Table 1. Literature Sources

Literature	Databases for published material (articles, books, reports, and Websites)	Key journals and conference proceedings	Examples of Relevant Organizations (for Web-based searches)
Medical	MEDLINE® Cochrane	Conference proceedings for the last two years (2001-2) for: American Medical Informatics Association Medical Decision Making Infectious Disease Society of America American Public Health Association American Pharmaceutical Association	American Hospital Association Joint Commission on Accreditation of Healthcare Organizations Council of State and Territorial Epidemiologists ProMED-mail National Association of County and City Health Officials National Professional Society of Pharmacists American Pharmaceutical Association Center for Civilian Biodefense Strategies
Emergency Management	Fire Academy (FEMA) HazLit (UC Boulder) Disaster! Finder (NASA) Global Emergency Management System Health and Safety Sciences Abstracts Risk Abstracts	*Disasters* *Prehospital Disaster Medicine* *Disaster Prevention and Management* *Disaster Recovery Journal*	Center for Excellence in Disaster Management and Humanitarian Assistance Natural Hazards Center (University of Colorado, Boulder)
Supply Chain	Harvard Business School case database Stanford Graduate School of Business case database Darden School of Business Administration (University of Virginia) case database Institute for Operations Research and Management Science (INFORMS) bibliographic database	*Interfaces* *Operations Research* *Management Science* *Harvard Business Review* *Manufacturing and Service Operations Management*	Institute for Operations Research and Management Science Fritz Institute American Red Cross
Government Documents	GrayLit National Technical Information Service National Academies Press	*Military Medicine*	Centers for Disease Control and Prevention (CDC) Federal Emergency Management Agency (FEMA) Metropolitan Medical Response System National Disaster Medical System (NDMS) Department of Veterans Affairs (VA) Health and Human Services (HHS) National laboratories U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID) Global Emerging Infections System, Department of Defense (DoD) U.S. General Accounting Office (GAO)

Preliminary Searches

This section describes our preliminary searches for potentially relevant response organizations, bioterrorism-related and naturally occurring outbreaks, responses to natural disasters, and supply chain management cases.

Preliminary Medical Literature Database Searches

To identify potentially relevant articles in the medical literature, we searched MEDLINE® and Cochrane databases and references provided by our Expert Advisors.

MEDLINE® search strategies. We searched MEDLINE® (January 1966 to February 15, 2003) using the search terms described in Table 2.

Table 2: MEDLINE® Searches to Identify Potentially Relevant Systems and Organizations

Search	Search Terms	Citations reviewed	Articles retrieved
Bioterrorism-relevant Events			
Anthrax attack, 2001	"anthrax"[MESH] AND bioterror* AND 2001	219	25
Salmonella bioterrorism , The Dalles, Oregon, 1984	"food contamination"[MESH] AND "disease outbreaks"[MESH] AND Oregon AND salmonella	2	2
Natural Outbreaks			
Smallpox, New York City, 1947	"smallpox"[MESH] AND "New York City"	7	0
Smallpox, Boston, 1903-4	"smallpox"[MESH]AND Boston AND 1903	2	2
Hantavirus pulmonary syndrome	"hantavirus"[MESH] AND "Disease Outbreaks"[MESH]	90	30
Meningitis, Minnesota, 1995	"meningitis"[MESH] AND "disease outbreaks"[MESH] AND Minnesota	4	2
Meningitis, other	"disease outbreaks"[MESH] AND "meningitis"[MESH] AND "North America"[MESH]	112	49
West Nile Virus (WNV)	"West Nile Virus"[MESH]AND "North America"[MESH]	198	46
Cryptosporidiosis, Wisconsin, 1993	"cryptosporidium"[MESH]AND Milwaukee	22	9
Severe acute respiratory syndrome, 2002-3	“severe acute respiratory syndrome” OR “SARS virus”[MESH]	140	29
Natural Disasters			
Disaster planning	“Natural Disasters”[MESH] AND “Disaster Planning”[MESH]	525	87
Hurricane Andrew	"Natural Disasters"[MESH] AND "Hurricane Andrew"	92	43
Hurricane Hugo	"Natural Disasters"[MESH] AND "Hurricane Hugo"	48	12
Hurricane Iniki	"Natural Disasters"[MESH] AND "Hurricane Iniki"	12	4
Loma Prieta earthquake	"Natural Disasters"[MESH] AND "Loma Prieta"	27	13
Northridge earthquake	"Natural Disasters"[MESH] AND "Northridge"	34	3
Mass Gatherings			
Olympics	Olympic* AND (surveil* OR “disaster planning”[MESH])	43	33
Political conventions	“Disaster Planning”[MESH] AND “Politics”[MESH]	64	21
Sporting events	"sports"[MESH] AND "disaster planning"[MESH]	32	29
Hajj-related	"disease outbreaks"[MESH] AND hajj	13	7
Man-made disasters			
Bombings	(“Terrorism”[MESH] OR bombing) AND “Oklahoma City”	85	24

Search	Search Terms	Citations reviewed	Articles retrieved
Sarin attacks, Tokyo, 1995	“Tokyo”[MESH] AND “Sarin”[MESH]	24	9
Plane crashes	"Disasters"[MESH] AND plane AND crash	20	7
Nightclub disasters	Nightclub AND (fire OR stampede)	1	1
Bhopal chemical spill	"Disasters"[MESH] AND Bhopal	95	12
Chernobyl nuclear disaster	"Disasters"[MESH] AND Chernobyl	44	9
Preparedness Plans for Bioterrorism			
General preparedness plans	Bioterror* AND “disaster planning”[MESH]	385	155
Hospitals plans	"disaster planning"[MESH] AND "hospitals"[MESH] AND bioterror*	18	17
Public health department plans	"public health"[MESH] AND "disaster planning"[MESH] AND bioterror*	213	81
Government plans	"Government"[MESH] AND "disaster planning"[MESH] AND bioterror*	74	61
Laboratories plans	"laboratories"[MESH] AND (bioterror* OR "disaster planning"[MESH])	55	21
Bioterrorism-relevant Tasks			
Planning and Preparedness			
Relationship development	"disaster planning"[MESH] AND ("relat*"[TITLE/ABSTRACT] OR "partner*"[TITLE/ABSTRACT])	3	3
Warning systems	“warning system” AND “disaster planning”[MESH]	6	4
Resource stockpiling	stockpile AND (disaster[MESH] OR bioterror*)	15	9
Field Assessment and Triage			
Rescue and stabilization of victims	("emergency treatment"[MESH] OR "emergency medical services"[MESH]) AND bioterror*	94	77
Rescue and stabilization of victims	("Regional Medical Programs"[MESH] OR "regional health planning"[MESH]) AND ("trauma centers"[MESH] OR "burn units"[MESH])	240	115
Transportation of victims	transport* AND bioterror*	14	7
First responder protection	("safety management"[MESH] OR "first responder"[TITLE/ABSTRACT] OR “personal protect*”) AND bioterror*	13	12
Field assessment	“Emergency Medical Services”[MESH] AND bioterror*	100	78
Triage	“triage”[MESH] AND bioterror*	9	6
Hazard assessment	(hazard OR danger) AND assess* AND bioterror*	4	3
Diagnosis			
Diagnosis and agent identification	("diagnostic equipment"[MESH] OR "laboratories"[MESH]) AND bioterror*	42	19
Management			
Decontamination of victims	"decontaminat*"[TITLE/ABSTRACT] AND bioterror*	20	9
Definitive medical care	("critical care"[MESH] OR manag*) AND clinic* AND bioterror*	24	12
Definitive medical care	("regional health planning"[MESH] OR "Regional Medical Programs"[MESH]) AND "Intensive Care Units, Neonatal"[MESH]	79	40
Distribution of supplies, equipment, pharmaceuticals	(“equipment and supplies”[MESH] OR pharmacy*) AND distribut* AND bioterror*	20	13
Prevention			
Immunization and prophylaxis	("mass immunization"[MESH] OR prophylax*) AND bioterror*	74	48
Isolation and quarantine	("quarantine"[MESH] OR "patient isolation"[MESH]) AND bioterror*	16	12
Surveillance			
Surveillance	(“epidemiology”[MESH] OR surveil*) AND bioterror*	135	103
Detection	Detection AND bioterror*	58	32
Outbreak Investigation			

