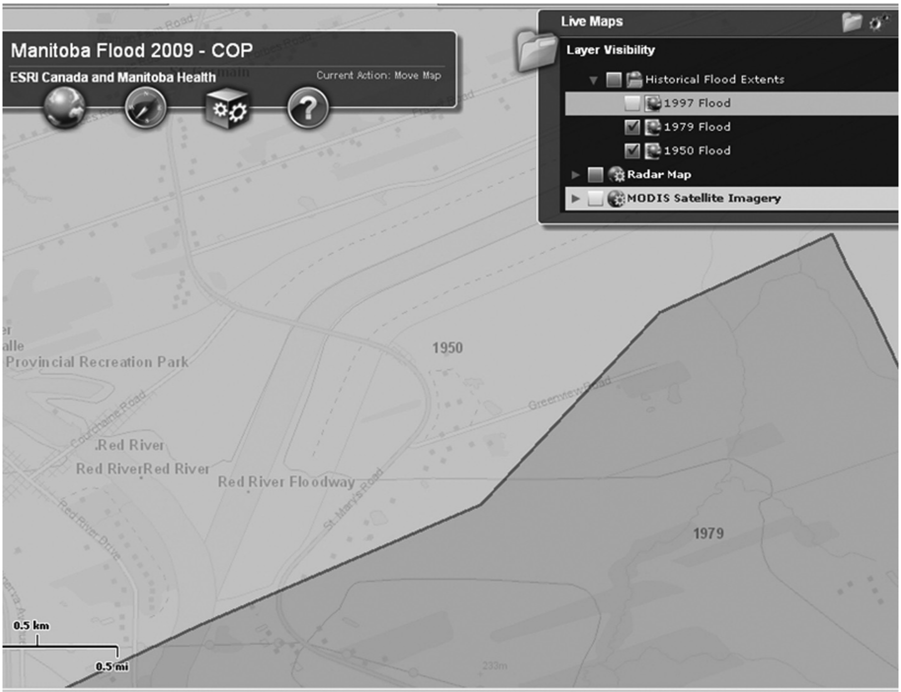

Figure 14.3 Historic flood information was used by the system to demonstrate the significant impact that the Red River Floodway has had on flooding in the area.

conditions and forecasts from Environmental Canada and weather stations across the province.

Real-time weather data and topographic information could predict future outcomes and launch evacuation plans. Information layers presented a multitude of factors, such as personal care homes, Emergency Medical Services (EMS) facilities, helicopter landing zones, hospitals, ring dykes, ice jams, broken bridges, and ambulances (Figure 14.5). The percentage of senior citizens in specific areas could help flag special evacuation needs. Each variable was depicted with simple and representative symbols to make maps more effective and easier to use.

Gerry Delorme, ODM director, emphasized the importance of creating a system that was simple to use:

> Our group had limited knowledge of GIS and there was no time to secure additional resources. However, the Common Operating Picture was so intuitive and easy to use that it allowed us to align all of our goals into a single platform and be fully operational quicker than I ever imagined possible.

Figure 14.4 The common operational picture (COP) showed road closures to help identify the best evacuation routes.

The COP was not only used for decision making and problem solving, but also during governmental meetings to justify further funding for emergency planning. Graphic depiction of complicated information reduced operational response times, allowing for a greater focus on rehabilitation efforts. Delorme indicated that the COP was the "first thing we looked at every morning … to form quick and confident predictions about where things were headed."

ODM plans to extend the operability of the COP further to monitor ambulances and bed counts and integrate a new public alert communications system. Flood risks are something that Manitoba will have to manage for a long time, especially with climate change. With the right GIS tools in place, they may be even better prepared the next time that a flood occurs. To read the full case study, visit the ESRI Canada Web site (www.esricanada.com).

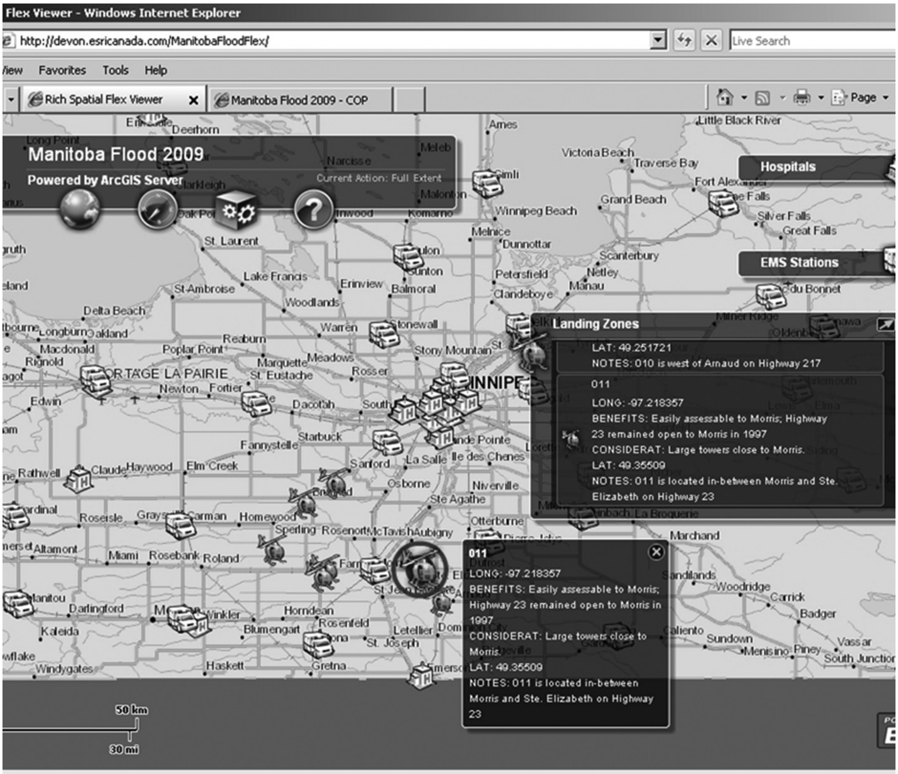

Figure 14.5 Landing zones, hospitals, and EMS areas are displayed on the map to plan for evacuations if necessary.

Acknowledgments

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Chapter 15

GIS Application and a Regionalized Approach for Mass Casualty Incident Planning

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Contents

Introduction

Present healthcare facility bed utilization is approaching near capacity. The potential of a large-scale mass casualty incident (MCI) places significant planning responsibilities on communities, healthcare facilities, and first responders. Hospitals are required to develop plans in collaboration with the community. These plans should realistically address the management of existing patient populations as well as the anticipated casualty surge from an MCI. Potential transfer of existing patients to other facilities as part of a community's ability to surge patient care requires identification of transportation assets, personnel, and transportation routes. Effective and coordinated regional emergency planning requires a thorough knowledge of the locations of critical facilities and impacted populations through all phases of the emergency. In addition, regional planning requires careful evaluation of resources that could be utilized in the planning, response, and recovery phases of any MCI.

In this chapter, we will discuss how mapping the healthcare resources available to a large western city made a difference as part of the development of a regional approach to planning for a MCI. A regional approach to planning brings together individuals from different disciplines and geographical locations. Regional planners may be unfamiliar with resources or critical infrastructures that are outside their city or county boundaries. ArcGIS™ identified resources, transportation routes, evacuation routes, locations of critical infrastructure, and other elements essential in the development of a regional plan. Geographic Information Systems (GIS) allows for the development of a common operating picture and facilitates the community planning partners' ability to identify the spatial relationship of the elements essential to the planning, response, and recovery phase of an incident.