Search	Search Terms	Citations reviewed	Articles retrieved
Outbreak investigation	“Contact Tracing”[MESH] AND bioterror*	0	0
Evaluation of responder, caregiver and victim health	"epidemiologic methods"[MESH] AND bioterror*	268	81
Communication			
Communication system development	("communication"[MESH] OR "communications media"[MESH]) AND bioterror*	81	46
Addressing the information needs of the public/media	("telecommunications"[MESH] OR "persuasive communication"[MESH] OR "Information dissemination"[MESH] OR "mass media"[MESH] OR "Hotlines"[MESH]) AND bioterror*	33	19
Emergency Management			
Command and control	(“incident command” OR “command and control” OR command control”) AND bioterror*	5	5
Volunteer utilization and control	("international agencies"[MESH] OR volunteer*) AND bioterror*	38	13
Mental health services for responders, victims, caregivers and families	("mental health"[MESH] OR counsel*) AND bioterror*	7	6
Fatality management	("coroners and medical examiners"[MESH] OR "fatality management") AND bioterror*	5	2
Mutual aid agreements	“mutual aid”	143	11
Bioterrorism-relevant Resources			
Material			
Pharmaceuticals and related equipment (syringes, gloves, etc.)	pharm* AND bioterror*	32	15
Communications equipment	Communicat* AND equipment AND bioterror*	3	3
Patient transportation equipment, including helicopters and ambulances	"Transportation of Patients"[MESH] AND bioterror*	2	2
Laboratory	"laboratories"[MESH] AND bioterror*	44	15
Trained personnel			
General personnel	Personnel AND bioterror*	157	48
Medical: physicians, nurses, hospital administrators, pharmacists	(doctor*[TITLE/ABSTRACT] OR nurs*[TITLE/ABSTRACT] OR physician*[TITLE/ABSTRACT] OR pharmacist*[TITLE/ABSTRACT] OR administrator*[TITLE/ABSTRACT]) AND bioterror*	92	66
Public health: local, regional, state and national officials; epidemiologists	"public health"[MESH] AND ("local"[TITLE/ABSTRACT] OR "state"[TITLE/ABSTRACT] OR "epidemiolog*"[TITLE/ABSTRACT]) AND bioterror*	65	58
Emergency response	("Emergency Medical Technicians"[MESH] OR firefighter*) AND terror*	35	10
Total		4669	1852

The use of the asterisk expands search terms such that all combinations of terms with the phrase preceding the asterisk will be returned in the search (e.g., bioterror returns searches for bioterrorism, bioterrorist, bioterror, etc.).
MESH = Medical Subject Heading

Cochrane search strategies. We searched the Cochrane databases from January 1, 1990 through May 1, 2003 (Ovid, Evidence Based Medicine Reviews Multifile) using the search terms described in Table 3.

Table 3: Search Terms and Citations for Cochrane Databases

Search terms	Citations reviewed	Articles retrieved
Anthrax	7	0
Bioterrorism OR bioterrorist OR terrorism OR terrorist	1	0†
Salmonella AND outbreak	4	0
Outbreak	137	4
Smallpox	38	1
Hantavirus	4	0
Meningitis AND outbreak	11	1
West Nile Virus	2	0
Cryptosporidiosis	22	0
SARS OR severe acute respiratory syndrome	9	0
Disaster	31	1
Hurricane	3	3
Earthquake	6	4
(Olympic OR Olympics) AND (sport OR game)	3	0
national convention AND politic*	0	0
Hajj	2	0
Bhopal	0	0
Chernobyl	10	0
Emergency AND prepare*	13	0
AND government	2	0
AND hospital	73	0
AND public health	13	1
AND laborator*	19	3
Regional trauma	8	1
Regional burn	1	0
First responder	6	2
Triage	126	1
Mass immunization	7	1
Quarantine	7	0
Coroner OR medical examiner	1	0
Media and public and communication	28	4
Hospital capacity	2	0
Laboratory capacity	0	0
Disease surveillance	7	0
MMRS OR Metropolitan Medical Response System	0	0
DMAT OR Disaster Medical Assistance Team	1	0
National Pharmaceutical Stockpile	0	0
Total	613	27

The use of the asterisk expands search terms such that all combinations of terms with the phrase preceding the asterisk will be returned in the search (e.g., bioterror returns searches for bioterrorism, bioterrorist, bioterror, etc.).
†This reference discusses clinical aspects of the anthrax vaccine but does not address regionalization.

Preliminary Emergency Management Database Searches

We searched six emergency management databases, using a similar search strategy for each (Table 4). Two databases (NASA's Disaster! Finder and FEMA's Global Emergency Management System) were eliminated after we searched them using terms similar to the terms

listed below and determined that they did not contain reports or articles meeting our inclusion criteria.

Table 4: Search Terms and Citations for Emergency Management Databases

Search Terms	Fire Academy (FEMA)		HazLit (UC Boulder)		Health and Safety Sciences Abstracts		Risk Abstracts	
	Reviewed	Retrieved	Reviewed	Retrieved	Reviewed	Retrieved	Reviewed	Retrieved
Mutual aid AND (health* or medicine)	16	6	2	1	0	0	0	0
Bioterror*	123	23	0	0	43	7	33	11
Regionalization	45	14	6	2	13	1	0	0
Total	184	43	8	3	56	8	33	11

The use of the asterisk expands search terms such that all combinations of terms with the phrase preceding the asterisk will be returned in the search (e.g., bioterror returns searches for bioterrorism, bioterrorist, bioterror, etc.).