Mass Casualty Incident Planning

The Need for GIS as Part of Mass Casualty Incident Planning

Recent events have underscored the continued need for mass casualty planning. An MCI is an incident that quickly causes injury or death to a large number of people and may arise from many causes including manmade events, transportation incidents, natural hazards, workplace accidents, and deliberate acts of terrorism. The MCI by definition may stress the community's resources and require assistance from outside their geographical boundaries or jurisdiction.

Mass casualty events can be considered to occur in two different spaces: the planning space and the physical space. The planning space is the world of disaster plans, both horizontal and vertical, that are brought to bear on the problem. Horizontal plans are those that integrate agencies at the same command level. An example of this could include the county Emergency Management Agency, county fire and police, and the local hospital. Vertical planning reflects the process of integrating agencies or jurisdictions that are subordinate, such as between a county and the state, or a hospital within its hospital system. Planning space also includes the community agencies that are designated as players in the mass casualty event plan: the levels of authority within the agencies and the systems that are implicitly or explicitly set up by the incident planning effort. Planning space also identifies the systems for communication within and between response agencies, systems for delegation of powers and assignment of roles by the plan for disaster response.

The physical space is the actual site or sites where the MCI occurs and includes the supporting physical areas, such as triage, vehicle staging, or transportation areas, that assist with the organization of the response. The three dimensions of the physical space (latitude, longitude, and elevation) comprise the spatial realm in which a GIS operates. The goal of the GIS is that an end user with a particular background and level of experience can successfully gain insights through a model of the spatial components of an MCI. The insights generally come through being able to see: (1) the manmade and natural features, e.g., facilities and transportation systems, in the model; and (2) perhaps most important, identify relationships between the features.

The Nature of Mass Casualty Incidents: Issues of Time and Space

MCIs are generally time limited and have a defined start time (when the incident began) and stop time (when the last individual is removed from the incident site). However, the process of event investigation and care of the injured may continue over hours to days. MCIs are usually geographically defined. This is easy to conceptualize when the event occurs in a discrete location, such as a highway, airport, or a building. An MCI may also occur in several sites at the same time, such as with a terrorist act (bombing) or outbreak of an infectious disease. MCIs create casualties with varying levels of injury (minor to severe). There will be variable requirements for definitive medical care that may require transfer to outside of the immediate impact area to a facility capable of delivering complex care. Local response and medical capabilities most often suffice; however, expansion to a regional, state, or national response could be required, such as with a catastrophic or large-scale event. The recent crash of two trains in the Metro system in Washington, D.C. illustrates the benefits of a regional response to an MCI. This event will be discussed further in this chapter.

Within the GIS realm, there is a physical and temporal space where an incident occurs. The physical space is the real, three-dimensional world. However, since MCIs also have a time component to them as described above, the physical space for disasters can be considered to include an extra dimension for time, i.e., the 3-D space becomes a 4-D physical–temporal space.

The first two dimensions within the 4-D space include the location of a disaster: an address, a street intersection, or a coordinate in some defined coordinate space. The third dimension could be a height above ground, an elevation above sea level, or a certain story of a building. The fourth dimension, time, is included because an MCI has a starting point in time, and it has a duration.

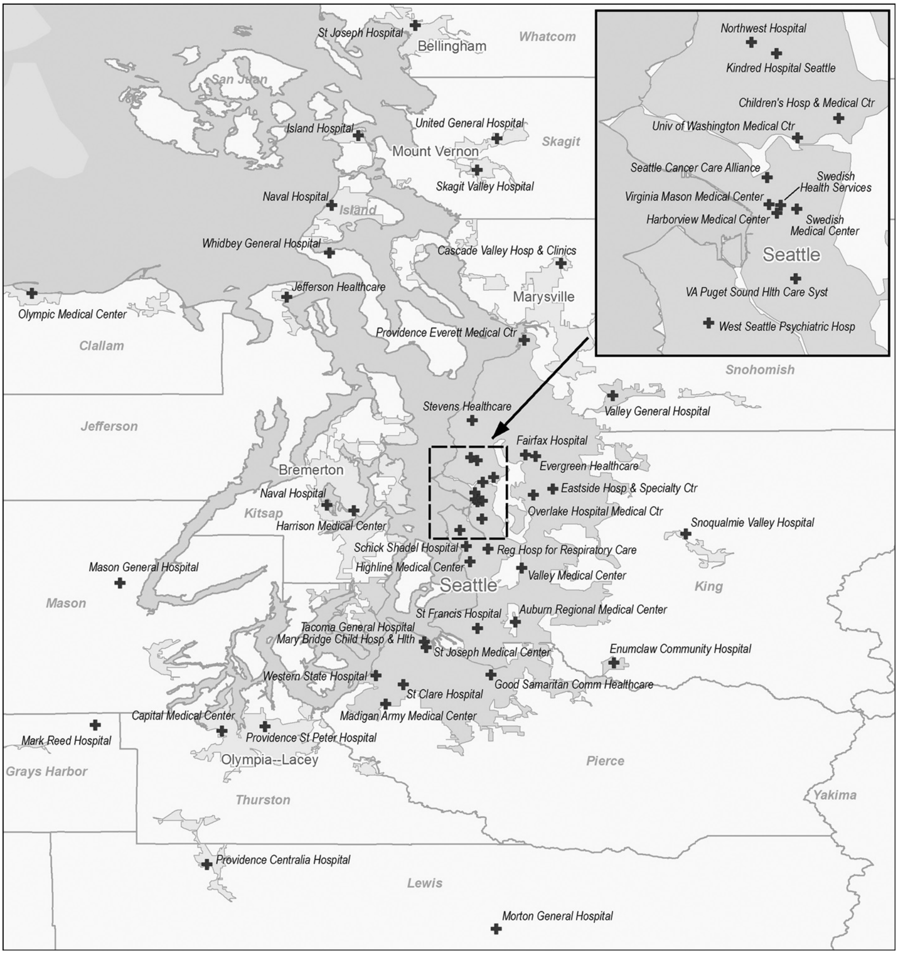

Figure 15.1 Shown is healthcare facilities in the Seattle, Washington area by county.

Incident location and geographical height can be represented simply by viewing geographic data. This is typically represented by designated graphic symbols on a paper map of the MCI area. GIS technology can produce a map, which is only a static snapshot of the problem: a particular area at a particular time, from one particular view, usually overhead looking straight down. A user can gain more insights by entering the space from which the map was printed. i.e., by exploring the model space through simple panning and zooming through the model. For example, consider the illustration in Figure 15.1 of hospital resources in the Seattle area, generated within a GIS. A user need not look at the graphic for very long to be able to see where the largest clusters of hospitals are, and what the relative distances are between them. Expanding further, still more insights can be gained by more active exploration. For example, if the geographic data has tabular data connected with it, a user can run a logical query to identify and highlight features with a certain data value or combination of values, and within a certain radius or driving distance of other features.

Mass Casualty Planning Requirements

Coordination between response agencies and definitive care centers will be essential in all phases of MCI planning and response. While the initial response will be based on local plans and resources, a large-scale event will require a coordinated regional approach. Mass casualty incident planning follows an all hazards-based approach. One approach is to frame planning in terms of the following phases:

Planning: A multilevel process that defines the scope of the problem including identification of trigger events, regional capability, identification of assets, and a plan of response.

Mitigation: Part of the planning process that attempts to reduce or limit the effects of disasters when they occur. The mitigation phase differs from the other phases because it focuses on long-term measures for reducing or eliminating risk (Haddow and Bullock, 2004).

Response: The actual work of police, firefighters, and EMS personnel at the scene of an incident. Response activities have several *subcategories* that include the following:

- **t riage/t reatment:** Medical resources in an MCI are focused on triage, which is the identification and sorting of injuries according to severity. Initial treatment of casualties may occur onsite or at a casualty collection point located nearby the incident. A complete assessment of the extent of the injuries and definitive medical treatment occurs at a healthcare facility. In many communities, hospital capability with respect to care for the injured (trauma care) is categorized as a Level I, Level II, Level III, or Level IV capability. Table 15.1 describes a way to categorize hospital capabilities for an MCI**.**
- **t ransportation**: A mass casualty response involves the movement of first responder agencies, such as police, fire, and Emergency Medical Services (EMS) *to* the site (and) moving victims and those affected by the event *out* of the incident site. A recent summer evening in June of 2009 tested the effectiveness of a Washington, D.C.'s MCI triage and transportation plans. A crash of two commuter trains that were part of the Washington, D.C. Metro system created 9 fatalities and 80 injuries (*Washington Post*, 2009). The individuals with severe injuries were taken to three Level I trauma hospitals within the Washington, D.C. area. Those with less severe injuries but who needed medical evaluation were taken to a hospital

Table 15.1 Hospital Capability for Mass Casualty Incidents

	Emergency Department	*Radiology*	*Surgical Services*	*Prevention through Rehabilitation Programs*	*Research Education Training*
Level I	Yes: Initial and definitive care regardless of injury severity	Yes: CT/MRI interventional radiology	OR available 24/7. Multispecialty (ortho/neuro/general surgery)	Capable of providing leadership and patient care from prevention through rehabilitation	EMS training Medical postgraduate training Nurse training Quality improvement and research
Level II	Yes: Initial and definitive care regardless of injury severity	Yes: CT/MRI, but services not as comprehensive	OR available for initial treatment, but may need transfer to a higher level capability	Same as above	May provide training and education as above Quality improvement program
Level III	Yes: Prompt assessment, resuscitation, and emergency stabilization; transfer to higher level center	Yes: But may not have all complex services as listed above	OR available for initial stabilization, but transfer for comprehensive care	N/A	N/A May provide medical control and education for regional EMS
Level IV	Yes: Stabilization and resuscitation; transfer to higher level center	May have limited radiology services	N/A	N/A	N/A

Source: American College of Surgeons Committee on Trauma. 2006. *Resources for Optimal Care of the Injured Patient*. Chicago, IL. With permission.

outside of the immediate impacted area for evaluation. This demonstrated a regional approach to the distribution of patients outside of the area of impact or event. The relatively smooth triage and transfer process clearly illustrated the benefit of regional MCI planning and exercise of that plan. Mass casualty-generating events, however, are not limited to transportation incidents. A more recent mass shooting event (Hauser and O'Connor, 2007) at Virginia Tech University in 2007 created 33 fatalities and 12 individuals with gunshot wounds transported to one hospital (Linkous and Carter 2009). A bridge collapse over a river in Minneapolis, Minnesota in 2007 created 13 deaths and 127 injuries (Hick et al., 2009); however, a regional approach to distribution of the injured was employed. Each of the previous examples underscore the need for appropriate MCI planning regardless of the cause of the incident.

Communications, Command, and Control: The transportation of the injured to a definitive care facility requires careful communication, coordination, and preplanning. During the Virginia Tech shootings, conflicting information from the scene created special challenges for hospital response activities. The regional hospital located adjacent to the campus had to rapidly determine if adequate supplies, staffing, and bed capacity would be sufficient to care for the yet unknown number of injuries. Were the roads leading to the hospital closed? Could staff safely drive to the hospital? Would ambulances be able to follow established transport routes or be diverted to staging areas for casualty collection? If additional support or supplies were needed, what surface roads were open? Could air transportation be utilized? What was the plan for transferring the higher acuity patients to a regional trauma center? Ongoing analysis using GIS could have identified safe transport routes to the responding agencies and healthcare personnel. Also, depending on how often data is updated, a GIS could have assisted decision makers in responding to medical supply levels, bed capacities, and other variables that change through time.

A casualty-causing event, such as the bridge collapse in Minneapolis, also impacted patient transportation and access to hospitals. Access to healthcare facilities was limited with only one remaining bridge left to span the river. Heavy rescue and response vehicles clogged the roads making transport of victims and responders difficult. During the 1999 tornado in Salt Lake City, Utah, downed trees, housing debris, and power lines were common not only at touchdown sites, but near the only two Level I trauma hospitals in the area. These barriers created unique challenges for first responder agencies and hospital personnel reporting for duty and for the transportation of the injured to area hospitals. Coordination of care and transport of severely injured individuals to healthcare facilities inside and outside the affected area is an important part of MCI response.

Hospitals are required as part of their accreditation process to establish an emergency operations plan in collaboration with their community partners (Kim et al., 2002) for care for a sudden influx of casualties related to an MCI (Scheulen et al., 2008). The Joint Commission, one of three hospital accrediting organizations, requires that hospitals conduct a hazard vulnerability analysis (HVA) to identify potential emergencies that could affect demand for the hospital's services or its ability to provide those services. Hospitals also must evaluate the likelihood of those events occurring, preferably in collaboration with community planning partners (Joint Commission, 2009). Not every healthcare facility will have the same characteristics or vulnerabilities, which makes an overlapping, regional MCI approach more attractive. Recent federally supported programs from the U.S. Department of Health and Human Services (HRSA [Health Resources and Services Administration] and ASPR [Assistant Secretary for Preparedness and Response] grants) have aided communities and healthcare facilities in reviewing and updating their plans to include developing a regional approach that includes surge capacity and alternate care sites. Additionally, plans that address local and regional management of critical resources, such as power, fuel, water, medical supplies, and pharmaceuticals, have also been recommended for meeting both local and regional requirements.

Critical Infrastructure Analysis

Analysis of critical infrastructure analysis including identification of key elements for an MCI response is a valuable part of any GIS undertaking. Critical infrastructure can be defined as facilities, utility networks, and information. The loss or damage of any of these elements could impair emergency services. There is a large amount of geographic data that has already been collected, which is designed to model the critical infrastructure as it exists in the real world. The geographic data can be incorporated into the development of a regional MCI plan. A large part of this data is called "point" or "0-D" data. Each feature in such a dataset designates one location, identified by a feature at a certain coordinate, along with any attribute data that is attached to it. Critical facility data is usually classified by theme, e.g., emergency services (EMS, police stations, fire stations), or hazardous materials. Aside from the categories described below, there are other classes of features that may come into importance depending on the nature of the MCI. For example, if the MCI leads to mass fatalities, locations of existing morgues need to be known, and this may include facilities that could be used temporarily as disaster mortuaries.

Examples of location data include:

- Emergency Response and Dispatch: This dataset includes EMS base locations, police and fire stations.

- Trauma Hospitals: This type of facility may be found under the Healthcare Resources section of a critical facilities database. This type of data includes hospitals, specialty medical centers, and smaller medical centers, such as community health clinics.
- Transportation: This dataset includes point data for highway bridges, railroad bridges, bus and rail stations, marine ports, airports, and heliports.
- Communications: This dataset includes the primary communications broadcast towers, although other types of towers, such as repeaters, are included.
- Hazardous Material Locations: For an MCI response, hazardous materials locations are important to identify prior to an incident occurring. Dangerous chemicals may be present at the location of the MCI, and if the event includes a resulting fire or chemical spill, there may be secondary releases or interactions with hazardous substances.
- Public Venues: These locations designate facilities, such as shopping malls, sports complexes, large museums, or fairgrounds, where large numbers of people are likely to be gathered when such locations are operating.

It is important to consider that not every jurisdiction compiles its own dataset of critical facilities. Large-scale providers of comprehensive critical infrastructure data for the United States are found within the Homeland Security Infrastructure Program (HSIP) and the U.S. government HAZUS disaster modeling software program.