Preliminary Supply Chain Management Database Searches

The search strategy used for supply chain case databases (e.g., Harvard Business School's case database and the Stanford Graduate School of Business case database) and for other supply chain management databases (e.g., databases maintained by the Institute for Operations Research and Management Science (INFORMS)) is presented in Table 5.

Table 5. Search Terms and Citations for Supply Chain Databases

Search Terms	Harvard Cases		Stanford Cases		Darden Cases		Bibliographic INFORMS	
	Reviewed	Retrieved	Reviewed	Retrieved	Reviewed	Retrieved	Reviewed	Retrieved
Bioterror	0	0	0	0	0	0	0	0
Supply chain	65[†]	11	31	7	6	0	69	7
Disaster	12	1	0	0	7	1	8	2
Logistics	67	7	3	0	8	2	34	2
Terror	5	0	0	0	0	0	1	0
Total	149	19	34	7	21	3	112	11

[†]Note that these search terms were often duplicative; for example, not surprisingly, the supply chain and logistics searches in any given database often returned the same articles.

Preliminary Government Documents Database Searches

The search strategy employed for government databases is presented in Table 6.

Table 6: Search Terms and Citations for Government Databases

Search Terms	GrayLit		NTIS**		NAP[††]	
	Reviewed	**Retrieved**	**Reviewed**	**Retrieved**	**Reviewed**	**Retrieved**
Bioterror*	80	35	89	29	15	7
Disaster AND "preparedness plan*"	39	1	0	0	15	6
Laboratory AND region*	201	2	10[†]	0	15	2
Disaster AND (manage* OR	213	48	100[§]	29	15	2

Search Terms	GrayLit		NTIS**		NAP††	
	Reviewed	Retrieved	Reviewed	Retrieved	Reviewed	Retrieved
respon*)						
All Hazards AND "preparedness plan*"	50	2	0	0	15	5
All Hazards AND (manag* OR respon*)	148	1	0	0	15	4
Total	731	89	185	58	90	26

The use of the asterisk expands search terms such that all combinations of terms with the phrase preceding the asterisk will be returned in the search (e.g., bioterror returns searches for bioterrorism, bioterrorist, bioterror, etc.).
†laboratory AND regionaliz* ; §disaster AND management AND response; **National Technical Information Service; ††National Academies Press

Focused Searches

Having reviewed the citations obtained in our preliminary searches, we identified systems and organizations that performed one or more of the tasks identified in our conceptual framework or facilitated the timely distribution of relevant material, personnel, and information. We then performed focused searches of these systems and organizations for articles describing their participation in regionalized responses to bioterrorism-relevant events (Table 7).

Table 7. List of Potentially Relevant Systems for Focused Searching by Primary Task

Main Task	Example System or Organization
Planning and preparedness	Systems for training (e.g., National Laboratory Training Network; State fire training centers (FEMA); National Emergency Training Center (Federal Emergency Management Agency); Metropolitan Fire and Emergency Medical Services Training Program (Department of Justice); Public Health Training Network) Organizations for hospital preparedness (e.g., Joint Commission for the Accreditation of Healthcare Organizations, the American Hospital Association) National Domestic Preparedness Consortium National Domestic Preparedness Office (Federal Bureau of Investigation) Office of Emergency Preparedness Office of Public Health Preparedness Domestic Preparedness Program (DoD) Bioterrorism Preparedness and Response Program (HHS)
Field assessment and triage	Castro Halloween Party Emergency Management System (San Francisco) Aeromedical Evacuation System U.S. trauma care system
Diagnosis	Laboratory Response Network
Management of the acutely ill	Systems for tracking capacity (e.g., BEDTRACK, HERIS) Systems that regionalize trained personnel (e.g., *Medicins Sans Frontiers,* Medical Reserves Corps, Disaster Medical Assistance Teams (DMAT), National Pharmacists Response Team, National Nurses Response Team, Metropolitan Medical Strike Teams, National Medical Response Teams) Systems that regionalize delivery of specialized medical care (e.g., trauma care, burn units, neonatal intensive care systems) Rapid delivery of essential medical supplies (e.g., America's Blood Centers, American Association of Blood Banks, Organ Procurement and Transplantation Network, United Network for Organ Sharing) Hospital Emergency Response Data System Emergency Management Strategic Healthcare Group (VA)

Main Task	Example System or Organization
	Modular Emergency Medical System (i.e., Neighborhood Emergency Help Center and Acute Care Center) from U.S. Army Soldier and Biological Chemical Command Modular Assistance Medical System Metropolitan Medical Response System
Prevention of the spread of disease	Strategic National Stockpile
Surveillance	Influenza systems (e.g., FluNet, FluWatch, Worldwide Influenza Surveillance Program [DoD], EuroGROG) Syndromic surveillance systems (e.g., ESSENCE, BioSTORM, RODS) Surveillance for food borne illness (e.g., FoodNet, PulseNet) Healthwatch (U.S. Army) DARPA Biosurveillance Project National Electronic Disease Surveillance System National Weather Service Smallpox vaccine related surveillance systems (e.g., Smallpox Vaccine Adverse Events Monitoring and Response System, Hospital Smallpox Vaccine Monitoring System, Vaccine Adverse Event Reporting System) Global Outbreak Alert and Response Network Biowatch ProMed
Outbreak investigation	Epidemic Intelligence Service (EIS)
Communication	Among public health systems (e.g., Health Alert Network, Epi-X) Communication to the public (e.g., Amber Alert, FCC Public Safety Program, Emergency Alert System, Disaster News Network, Cable News Network (CNN), National Communications System, Homeland Security Advisory System, Farm Disaster Helpline) Warning systems for military responders (e.g., LERTCON system) Public Safety Radio Pool Rapid Response Information Center (FEMA) Warning systems for emergency medical services (e.g., FirstWatch)
Emergency management	Mutual aid agreements (e.g., California Master Mutual Aid Agreement, Emergency Management Assistance Compacts) Federal Response Plan Charitable organizations (International Federation of Red Cross and Red Crescent Societies, Red Cross, USAID) Federal Emergency Management Administration (FEMA) National Association for Search and Rescue Transportation systems (e.g., U.S. Postal Service, Federal Express) Global Expeditionary Medical Systems Chemical and Biological Rapid Response Teams (DoD), National Guard Weapons of Mass Destruction Civil Support Teams, Civilian Support Teams (National Guard), Emergency Response Team (EPA), Technical Escort Units (DoD), Strike Teams (Coast Guard), Chemical and Biological Response Teams (National Guard), DMORTs, Community Emergency Response Team Incident Management Systems (e.g., Unified Command System, National Interagency Incident Management System, Hospital Emergency Incident Command System) Enhanced Consequence Management, Planning and Support System Specially trained military responders (e.g., Soldier's Biological and Chemical Command, Chemical and Biological Immediate Response Force) Biological and Chemical Weapons Improved Response Program Joint Forces Command: Force Packages (DoD) Joint Programs Office for Biological Defense (DoD) U.S. Government Interagency Domestic Terrorism Concept of Operations Plan Bomb Data Center (DOJ)