The U.S. Department of Homeland Security's HSIP's Gold infrastructure database has included a new version each year since 2006. It includes data for approximately 30 categories of critical infrastructure data, including the categories enumerated above. Data sources include both public and private ones, such as business location data gathered from private companies. This database has limited distribution, with U.S. government sponsorship as a condition, to emergency managers in the United States.

HAZUS is an example of another U.S. Federal Emergency Management Agency-developed disaster modeling and damage estimation software program (http://www.fema.gov/plan/prevent/hazus/index.shtm). The installation media for HAZUS includes critical infrastructure data that is used in the default installation for damage estimates for the different disaster models, such as flood and earthquake. The content of HAZUS critical infrastructure data is very similar to HSIP Gold. Often more localized, entity-specific datasets are more accurate and comprehensive than HSIP Gold and HAZUS for the specific geographic area provided. Two initiatives that capitalize on this are described in brief below.

The latest initiative from the Homeland Security Infrastructure Program (HSIP) is HSIP Gold/Freedom (Neighbors, 2008). This program is designed to compile local data into one comprehensive database that can be used on a number of platforms, including popular GIS software packages and the Google Earth visualization products. HSIP Freedom was designed by the National Geospatial–Intelligence

Agency (NGA) in collaboration with the Department of Homeland Security, the Department of Defense, and the U.S. Geological Survey.

The Protected Critical Infrastructure Information (PCII) program, managed by the Department of Homeland Security (DHS), is a program that manages information that is voluntarily shared with respect to critical infrastructure, key resource (CIKR) data between the public and private sector providers, and the U.S. government (U.S. Code of Federal Regulations, Department of Homeland Security, 6, Part 29, 2006; http://www.dhs.gov/xlibrary/assets/pcii_final_rule_federal_register9-1-06-2.pdf). The PCII program is a revision of the Critical Infrastructure Information Act of 2002 (CII Act), and is an important tool in assisting the DHS's analysis of infrastructure vulnerability and related information for planning, preparedness, warnings, and other purposes. The CII Act enables DHS to collaborate effectively to protect America's critical infrastructure, 85% of which is in the private sector's hands. This program is more akin to an "open source" concept of data warehousing and improvement. As such, it could be valuable as a more open platform for addressing issues with new or existing critical infrastructure data. Private sector entities who voluntarily share specific information are afforded protection from legal discovery. In addition, reports that are generated using PCII data are constructed in such a manner as to be general in nature, without identifying the specific data contributors. Healthcare facilities have recently been included in the PCII program. This is a new data reporting option for hospitals, and one that cannot be used as part of an accreditation or licensing review process.

The construction of any dataset involving critical infrastructure includes issues of accuracy and data security. Critical infrastructure data, from either major national or local providers, may contain errors in location data as well as infrastructure attribution, such as name and address. What is true of all data of any type and from any source is: GIGO (garbage in, garbage out). It is one of the better-known acronyms in the world of GIS data maintenance and analysis. Analysis results from a GIS, at best, will only be as good as the lowest-accuracy dataset in the system.

Two of the most time- and money-intensive tasks surrounding the maintenance of a useful GIS are data ***compilation*** and data ***correction***. These are the two parts of data gathering that entail the most expense. First, what is perceived as the "best" data theme for a particular purpose must be found. Second, in order to enable results from analysis within that GIS that are as true to reality as possible, the data within the dataset must be verified or corrected for optimal accuracy.

Geographic Features That Could Pose Difficulties

The most effective role that a GIS can play in MCI planning and response is to let a user see relationships between various features that make up their community or region. Relationships will include ways in which the lay of the land, that is, the positions of natural and manmade features, will either help or hinder the response to an MCI. The features all form a body of potential barriers to response. The barriers can take the form of conceptual or legal barriers, such as national, state, or local district or jurisdictional boundaries. The second type of barrier is the physical one, taking the form of natural features or manmade features. Boundaries, and the major physical barriers, namely water, mountains, and transportation networks, are briefly discussed here.

Boundaries are designated at many different levels. The more well-known levels are city, county (or parish, if in Louisiana), state, and country. Within, and sometimes crossing, these established boundaries are boundaries, such as those for emergency medical system (EMS) response, medical service areas, and catchment areas. MCI response plans must be integrated smoothly across the entities that the boundaries represent. The most useful function of a model of boundaries within a GIS is to answer the question "Who is next door to me?" That is, what is the district, or service area perhaps, that is immediately adjacent. An agency can thereby begin to answer the question of which peers they need to most closely coordinate with for mitigation and response planning.

One function of a GIS is to be able to answer questions that go deeper than the obvious relationships that are visible on the screen. Boundaries are usually thought of as lines that divide; the area to the left of the boundary is a different district or service area than that to the right of boundary. In a GIS, boundaries are usually stored as two-dimensional data features. That is, they have an area measurement, and a perimeter formed by the complete boundary around the area. Data stored in this way can be used to answer questions of *containment*. That is, out of another class of features or combination of classes, what are the features that fall within the boundary and, by implication, fall outside the boundary? The real or concrete barriers include water, topography, or terrain characteristics, and the layout of transportation networks.

Water barriers include rivers, lakes, and manmade structures, such as canals. Any water feature usually implies the need for either a bridge or a tunnel with unobstructed access for responders to traverse by vehicle. If an ambulance finds a bridge obstructed, the response team must try to navigate to the next closest bridge. If a responder's mission is search and rescue, or recovery of deceased individuals, then boats could be used to reach a wide array of otherwise inaccessible locations. An example of this is the New Orleans search and rescue operations in the wake of Hurricane Katrina in 2005. Water barriers also present different types of transportation modalities aside from bridges.

An example of a city with freshwater, ocean, and mountain terrain all within an urban region is Seattle, Washington. Consider the illustration in Figure 15.1 of how GIS can display hospital resources. When looking at the map, it might be helpful to think about the following: Note the clustering of resources in one county. How would this affect planning or a regional response if this area experienced the mass casualty event itself? The use of GIS, even at its most basic level, will assist the planner in identifying geographical, water, and transportation challenges that must be met.

Events involving water that may contribute to the damaging effects of an MCI often happen very quickly and unpredictably. For example, a lake that is beginning to overtop its shores causes a dam to burst, producing rapid and catastrophic flooding. A landslide caused by heavy rains destroys part of a coastal highway, such as occurs in California or Oregon. A GIS that tries to model the water features generally does the best job either in the planning stage of MCI management or in the prioritization of response and recovery tasks. Planning in a GIS would include the identification of features that sit within a floodplain or spillway area. Response and recovery would include prioritization of cleanup areas based on the depth of flooding in the incident area. Unless a system is set up for the delivery of data to a GIS in real time (which may be logistically difficult), a GIS is more useful when enough time has passed after the incident that a reliable survey of the disaster area can be performed, and accurate feature status updates can be made. For example, an analyst can update a GIS with daily status reports of which road sections within a transportation network remain impassable to vehicles, such as with the 2009 fall flooding that occurred in the Atlanta, Georgia, region.

Specific types of terrain, including mountains, can pose unique challenges for responders to an MCI. In mountainous terrain, such as Seattle, Denver, or Salt Lake City, skiing parties that fall victim to backcountry avalanches are in areas that are impossible for ground vehicles, even snowmobiles, to reach. Addition rescue activities can pose great difficulties for aircraft, such as helicopters. Data from past avalanche activity also can be added by aspect or degree of slope of a particular mountain face. In attempting to rescue individuals caught in a snow slide, having this prior information would be beneficial for responding ground-based search and rescue teams or responders that may be arriving by air. The goal of the rescuers is to find and assist those buried in the snow, and not to become buried themselves by a potentially unstable snow shelf at the incident site.

Terrain is another example in which modeling in a GIS is made much easier if the real-world features can be accurately surveyed in advance or modeled with frequent status updates. MCIs created by avalanches and earthquakes require frequent and accurate status reports. In these types of disasters, new temporary terrain features and barriers are created unpredictably out of the natural and manmade environment. In an earthquake, new fault scarps may be created, and roads, railroad tracks, and waterways may become disjointed or warped. In a major avalanche, significant stretches of road may be buried under many tons of compacted snow and associated debris.

Transportation networks contain their own sets of barriers, in particular, in locations where one set of features intersects another. First responders need to know, for example, whether a railroad crossing is at-grade or grade-separated, and how often and for how long trains could be expected to obstruct passage from one side of the tracks to the other. For purposes of moving heavy equipment into an area, everyday restrictions on weight and height for passage over or under bridges still apply, with the added possibility of new restrictions imposed by the effects of the MCI.

A useful GIS will be one where such conditions and everyday limitations are modeled accurately. Transportation networks are one data component of a GIS in which the costs of data acquisition figure significantly. As is discussed shortly, transportation detail that is sufficiently detailed for emergency response is costly. Either an agency must spend time and money surveying conditions in their jurisdictions themselves, or it must purchase presurveyed transportation data with accurate road attributes. A potential cost-saving advantage of developing a regional MCI approach is that a single agency would not have to bear the expense of obtaining transportation data, but instead share the expense with other jurisdictions.

Aside from its perhaps more familiar use in identification of transportation routes, GIS can also identify critical resources. Strategic allocation of resources during an MCI will be essential as part of a coordinated, regional response. Mass casualty incidents require multiple resources including people (staff), healthcare facilities, medical supplies, and pharmaceuticals. Identification of resources not only by location but perhaps by jurisdiction (county/parish), planning region, or resource quantity is what utilization of GIS is all about. GIS technology and analysis assists planners at all levels see spatial relationships between these resources from various perspectives, an important capability in the development of an effective regional MCI plan.

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Chapter 16

Building a GIS Common Operating Picture for Integrated Emergency Medical Services and Hospital Emergency Management Response

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Contents

Introduction

The role of Geographic Information Services (GIS) data within emergency medical services and hospital emergency management operations is a key element to providing integrated emergency response services and managing comprehensive emergency response resources. In addition to the traditional role of publishing, sharing, storing, and utilizing geocoded data for integrated emergency medical services and hospital emergency management response, the emerging wave of innovation that is surrounding the application of geospatial technology presents exciting and breakthrough opportunities for operationalizing a range of expanded capabilities appearing on the horizon. These include:

- Utilizing Service Oriented Architectures (SOA) to create new Web-based service interfaces.
- Consolidating external/internal interfaces through next-generation integration platforms.
- Enterprise architectures that leverage increased levels of data standardization and business process integration.
- Use of spatial visualization of aggregated data to provide real-time access to critical trends.
- Metrics and key performance indicators.
- Fusion of geospatial data to drive spatial business intelligence.

The benefit of integrating geospatial data with patient-based emergency healthcare data is to provide a common operating picture where situational awareness is enhanced and critical life-saving decisions can be made.

This case study describes the design considerations and process for the development of a GIS-based Common Operating Picture (COP) display capability for emergency dispatch within an integrated and interoperable system design for emergency healthcare response. This system design integrated Emergency Medical Dispatch (EMD), Emergency Medical Services (EMS), and hospital resource information system environments. The goal of this chapter is to provide insights and real-world experiences when developing system designs intended to integrate geospatial data contained within Computer-Aided Dispatch (CAD) dispatch systems with emergency healthcare and hospital information systems. The role of GIS data within EMS prehospital patient care and hospital emergency information systems is a key element to providing and managing comprehensive emergency response and management resources. As this case study illustrates, it is particularly important when planning the effective resource coordination and data sharing in a metropolitan location with overlapping jurisdictional boundaries where business rules, practices, and response protocols differ.

Integrating Data Systems

Historically, key hurdles to effective geospatial data integration within emergency dispatch information systems have been driven by the lack of adoption of interoperability standards by the CAD vendor community restricting data sharing and connectivity amongst and between disparate systems (Department of Homeland Security (DHS), 2008a). Unlike APCO 25 or Project 25 (DHS, 2009), where standards for radios currently provide a standard level of interoperability between disparate radio systems, no industry-wide standards have been developed nor adopted by CAD vendors to produce similar levels of interoperability between their products. Further, not all CAD systems have system interface capabilities or contain, manage, or offer informational records or data in the same or similar formats, elements, syntax, or specifications such that they cannot be understood or readily used by other CAD systems. Based on observational experience, most vendors maintain strict proprietary CAD system products that lack or provide very limited system interface capabilities for sharing data with other CAD systems, as well as between their own systems operating on separate servers. In many cases, when more advanced interfaces are made available, dispatch centers may opt not to purchase them as added options due either to limited project funds or the fact that the open and automated sharing of CAD data with other agencies is a relatively new concept. As a result, where multiple CAD systems in multijurisdictional regions are used to track and dispatch field personnel, then dispatchers within the 911 centers do not have access to and cannot readily monitor field personnel and resource information in neighboring jurisdictions. Therefore, they must often engage in time-consuming phone calls to share critical information or locate and request the dispatch of the closest available fire or medical resource. Resources are not linked and there are no electronic interfaces to share time-critical CAD event and/or GIS-based information. Dispatch centers providing 911 alternate answer backup services must contact the responsible jurisdiction by phone and relay 911 call information verbally rather than electronically. This prolongs the response to emergency calls. Additional historical technology and process impediments include the lack of availability of robust geospatial integration platforms, the complexity of integrating multiple disparate communications systems and databases, the lack of standardization of auto-aid (or first in) protocols within multijurisdictional boundaries, and the relatively slow rate of business process standardization within public health and public safety organizations.

Currently, an emerging series of recently enacted statutory, regulatory compliance requirements are affecting emergency communications. For example, interoperability requirements and solution frameworks are represented by the SAFECOM Interoperability Continuum (DHS, 2008c). This evolving tool, developed from the DHS's SAFECOM program, is designed to help emergency response agencies and policymakers plan and implement interoperability solutions for data and voice communications. The SAFECOM Interoperability Continuum supports the National

Preparedness Guidelines (Federal Emergency Management Agency (FEMA), 2007) and aligns with national frameworks, including, but not limited to, the National Response Framework (FEMA, 2008), the National Incident Management System (DHS, 2004), the National Emergency Communications Plan (DHS, 2008b), and the National Communications Baseline Assessment (DHS, 2007). At the data level, for prehospital patient emergency reporting, the National EMS Information System (NEMSIS, 2009) is an effort to standardize the collection of EMS data and the creation of a national EMS database. These requirements, governance standards, and standard operating procedures address emergency communications locally, regionally, and nationally.

Concurrently, there has been a significant amount of development of late focused on integrated emergency medical services (EMS), healthcare and hospital emergency management. By reference, the Hospital Incident Command System (HCIS) (California Emergency Medical Services Authority (CEMSA), 2006), developed in California, is an emergency management system for hospitals for use during a medical disaster. The HCIS system helps coordinate emergency response between hospitals and other emergency responders and is based on a clear chain of command management, defined responsibilities, prioritized response checklists and clear reporting channels for documentation and accountability, and a common nomenclature. Integrating EMS and hospital resource management systems is now becoming a compliance requirement based on standardizing data element reporting (i.e., NEMSIS), emergency communications (i.e., National Emergency Communication Plan (NECP)), and incident management (i.e., HCIS, National Incident Management System (NIMS)). To provide integrated emergency management within the continuum of emergency healthcare, local governments and jurisdictions must have in place a system of emergency data coordination with local hospitals, public health departments, incident commands, EMS, Emergency Medical Dispatch (EMD), and public safety information systems. In the event of either a 911 emergency or catastrophic multicasualty incident, it is EMD services that provide communications to first responders for the rescue, assessment, care, and transportation to the emergency healthcare delivery system (e.g., hospital emergency departments, trauma centers, triage units, etc.). EMD services are provided through highly varied organizations that receive emergency dispatch communications from 911 call centers. Emergency communication centers vary significantly from community to community and jurisdiction to jurisdiction. These communication centers may be fully integrated, acting as the single conduit for all 911 calls, or they may be distributed, with one entity receiving the initial request for help and transferring the caller to a secondary call-taker depending on the need (e.g., police, fire, or medical). Table 16.1 shows the results of a survey of 200 cities in which organizations provide EMD services.