For bioterrorism preparedness, incentives might include monetary payments, additional supplies, additional power to respond to potential bioterrorist events, and for some organizations (such as the Red Cross) positive media exposure. (The flows of money associated with the health care supply chain are highly complex. A detailed analysis of these is outside the scope of this project; we direct interested readers elsewhere.[*48])

Management of information. Evaluations of supply chains demonstrate that accurate and up-to-date information about the level of raw materials, finished products and their locations, and customer demands are essential to keeping inventories low and supplying customers in a timely manner.[49, 52] Sophisticated supply chain management information systems—in addition to real-time tracking of products through the supply chain—include decision support tools that optimize routing and scheduling and minimize costs of component parts and inventories.[48, 57] In the health care industry, during the process of ordering goods, clinicians, pharmacists, and other customers submit purchase requests to a procurement officer who identifies the requested items in a distributor's catalog (often paper-based) and submits the order to the group purchasing organization and to the distributor.[48] These orders are communicated to the manufacturer for shipment. The industry is increasingly adopting a common electronic data platform for the direct electronic transmission of standard business forms (e.g., purchase orders, shipping notices, and invoices); however, this protocol is far from universal.[48]

For bioterrorism, management of information about the needs of local responders and the availability of regional inventories is an essential component of a coordinated response.

Table 8. Evaluation Concepts from the Supply Chain Literature and their Relevance to Regionalization of Bioterrorism Preparedness

Key Concepts and Evaluation Criteria For Traditional (Manufacturing) Supply Chains	Key Concepts and Evaluation Criteria For Bioterrorism Response Supply Chains
Network Design	
Entities: • Suppliers and manufacturing plants • Warehouses • Distribution facilities • Customers • Transportation network	*Entities:* • Antibiotic and vaccine manufacturers and wholesalers • Antibiotic/vaccine stockpiles (e.g., Strategic National Stockpile and local inventories) • Hospitals, pharmacies, and local dispensing sites • Exposed population • Transportation network

[*] The Wharton review of the health care supply chain describes some money flows among supply chain members as follows.[48] Products are sold by manufacturers—at prices set by them—to distributors. Distributors sell products to providers, typically at discounted prices resulting from contracts negotiated by a group purchasing organization. Distributors issue credits or rebates to the manufacturer for the difference between the list price that it paid for the goods and the discounted price (plus a handling fee) that it received from the purchaser. In general, the fees paid to distributors for shipping, marketing, and tracking products is about 1-2% of sales. Group purchasing organizations receive contract administration fees from the manufacturer, which typically amount to 2-3% of the sales contract. Depending on the purchasing organization, these fees are sometimes returned to its purchaser members. It is estimated that 40-67% of hospital supplies (approximately $25.1 billion) are purchased through contracts negotiated via national purchasing organizations. The remaining items are purchased via regional and local contracts.

Key Concepts and Evaluation Criteria For Traditional (Manufacturing) Supply Chains	Key Concepts and Evaluation Criteria For Bioterrorism Response Supply Chains
Considerations: • Determining the number and location of manufacturing and distribution facilities • Determining an appropriate distribution network for finished goods • Iterative improvement of an existing supply chain	*Considerations:* • The number and location of stockpiles of necessary resources such as pharmaceuticals, medical supplies, and equipment • Appropriate distribution network for these necessary resources • Iterative improvement of a bioterrorism response supply chain
Evaluation criteria: • Profit • Order fulfillment (percentage of customer requests that can be filled immediately from stock on hand)	*Evaluation criteria:* • Reduction in morbidity, mortality, timeliness of treatment/prophylaxis • Cost
Inventory Management	
Entities: • Inventories of raw materials and finished goods • Information systems that monitor inventories and customer demands	*Entities:* • Inventories of equipment and drugs • Information systems that monitor inventories of needed resources
Considerations: • The fewer distribution centers that serve a region, the less product they must stock to provide the same level of customer service • Fewer distribution centers can often provide the same level of service to customers with reduced total inventory • Marketing affects demand and subsequent inventory (e.g., advertisements for products may enhance demand and require changes in inventory management)	*Considerations:* • Resources required for a bioterrorism response can be held in regional stockpiles rather than in individual local communities • Regionalization of inventories of bioterrorism resources requires accurate and timely information about demands for these resources and the availability of local and regional stockpiles • Communication of information about a suspected or actual bioterrorism event may affect the behavior of the public to seek medical attention
Evaluation criteria: • Time to fill customers' demands • Costs of inventories • Timeliness and accuracy of inventory information	*Evaluation criteria:* • Time to supply the demands of the exposed population • Costs of inventories • Timeliness and accuracy of inventory information
Postponement and Modularization	
Entities: • Subassemblies (i.e., components of the final product) and final products	*Entities:* • Resources required for treatment and prophylaxis of bioterrorism-related illness (e.g., prophylactic antibiotics could be assembled into a variety of products of distribution including individual packages containing multiple days of adult or pediatric therapy)
Considerations: • Products are customized for a specific market late in the supply chain • Products are designed in modular parts that can be used in a variety of end products • Postponement and modularization can minimize inventory while still providing a high level of customer service	*Considerations:* • Individualized packets of supplies can be prepared regionally to reduce the preparation time required at the local dispensing site to divide up and repackage the antibiotic arriving in 500+ tablet shipments. (The Push Packs have pre-packaged antibiotics in 10day regimens and the Vendor Managed Inventories provide pre-packed 25-day regimens.)
Evaluation criteria: • Time to fill customers' demands • Costs of inventories	*Evaluation criteria:* • Time to supply the demands of the exposed population • Costs of inventories

Key Concepts and Evaluation Criteria For Traditional (Manufacturing) Supply Chains	Key Concepts and Evaluation Criteria For Bioterrorism Response Supply Chains
Supply Chain Coordination and Management of Incentives	
Entities: • Partners in the supply chain: suppliers, manufacturers, distributors, retail outlets	*Entities:* • Partners in the supply chain: pharmaceutical companies, medical supply manufacturers, pharmacies, transportation companies, clinicians, hospitals, governmental agencies responsible for the storage and distribution of antibiotics, vaccines, and medical supplies
Considerations: • Coordination of activities of supply chain members results in lower cost and improved customer service • All partners in the supply chain are incentivized to work toward the same final goal • Different members of the supply chain have different financial incentives	*Considerations:* • Coordination of activities of all relevant bioterrorism responders results in quicker response and improved clinical outcomes • All relevant bioterrorism responders are incentivized to work to protect the public health • Different elements of bioterrorism response (e.g., clinicians vs. pharmaceutical manufacturers) have highly heterogeneous financial and legal responsibilities
Evaluation Criteria: • Profits for the overall supply chain • Satisfaction of supply chain partners	*Evaluation criteria:* • Speed and effectiveness of response to bioterrorism events • Clinical outcomes
Management of Information	
Entities: • Partners in the supply chain: suppliers, manufacturers, distributors, retail outlets • All relevant data	*Entities:* • All relevant bioterrorism response partners • All relevant data
Considerations: • Accurate information on inventory and parts made available in a timely manner to plan for resources required • Centralized database to manage the data, thus making all information readily available in one place	*Considerations:* • Accurate and timely information on inventories of pharmaceuticals, vaccines, medical supplies • Accurate information on number of infected cases and exposed individuals, and availability of personnel and supplies made available in a timely manner to allow for planning of resources required
Evaluation Criteria: • Data completeness and accuracy • Date timeliness (up-to-date)	*Evaluation Criteria:* • Data completeness and accuracy • Date timeliness (up-to-date)

Evaluation Concepts from Government Documents

Because a major component of the response to bioterrorism includes government agencies, evaluation concepts from the military, emergency response agencies, and other governmental responders are relevant to considerations of bioterrorism preparedness. In our review of government documents, in particular those from the military, we found that emergency responses often benefited from a clear chain of command and from careful review of the lessons learned from previous related responses. For example, in its report to NASA, the Columbia Accident Investigation Board described the Navy as having "institutionalized their 'lessons learned' approaches to ensure that knowledge gained from both good and bad experiences is maintained in corporate memory. This has been accomplished by designating a central technical authority

For bioterrorism, "components" include antibiotics and medical supplies packaged in local and regional inventories, teams of trained personnel available for deployment to the affected locality, and protocols such as clinical practice guidelines for the diagnosis and management of populations exposed to a biothreat agent.

4. *Coordination of activities of supply chain members, along with specific consideration of the incentives of all stakeholders in a supply chain, can improve service, increase efficiency, and reduce costs.* The bioterrorism response supply chain is highly complex with numerous stakeholders. Specific delineation and alignment of their (sometimes competing) incentives may benefit programs to coordinate response efforts.

5. *Timely and accurate information about customer demands facilitates inventory management and rapid delivery of products.* For the bioterrorism response supply chain, information systems that can accurately characterize the available supply of goods and personnel and the ongoing needs of the community affected may benefit the response.

Table 9. Lessons Learned From the Traditional (Manufacturing) Supply Chain Literature

Reference	Company/supply chain under evaluation	Key lessons learned from the supply chain case study
Lee, Billington[58]	**Hewlett-Packard** (HP) manufactures and distributes computers and computer peripherals such as printers.	The authors describe evaluations of several changes in the HP supply chain **network design** including "design for localization" which requires that local distribution centers customize products for local countries, rather than relying on a distant factory to perform this step. This allows factories to reduce total inventory and allows demand uncertainty to be managed both at the local and factory levels. The authors describe the strategy of **postponement** of product customization. This allows the greatest possible flexibility to respond to changing customer demands. These supply chain initiatives enabled HP to reduce inventory levels by 10-30%; redesign of HP's European distribution network saved the company $8 million annually; product postponement saved the company money and improved service. Supply chain management strategies such as "design for localization" and postponement increased order fulfillment (the percentage of customer orders that can be filled immediately) and contributed to the company's profits directly (by decreasing inventories) and indirectly (by increasing customer satisfaction).
Ernst, Kamrad[59]	**Hewlett-Packard**	HP adopted **postponement** and **modularization** principles in its production of the company's popular DeskJet printers, allowing different models to share manuals, software and accessories. The result was a 187% decrease in material handling cost and a 47% reduction in storage space.

Reference	Company/supply chain under evaluation	Key lessons learned from the supply chain case study
Lin, et al.[50]	**IBM** manufactures personal computers (PCs) and servers.	Changes in IBM's supply chain **network design,** including reductions in the number of assembly facilities, resulted in a 6% improvement in customer service and a 5% reduction in inventories. **Postponement** of computer customization cut costs by 12% while improving service. Improved i**nventory management** (specifically, pooling of inventories at regional warehouses) resulted in a 50% reduction in inventory levels, while maintaining the same level of customer service. IBM's supply chain redesign resulted in $650 million in annual savings.
Nahmias[56]	**IBM**	IBM optimized **inventory management** in its supply chain. This resulted in improved service and $20 million in annual savings.
Cheng, et al.[57]	**IBM**	IBM used **information management and inventory management** to cut costs. IBM used customer demand information from retailers to optimize inventories for its configure-to-order operations. IBM employed risk pooling strategies to significantly reduce inventories: when inventories are consolidated, less inventory can be held while still providing the same level of customer service.
Arntzen, et al.[51]	**Digital Equipment Corporation** (DEC) manufactures computers.	DEC optimized its supply chain **network design**. By reducing the number of manufacturing plants from 33 to 12 and service facilities from 34 to 17, DEC saved $300 million in operating costs, $80 million in service facility costs, and $70 million in inventory costs.
Davis[52]	**General Electric** (GE) Transportation Systems manufactures railway locomotives and motors for other off-highway vehicles.	GE examined its supply chain **network design**. Network redesign resulted in fewer purchasing entities. Remaining entities achieved improved **coordination**, resulting in an estimated total savings to GE of $4 million.
Mohammed, Hammond[53]	**Polaroid** manufactures a variety of instant photographic products.	Polaroid examined its supply chain **network design**. Polaroid changed its European distribution system from 12 local warehouses to a single centralized inventory location. Operating costs were reduced by $5 million annually (due to inventory pooling and reduced warehouse operation costs) and customer service improved. However, local managers required **incentives** to move to a regional warehousing system.
Graves, Willems[55]	**Eastman Kodak** manufactures cameras and camera accessories.	Kodak examined its supply chain **network design** and **inventory management** in its warehouses. Regionalization of warehouses for safety stock (inventories of component parts) for their high-end digital camera division minimized inventories by as much as 30% and improved delivery times. (The authors describe a free software and optimization algorithm for the placement of strategic inventories they applied to the Eastman Kodak supply chain [available at: http://web.mit.edu/lfmrg3/www/]. [88])