The variability of EMD response systems, differences in guidelines, response capacity, and lack of adoption of data standardization and sharing between CAD vendor systems pose significant coordination and data communications challenges

Table 16.1 Organizations Providing Emergency Medical Dispatch (EMD) Based On a 200 City Survey

Organization Type	*Percent of Cities in Which EMD is Provided by Organization*
Fire Departments	27.9%
Combined Public Safety Departments	23.4%
Private Ambulance Providers	10.8%
Third-Service EMS Departments	9.9%
Law Enforcement Departments	8.1%
Hospitals	4.5%

Source: Williams, D.M. 2008. *JEMS 200 City Survey 2008*. Elsevier: Burlington, MA. With permission.

for integrated and interoperable emergency information systems. Integrating CAD event data elements, such as GIS data, with both EMS data collection and hospital resource management systems is critical to both prepare and respond for any emergency medical response or catastrophic event. Planners must develop integrated and interoperable data communications between EMD (communications centers), CAD, and EMS data systems, and link the EMS database with hospitals, trauma centers, public safety departments, emergency management offices, and public health agencies. Most jurisdictions have yet to integrate their EMD, EMS, and hospital resource information systems to enable seamless and two-way data transfer (publish/subscribe) for integrated emergency response and management communications. Fewer yet have sought to create the functionality within their EMD systems with data from disparate CAD systems for a system-wide GIS-based COP.

Recently, the County of Santa Clara California, County Communications Department and the EMS Agency developed a multi-CAD to CAD system design providing a GIS-based Common Operating Picture among regionally dispersed 9-1-1 call centers. This system design was incorporated within an advanced EMS data system architecture. The EMS data system enterprise architecture design, when implemented, would enable GIS-based dispatch data to be integrated with all EMS Agency business partner pre-hospital patient care record (PCR) data and stored in a NEMSIS central database managed by the EMS agency. The EMS Agency business partners consist of ten (10) fire departments, twelve (12) city agencies, eleven (11) hospitals, eight (8) ambulance care providers, three (3) air ambulance care providers, thirteen hundred (1300) EMT's, seven hundred (700) Paramedics, County Information Services Department, County Communications Department and twelve (12) other Primary 9-1-1 Call Centers (PSAPs). The existing EMD and EMS data systems were imposing business constraints created over time by the proliferation of non-interoperable systems and creation of functional data silos by the business partners. These effects included difficulty and obstruction in both the standardization of business processes and level of data integration. It further imposed the inability of storing a standardized data set by the EMS agency. To begin the process of developing of the enterprise architecture system design, incorporating the data systems and environments of the business partners, several conceptual frameworks were considered and utilized to develop a design philosophy and approach as the initial design step. These frameworks are recommended to planners to consider when faced with integrating time-critical and enterprise-level information systems.

First, as Horan and Schooley (2007a) describe in their comprehensive research of information systems for emergency response, including GIS services for EMS, a framework is needed to provide a multi-dimensional view of "end-to-end" systems to improve performance in time-critical situations.

As depicted in Figure 16.1, this framework was used to baseline the characteristics of the EMS system architecture in place, analyze relevant information and performance gaps and help determine the needs and requirements for the desired next-generation architecture design meeting the project's vision, goals and objectives. Next, as Ross and colleagues describe (Ross et al. 2006), the relevant enterprise operating model was developed. An operating model is the level, or extent, of business process integration (i.e., the extent to which business units share data) and the appropriate level of business process standardization (i.e., the extent to which business units will perform the same processes the same way). The degree, or level, of these two dimensions of process standardization and process integration are defined as the key dimensions of an operating model type necessary to achieve enterprise execution goals (i.e., in effect "the architecture is the strategy"). The operating model is described as one of three (3) components needed for creating a foundation for "business execution". These components, according to Ross and colleagues, include the Operating Model Type, the Enterprise Architecture, and the IT engagement model. The operating model type considered relevant during the design for the Santa Clara County EMS data system architecture was a Diversification Model.

Further, as Horan and Schooley (2007, 2007a, 2007b) point out, "enterprise systems are embedded in a much larger set of processes that reflects the organization's operating model. To design their enterprise architecture, organizations must understand this "embeddedness", or the strategic direction in which they are moving, which will dictate the kind of IT infrastructure required and the activities that are important for achieving alignment between business objectives and IT capabilities". Planners will need to begin assessing the current levels of business process integration and standardization within their IT environments. Advances in high-performance and comprehensive healthcare data integration technology provide opportunities to create connections with disparate health information systems. New developments in integration platforms are providing more cost-effective alternatives

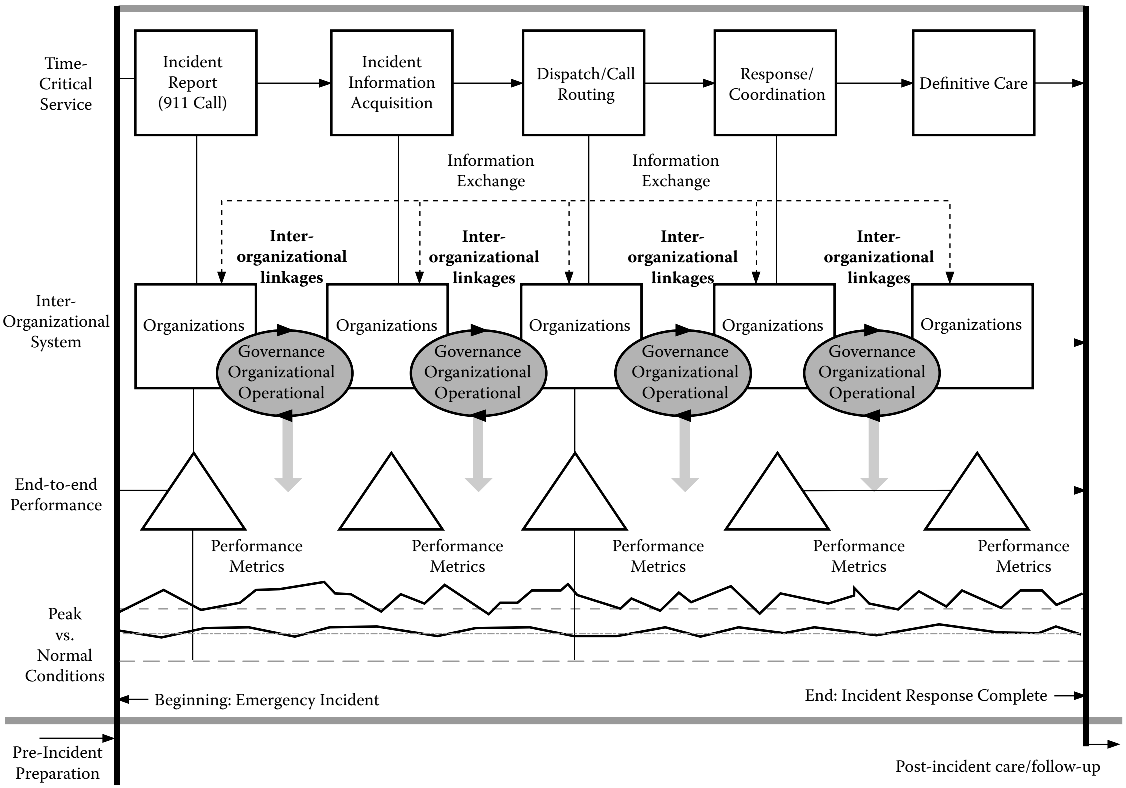

Figure 16.1 Shown is the Time Critical Information Services (TCIS) Framework. (Adapted from Horan, T. and B. Schooley. 2007a. *Government Information Quarterly* 24(4): 755–784.)