Reference	Company/supply chain under evaluation	Key lessons learned from the supply chain case study
Sery, et al.[54]	**BASF Group** manufactures a range of chemicals and chemical related products.	After examining its supply chain **network design**, BASF regionalized its distribution network, moving from 86 distribution centers to 12 centers. As a result, service improved and costs decreased. Cost savings were about 6% of original transportation, facility and inventory costs. Some savings came from improved network design; other savings resulted from improvements in **inventory management.**
Karabakal, et al.[80]	**Volkswagen** (VW) of America imports and distributes Volkswagen and Audi vehicles in the United States.	VW of America examined its supply chain **network design**. The company increased its distribution centers from 5 to 12. This resulted in improved service and reduced costs for dealers in the Midwest region of the United States. However, the 12 distribution centers could not maintain sufficient inventory of certain very popular models to remain financially viable.[*]
Ernst & Kamrad[59]	**Suzuki** is an automotive manufacturer.	**Modularization** of new car design, so that cars share as much as 70% of their parts with other models, allowed Suzuki to minimize inventory levels of component parts.
Brown, et al.[60]	**Xilinx** manufactures semiconductors.	**Postponement** of product customization helped Xilinx reduce its inventory by 23%.
Maniscalco & Christen[45]	**EMS Incident Management System** (IMS) provides logistical support and command and control for emergency medicine professionals.	IMS is partly a system for **inventory management**. Push-packs (inventories) of emergency supplies can be regionally stored for rapid response following an emergency that requires a major EMS response.
Burns[48]	**OmniCell.com** manufactures "smart cabinets" that automate the dispensing of medical supplies and pharmaceuticals. These cabinets require users to enter a code before removing supplies and the product facilitates tracking of supplies and provides information used automated reordering of supplies.	OmniCell.com has a web-based procurement platform (called OmniBuyer) for **inventory management** and **management of information**. OmniBuyer offers a customized multisupplier catalogue that automates the approval and workflow process. This purchasing program links to all automated supply cabinets so that suppliers can automatically replenish depleted stocks. Users of OmniBuyer report savings in personnel costs, inventory costs, and greater compliance with negotiated purchasing contracts. However, the system is not widely used throughout the health care supply chain, and even in facilities where it is used, it is not universally used in all departments. Many users remove items without pressing the buttons required for the inventory management system to log the transaction.
Hahn, et al.[81]	**Hyundai** Motor Company is an international car manufacturer based in South Korea.	Supply chain **coordination** led to improved customer service (cars were delivered to dealerships more quickly). Improvement in customer service not quantified by the authors.
Thonemann, Brandeau[61]	An unnamed major **automobile manufacturer**.	The auto manufacturer incorporated **modularization** into the design of automobile components. The company found that designing products using common components, even if those components are more expensive than customized components, can save money. An appropriate balance must be struck between no commonality and full commonality.
Ernst & Kamrad[59]	**Magnero-Marelli** is an international automotive component manufacturer.	The company streamlined and reorganized its French manufacturing facilities, resulting in simplified material flow and minimized inventories. Specific savings from **inventory reduction** not reported by the authors.

[*]Volkswagen was able to reduce costs and improve customer service by *increasing* the number of its distribution centers, but several other companies found that *decreasing* the number of distribution centers achieved the same result. Each supply chain is unique, so the appropriate number of entities in each level of the supply chain (e.g., suppliers, manufacturers, warehouses, distribution centers) depends on the nature of the particular supply chain.

Reference	Company/supply chain under evaluation	Key lessons learned from the supply chain case study
Rao, et al.[82]	**Caterpillar, Inc.** manufactures construction and mining equipment, diesel and natural gas engines, and industrial gas turbines.	Managers at Caterpillar, Inc. developed a system to design a rapid-response supply chain and to determine the most cost-effective level of regionalization. This modeling system recommended modifications in supply chain **network design,** that resulted in cost savings for Caterpillar, Inc. Dollar amount of cost savings not reported by the authors.
Nahmias[56]	**Dell Computer** manufactures made-to-order personal computers (PCs).	Dell Computer was able to dominate the PC market through innovations in **inventory management** and supply chain **network design**. For example, Dell builds every computer to order, allowing the company to hold no finished products as stock, limiting inventory to component parts.
Hoyt, Lee[83]	**Lucent Technologies** provides networking systems and software to local and long distance telephone companies and cable companies.	Lucent examined its supply chain **network design**. Redesign of its network resulted in reduced costs and improved customer service. Cost savings and improvements in customer service not quantified by the authors.
Chen, et al.[84]	**Instill Corporation** provides electronic commerce and information services to the foodservice industry.	Instill Corp. created and marketed products to assist in the implementation of Efficient Foodservice Response (EFR), resulting in more efficient **information management** and product flows in the food service industry.
Ernst, Kamrad[59]	**Texas Instruments** manufactures electronic equipment.	Texas Instruments employs **postponement** to enhance its capacity to manufacture distinct products, giving Texas Instruments "a strategic edge". [59] Benefit to Texas Instruments not otherwise quantified by the authors.
Takeda, Matsuo[85]	**7-11**, **York Mart** and **Yokado** retail perishable goods such as fresh-baked bread, morning-harvested vegetables and sushi in Japan.	For timely and coordinated distribution of perishable products, Japanese companies rely on real-time **management o**f **information**, hourly logistics **coordination**, and **coordination** between members of the supply chain.
Nahmias[56]	**Wal-Mart** is an international discount retailer.	Wal-Mart was able to dominate the competitive discount market largely through its supply chain **network design** and through effective **management of information**. For example, Wal-Mart invested in information technologies that link cash registers in retail stores directly to company headquarters, keeping inventory records and demand forecasts as accurate as possible. Wal-Mart also invests heavily in distribution centers in order to keep stores supplied in a timely fashion.
Lockamy, et al.[86]	**3M** manufactures over 60,000 products marketed worldwide.	3M examined its supply chain **network design** and its processes for **management of information**. Redesign of 3M's distribution system and the introduction of electronic data interchange led to improved service and reduced costs.
Ghemawat, Nueno[87]	**Zara**, a Spanish clothing retail chain, produces and distributes fashion items.	Zara remained competitive with its supply chain **network design**, specifically its supplier and distribution network. The company maintains a single distribution center and no warehouses, allowing inventory levels to remain low and eliminating the "bullwhip" effect (wildly fluctuating order sizes placed to suppliers caused by inadequate logistics information and improper resupply procedures at intermediate-level distribution facilities). A carefully configured network of suppliers and internal manufacturers also contributes to the company's ability to respond quickly to demands from individual stores.