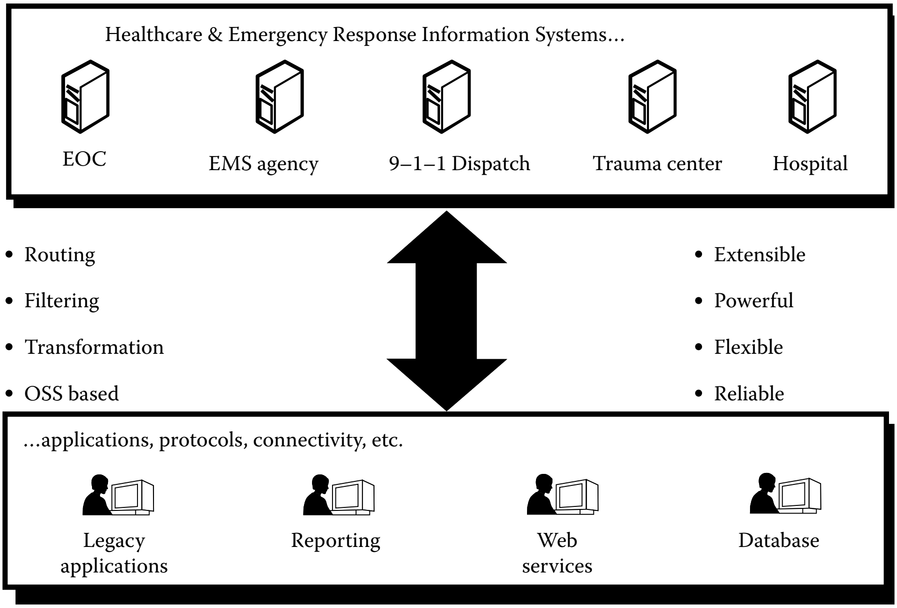

Figure 16.2 Advanced Healthcare Interoperability and integration technology (IT) enabled by MirthConnect™, Mirth Corporation, Irvine, California.

to developing and maintaining separate custom programmed interfaces. For example, over 16 separate data system interfaces were specified as a design requirement within the Santa Clara EMS data system enterprise architecture system design in order to provide the needed level of business process integration. This included geocoded data elements from the CAD-CAD system environment. Separately, a price-cost analysis determined that an advanced interface engine providing robust integration functionality was more cost effective than building separate interface solutions. An advanced integration technology was identified as capable of providing this level of integration.

Depicted in Figure 16.2, the open-source Mirth-Connect™ (Mirth 2009) interoperability platform represents an example of an advanced healthcare integration technology considered during the design of the County of Santa Clara EMS enterprise data system.

When integrating EMS data systems planners should also consider data integration of not only the traditional PCR data elements captured by EMS data collection systems but also all relevant geocoded data elements created or collected by CAD systems managed through EMD, and ultimately stored within NEMSIS-compliant EMS agency central respositories. While geocoded data is not currently part of the required NEMSIS data elements to be reported by EMS Agencies, geocoded data elements are part of the overall NEMSIS dataset in which NEMSIS-certified EMS data collection systems must be capable of collecting. An assessment of external vendor PCR data collection applications that were surveyed during the County of Santa Clara project had user interfaces that included data fields for geospatial data such as patient location, patient arrival time at hospital, patient transport time, hospital location details, and/or patient transfer details (e.g., ground location to air ambulance location, etc.).

The aforementioned information system design frameworks, design concepts and technology assessments were utilized in the design-analysis process to define the business execution needed by the EMS agency and encompassing all County of Santa Clara business partners data needs.

Designing a GIS-Based Common Operating Picture (COP)

In order for all CAD event based GIS to be integrated within the emergency continuum of care data system, a design requirement was established which specified that geocoded data from all medical event 911 dispatch calls be incorporated as part of the EMS enterprise data system design. This would provide the capability of integrating CAD event generated geocoded data elements within the first responder's PCR data collection systems. Ultimately, all first responder PCR records (i.e., those generated by fire departments, ground ambulances, air ambulances) would become part of the EMS agency central database. As part of the EMS data system, the geocoded data elements could be integrated with hospital resource management systems currently installed in County of Santa Clara hospitals. Hospital resource management systems, located on dedicated computer screens in the emergency department, provide real-time visibility of patient transport status, hospital capacity status, and other data between the hospital, the emergency transport provider, and central communications dispatch. Connecting the 911 dispatch geocoded data with the EMS data system and the hospital resource management data systems would effectively create an integrated and GIS-based emergency healthcare and hospital emergency management information system. Key benefits would include enhanced and leading-edge emergency management capabilities, such as real-time patient tracking, creation of a master patient index dataset, enhanced EMS reporting and data analytics, and enhanced spatial business intelligence.

In Santa Clara County, the complexity of standardizing business processes and the level of integration is characterized by the number of disparate systems and size of the region. Comprised of multiple operational areas and boundaries, the County of Santa Clara is a jurisdiction whose business partners consist of an EMS agency, an emergency management (EM) agency, county communications, and 12 other 911 call centers, and 10 fire agencies. The fire agencies coordinate the provision of fire suppression, rescue, medical response services, and emergency management services among and between all 15 cities and the unincorporated areas of the county. There are currently 13 disparate CAD systems used by the PSAPs within the operational areas and boundaries of Santa Clara County. The basis of all geospatial data that would be used to integrate with the EMS data system and emergency dispatch systems resided in the disparate CAD datasets used in support of the 10 fire agencies.

In order to solve the lack of data interoperability between the disparate CAD dispatch systems, County of Santa Clara Communications and County Information Services Departments developed a leading-edge system design and implementation approach to link all 911 call centers and CAD systems. The system design would create an advanced design interface bridge to standardize, centrally store, and distribute data from the disparate CAD systems. This interface bridge would uniquely identify each CAD record by jurisdiction, service provider, major call (law, medical, fire) type, and GIS data and store it in a database. Evolving from this database are the standardized results of the emergency call processing. When these results are geocoded to the county's comprehensive GIS road centerline database, a GIS-based COP display capability is created. The COP would spatially display active calls, as well as hospital, fire station, and resource (personnel/equipment) status able to be viewed by a browser-based product by dispatch staff at every 911 call center and at other locations as needed to address public safety and all hazard emergency response operations. Dispatchers would be able to identify the closest available and most appropriate emergency resource.

The first step in developing COP functionality was to develop a process for standardizing CAD datasets. This process would include identifying with each of the 10 fire agencies and their respective dispatch centers the following information: jurisdictional boundary drops, business rules, practices, response protocols, and auto-aid first response protocols. This information along with the results of a complete analysis of the existing disparate CAD systems identifies where standardization would be possible and provides a basis to identify the required programming and procedural solutions needed to achieve local and regional standardization. Once CAD data that are published to standardized data translation tables have been built and tested, then event location and resource data also can be geospatially coded and displayed on the county's standardized base map to create a COP display for easy browser viewing by all authorized public safety agencies. A Web portal will allow access by any of the 12 PASPs to enable dispatch staff to view the COP. Once publishing data has been achieved, the next step will be the development of the translation tables to enable local dispatch centers to automatically place requests for resources (personnel/equipment) from other dispatch centers in a format that will be accepted by its disparate CAD system (a data subscription process), based on their availability and preestablished protocols and/or business rules (e.g., auto-aid, mutual-aid, 911 call answering backup support, misroutes, etc.).