Table 10. Regionalization of Outbreak Response

Disease	Time and place	Scope of outbreak	Lessons learned
Smallpox[235, 363]	New York City, 1947	12 cases and 2 deaths (case fatality rate of 17%); 6 million residents of New York City vaccinated in less than a month (5 million were vaccinated in two weeks).	• Benefit of consistent, accurate and calming communication from top officials (Mayor of NYC) • Successful distribution and administration of millions of doses of vaccine using volunteer clinicians at police precincts
Smallpox[364, 365]	Boston, 1901-3	1596 cases and 270 deaths (case fatality rate 17%).	• Benefit of teams of clinicians going out into the community to vaccinate at-risk people who might not otherwise seek vaccination (e.g., homeless men) • Problem of incentivizing public to be vaccinated against smallpox given difficulty estimating the probability of smallpox bioterrorism • Benefit of disease-designated hospitals for infection control
Smallpox pre-event vaccination campaign[237, 408-433]	Acute care hospitals and public health departments across the United States, 2003	Phase 1 of the vaccination campaign intended to vaccinate 500,000 civilian responders; fewer than 30,000 actually vaccinated as of March 16, 2003.	• Problem of incentivizing responders to be vaccinated against smallpox without compensation in place for adverse events • Problem of identifying of personnel to serve on teams of local responders
Severe Acute Respiratory Syndrome (SARS)[2, 214-216, 219-221, 223-227, 230-234, 238-241, 243-306, 434, 436]	International outbreak with the majority of victims in China, Hong Kong, Singapore and Canada, 2003.	As of 11 July 2003, 8427 patients infected with SARS in 29 countries; 813 died.	• Importance of timely, accurate disease reporting internationally • Benefit of internationally networked laboratory response • Benefit of disease-designated hospitals for infection control and volume outcome associations
West Nile Virus[77, 91, 217, 228, 236, 242, 311, 366-386]	New York City, 1999	59 cases hospitalized and seven died. No more cases reported after initiation of vector mosquito measures.	• Better interjurisdictional agreements for information sharing should be in place before an outbreak • Public must be educated and incentivized to perform key public health functions, such as reporting dead birds • Information sharing between agencies (e.g., between public health and animal health agencies) should be in place before an outbreak to perform more complete surveillance for zoonotic illness • More than one laboratory in the United States should possess the capability to perform diagnostic tests for a pathogen
Pandemic Influenza[213, 218, 305, 338, 387-407]	Worldwide, 1918-1919	International outbreak of swine flu, possibly of Spanish origin. 500,000 people dead in the United States; estimated worldwide deaths 20-40 million.	• Problem of educating and incentivizing public to follow infection control recommendations • Critical shortage of caskets and mortuaries • Networks of nurses and physicians formed by the ARC and the U.S. Public Health Service from a pool of personnel not able to serve as part of the overseas war effort

Disease	Time and place	Scope of outbreak	Lessons learned
Hantavirus Pulmonary Syndrome[320, 323-339, 341-347, 437]	Four Corners region of the U.S. southwest, 1993	By October 1993, 42 cases and 25 dead.	• Benefit of unofficial networks of clinicians who communicate and consult with each other for the detection of geographically dispersed outbreaks (Indian Health Service) • Effective use of aeromedical resources to link community and regional hospitals
Meningococcal meningitis[348-362]	Mankato, Minnesota, 1995	Seven cases and one death; 30,000 people vaccinated.	• Need for standardized forms for obtaining informed consent to give prophylactic antibiotics (in multiple languages)
Cryptosporidiosis[307-319]	Milwaukee, Wisconsin, 1993	403,000 people made sick; the illness contributed to at least 100 premature deaths in immuno-compromised people.	• Benefit of prospective surveillance of water supply

Synthesis of Evidence about Regionalization of Responses for Disasters

> It is necessary that all of the resources and facilities of the State, its various departments and agencies, and all its political subdivisions, municipal corporations, and other public agencies be made available to prevent and combat the effects of disasters which may result from such calamities as flood, fire, earthquake, pestilence, war, sabotage, and riot; and it is desirable that each of the[se] parties… should voluntarily aid and assist each other in the event that a disaster should occur, by the interchange of services and facilities, including but not limited to, fire, police, medical and health, communication, and transportation services and facilities, to cope with the problems of rescue, relief, evacuation, rehabilitation, and reconstruction which would arise in the event of a disaster.
>
> —Earl Warren, Governor of California, November 15, 1950[438]

The International Federation of Red Cross and Red Crescent Societies defines a disaster as an event that causes more than ten deaths, affects more than 100 people, or leads to an appeal by those affected for assistance.[439] Excluding droughts and war, approximately 500 such disasters occur annually worldwide, killing 50,000, injuring an additional 74,000, and displacing 5 million. More than 80 million people are affected by disasters in some way each year.[439]

Much of the U.S. response infrastructure designed for disasters would be activated during a bioterrorism response. Additionally, many of the primary response tasks necessitated by disasters are identical to the tasks required for a bioterrorism response. These include declarations of emergency; evacuation; quarantine; crowd and traffic control; emergency provision of mental health services for responders, victims, caregivers and their families; and volunteer utilization and control. Because earthquakes, hurricanes, floods, and volcanic eruptions tend to recur in specific geographic areas, elements of the U.S. planning and response infrastructure for disasters have been regionalized. As a result, in 1997, when FEMA was required by Congressional mandate to assess states' level of disaster readiness, the Agency concluded that states generally do have the ability to respond to disasters without significant federal assistance.[440] The following sections describe the regionalization of disaster management preparedness and response programs, present the results of evaluations of these regionalization

Lessons Learned from the Disaster Literature for the Regionalization of Services for Bioterrorism Preparedness

From our review of the disaster response literature, we synthesized three key lessons learned.

1. *Information management, using common technology platforms, is essential for assessing the needs of the local community and the resources available to them, and for coordinating responses from regional agencies.* The disaster literature emphasizes the need for updated information so that response resources can be dispatched to those in need in a timely manner. Bioterrorism responses may benefit from a common technology platform. These may be as simple as a common radio frequency or as complicated as multiple computer networks from different regions communicating with each other to exchange information on resource placement and availability.

2. *A key component of effective regional responses to disasters includes mutually agreed upon pre-event protocols that establish chain of command structures.* The evidence suggests that these protocols are most effective when they delineate the chain of command for an event at several levels: a chain of command utilizing only local responders should be established, as should plans for how the chain of command changes when regional and federal response agencies become involved.

3. *Mutual aid agreements are key components for providing surge capacity for regional response to disasters.* These agreements ensure that every locale does not have to be staffed and prepared for a maximal intensity event. They enable risk to be spread among several locales, and provide cost-sharing of disaster preparedness. Mutual aid agreements for bioterrorism are likely to benefit from careful pre-event consideration of liability issues, remuneration, and licensing.

Table 11. Lessons Learned From Regionalized Responses to Disasters

System	Description of System and its Regionalization	Lessons Learned
The Homeland Security Advisory System[459-462]	Uses colors to describe the level of terrorist threat from Red (severe threat) to Green (low threat) (Figure 7). Threat level set by the Secretary of Homeland Security, in coordination with other officials. Most alerts are given on a national basis and not regionalized or otherwise limited to geographic areas or specific terrorist targets.[459, 460]	A warning system benefits from specifying actions to be taken for a particular alert.
Emergency Alert System[465-467, 507]	General alert system used to issue warnings about weather emergencies and other natural disasters. Fully integrated with the National Weather Service and FEMA. The system includes the Radiological Emergency Preparedness Program, which requires all broadcast media to purchase and maintain equipment for the automated broadcasting of emergency messages. The Radiological Emergency Preparedness Program additionally designates 30 National Primary Stations (both radio and television), which are required to automatically broadcast presidential messages.	Pre-event designation of communication resources facilitates the timeliness of alerts issued to the public.