The following sequence of events will create the status information on the COP display and event creation process:

- The originating agency will enter the event into its CAD system.
- Based on business rules, the event data will be sent through the interface bridge/information broker, be standardized, geospatially coded, and displayed on the county's standardized base map for browser-based viewing by authorized agencies.
- All event updates and resource (personnel/equipment/fire station, and hospital facilities) status changes will be displayed providing a clear COP for agencies directly involved or monitoring local events.
- Based on established protocols and business rules, the interface bridge/information broker will route event/resource requests automatically to the responding agency's CAD system ready for dispatch.
- The dispatcher will then dispatch the requested resources to the scene. This action will be displayed on the COP as an event update and resource status change.
- The responding units will switch over to the primary radio channel of the requesting agency when they are enroute to the call and will remain under the control of the requesting agency's dispatcher until the call is completed and they have cleared the scene and are returning to base.
- All unit ID and unit status, as well as facility ID and status, will be displayed on the map using standard icon conventions to provide a COP display.
- Additional CAD event data may be used to update the COP display to show resource (e.g., equipment and personnel) and facility status in response to calls for service received from other 911 call centers.

In addition to the CAD event data used to build the COP display, collected GIS data will be used for spatial data analysis, short-term data restorations, and improving day-to-day operational efficiencies and response to all-hazards emergencies.

When implemented, this CAD–CAD system design providing a common COP display is planned to be integrated with the EMS data system. These combined systems will provide Santa Clara County with a truly innovative and leading-edge emergency response enterprise information system architecture and capability.

Innovations

Access to GIS data typically isn't the limiting factor in utilizing geospatial data. For example, within emergency medical services response nearly all current CAD and EMS data collection systems originate and/or create a provision to capture and store geocoded data elements. It is the expense and complexity of system integration needed to access legacy systems containing spatial data that tends to limit the information availability of geospatial data. However, technologies have evolved to the point of providing planners and system designers with methods and processes to create faster and easier system integrations. For example, automation tools to

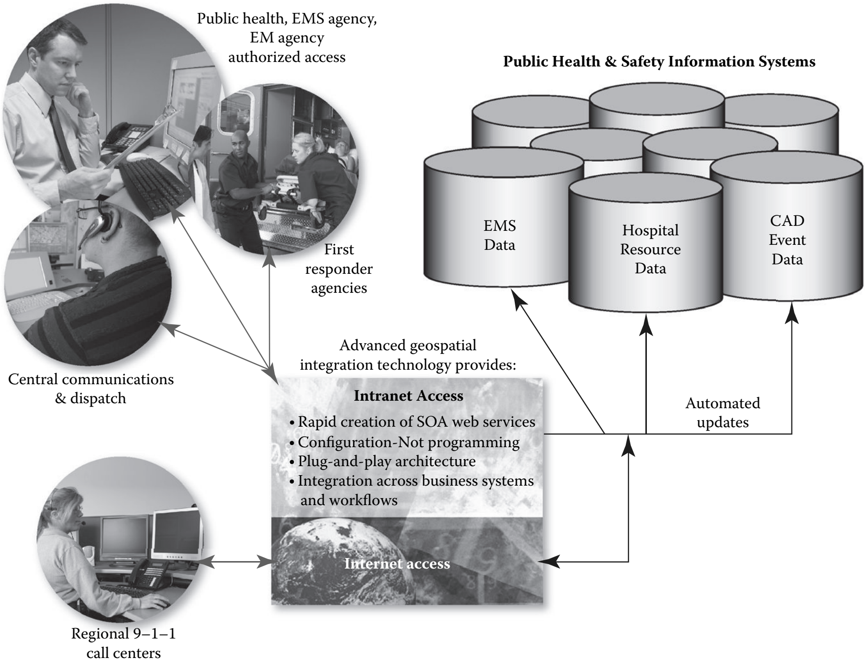

Figure 16.3 Enterprise Spatial Integration and Intelligence enabled by Rolta Geospatial Fusion™, Rolta Inc., Atlanta, Georgia.

create and manage Web services and reduce custom programming to build business service interfaces are emerging to advance spatial integration. The benefits of advances in spatial integration and fusion technology include:

- Extending the value of traditional business systems, GIS platforms, and investments in engineering data.
- Enabling more cost-effective integration of systems.
- Creating spatial business/operations intelligence capabilities.

In addition, GIS-based information that was previously "hidden" is brought together and made it available in a context appropriate for nearly any level of decision making. Within emergency healthcare response and hospital emergency management opportunities exist for planners to achieve more robust integrations of geospatial data with available technology.

As depicted in Figure 16.3, advanced geospatial integration and fusion technologies, such as Rolta's Geospatial Fusion™ platform (Rolta, 2009), provide the potential for creating system designs capable of providing business and operational intelligence solutions by integrating 911 dispatch geospatial, EMS, public health, and hospital resource data.

Summary and Conclusions

Planners who seek to integrate emergency data systems should seek to establish enterprise business execution foundations to define and identify the levels of business process standardization and integration that are consistent with organizational and enterprise business goals as they develop architecture designs. More evidence continues to indicate that the enterprise architectures is the strategy and foundation for business execution.

A GIS-based COP capable of displaying event, resource, and facility status and location on top of a public safety-focused, base-map layer will enable managers to better coordinate emergency response resources. When CAD event data are integrated in real time with EMS and hospital emergency and resource management data systems, managers can optimize the allocation of emergency resources, which enables them to develop incident management strategies as the event unfolds. This is a powerful capability to better coordinate daily operations and all-hazards responses.

Establishing interoperable data standards that provide for CAD-to-CAD connectivity and data sharing will greatly assist promoting the utilization of GIS data within public safety and public health information systems. The potential for further integration of GIS data relevant to emergency response information systems is an exciting and emerging landscape as advanced geospatial integration and fusion technologies continue to evolve. As an example, consider the integration of real-time traffic information for the potential of being used for routing analysis to support GIS displays in providing EMS responders with fastest route information.

Creating operational and spatial intelligence from geospatial data created or collected within integrated emergency information systems should be a system design goal. The potential exists for the availability of GIS-based information to be utilized in the emergency continuum of healthcare to save lives. Note that geocoded data elements are created or collected within various information systems such as EMS data collection systems, CAD-dispatch systems, and hospital resource management systems, are able to be utilized in many ways to improve emergency healthcare and hospital emergency management. For example, these geocoded data elements have potential application within real-time data streams useful to emergency communication and information architectures such as a Master Patient Index system, various forms used in the HCIS hospital disaster response system, and in crisis communications systems within Emergency Operations Center (EOC) software systems.

Providing a COP to all 911 dispatch centers providing real time visibility of first responders and emergency resources within a region greatly improves time-critical communications between all constituents improving response. Advanced integration engines are now available that provide the means to simplify the complexity of system integrations in healthcare data environments. Innovative spatial fusion technologies provide a new level of configurability that replaces complex spatial custom programming. These solutions can rapidly create Web services from existing data and stored procedures to allow a new level of information visibility from GIS data. These technologies allow the complexity of IT to be hidden from operations staff so that the focus can be returned to what is most important—improved healthcare emergency services for daily events and robust capabilities to provide hospital emergency management and response.

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