System	Description of System and its Regionalization	Lessons Learned
Aviation Incident Response (AIR) Team[468]	AIR Team members are mental health professionals with special aviation incident/grief counseling training and experience. Sponsored by the American Red Cross, AIR Teams are drawn from a pool of 400 trained mental health professionals deployable immediately following a domestic aviation disaster. Members of the AIR team are positioned near every major U.S. airport, allowing for timely deployment following a disaster.[468]	Regionally organized and localized groups of highly trained professionals can be rapidly deployed to augment services available locally.
Renal Disaster Task Force[493]	Maintained by the International Society of Nephrologists for disaster response, an advance team of nephrologists performs a needs assessment, after which additional assistance in the form of equipment, logistic support, transportation, and personnel are delivered. In the case of the 1988 Armenian earthquake, the Task Force established a presence in Armenia within 24 hours of the disaster and provided dialysis to nearly 500 people suffering from acute renal failure following crush injuries. The Task Force is internationally organized in three regions. Each region maintains rosters with the names of volunteers who can be deployed on short notice, as well as stocks of hardware and supplies to facilitate a response to a major earthquake requiring renal intervention.[493]	Regionally organized groups of highly trained professionals can be rapidly deployed to provide services unavailable locally.
Medecins Sans Frontieres (MSF)[469-473, 494]	The mission of MSF is to provide "emergency medical assistance to populations in danger." MSF operates under a formal hierarchy that includes four international regions with operations in 80 countries to which it dispatches over 2500 volunteer medical personnel.[473]	Highly trained volunteers can be rapidly deployed to augment a local response.
Urban Search and Rescue (USAR) Teams[495]	Maintained by FEMA, the 28 regionally located USAR teams are highly trained and equipped to travel to disaster scenes to rescue victims from collapsed buildings. Following the 1995 bombing of the Alfred P. Murrah Federal Building in Oklahoma City, FEMA deployed 11 USAR teams.	Regionally established teams with training and equipment can provide essential services unavailable locally.
Marine Corps' Chemical and Biological Incident Response Force (CBIRF)[474, 475]	This team is trained in weapons of mass destruction mitigation services including security, medical aid, decontamination, and search/rescue. Based in North Carolina, the 350-person team is designed to be deployed anywhere in the United States in response to a known incident, or can be pre-positioned at a high-risk mass gatherings such as the Olympic Games or a political inauguration.[476]	A single, highly specialized team may contribute to local responses.
Mental Health Community Response Coalition (MHCRC)[496]	Created by mental health responders following the September 11, 2001 attack on the Pentagon, it includes representatives from a variety of response organizations such as the American Red Cross, the Virginia Disaster Response Network, and the Capitol Area Crisis Response Team to manage the long-term mental health needs of those affected by the attack on the Pentagon. The group met regularly for months following the attack to avoid duplication of efforts, prevent any single agency from becoming overwhelmed, identify victims with unmet needs (e.g., non-English speakers, friends of victims), and facilitate collaboration and referral.[496]	Response agencies with similar or related purposes can effectively coordinate disaster response services in a geographic area.
World Food Program (WFP)[477]	The principal United Nations agency responsible for famine relief. In 1999, the WFP fed 89 million people in 82 countries organized according to the seven regional bureaus. To facilitate its logistics, the WFP partners extensively with governments, other UN agencies, and with non-government organizations. The non-government organizations are largely charged with the transport, storage, and distribution of food on behalf of the WFP.	The regional organization of the WFP facilitates famine surveillance, the establishment of relationships between WFP and local governments, and more consistent logistical support.
Veterans' Affairs (VA) mobile health clinics[497-499]	Deployable to the scene of national disasters to provide primary care to victims (including non-veterans).[497] Following the Northridge earthquake, the VA hospital in Spokane, Washington sent mobile outpatient medical clinics to the LA area.[499] Mobile health clinics have also assisted in the aftermath of Hurricane Andrew and 1993 Midwest flooding.[498]	Regional resources can be deployed to provide ongoing services (as opposed to disaster-related services) to reduce the effect of the disaster on the population.

System	Description of System and its Regionalization	Lessons Learned
International Federation of Red Cross and Red Crescent Societies (IFRC)[488, 489]	IFRC coordinates relief efforts of individual National Societies according to a regional plan: The IFRC has 14 regional offices, 63 country field offices, six sub-delegations, and two regional logistics centers. This regional structure allows for graded levels of disaster response: National Societies respond to small emergencies, regional offices respond to mid-size emergencies, and the IFRC in Geneva responds to large disasters.[488] This plan required providing training to local responders at the National Society level and pre-positioning supplies at the regional level.[489]	The regional organization of the IFRC has developed through iterative application of lessons learned from prior responses.
United Nations Joint Logistics Centre (UNJLC)[500, 501]	Coordinates logistics (particularly transportation needs) among UN organizations operating in a single geographic area.[500, 501]	Expert logistical support can be coordinated and may improve cost-efficiencies for numerous agencies working in the same region.

Synthesis of Evidence about Regionalization of Emergency Trauma Care

We searched the medical literature for examples of regionalization of the delivery of specialized medical care (e.g., care for the severely burned, neonatal intensive care, and trauma care). We found that regionalized trauma care was the most extensively evaluated. Thus, we reviewed the literature in this area in more detail to identify lessons that could be applied to regionalization of bioterrorism responses.

The purpose of the trauma care system in the United States is to provide rapid, coordinated medical services to injured patients by matching "a facility's resources with a patient's needs so that optimal and cost-effective care is achieved."[508] This purpose is achieved through a coordinated system in which pre-designated trauma hospitals work with emergency medical personnel to expedite the delivery of specialized trauma care. Trauma systems are relevant to regionalization of bioterrorism preparedness and response for two reasons: trauma systems have adopted regional approaches that can serve as models for regionalization of components of bioterrorism preparedness and response, and elements of the trauma system such as hospitals, emergency response personnel, management of patients, and communication systems are essential components of a bioterrorism response. The following sections describe the regionalization of trauma systems, present the results of evaluations of these regionalization efforts, and summarize the evidence for and against regionalization of trauma-related services relevant to bioterrorism preparedness and response.

Regionalization of Trauma Care

A regionalized trauma system includes classification of hospitals within the region according to the services that they can provide, protocols for pre-hospital trauma care and transportation by emergency medical personnel, and coordination of these pre-hospital and hospital-based services.[509] Regionalization of trauma care efforts in the 1980s and 1990s was spurred by a

and transportation of patients to appropriate trauma care centers are directly relevant to the field assessment and triage that will need to be conducted during a bioterrorism response. A regionalized bioterrorism response may benefit from similar protocols so that first responders know where and how to transport exposed patients in a timely manner so as to contain exposure and ensure rapid delivery of definitive care to the patients.

3. *An established communication network is essential to the coordinated regionalized provision of trauma care*. It is likely that an established communication network such as that used by trauma care systems could also be used during a bioterrorism event. The existing traumacommunications network enables emergency medical personnel to reach the site of an accident in a timely manner and permits ongoing communication between the field and the destination hospital. Such a system could play an equally important role during a bioterrorism response. It could serve as a centralized command and control system to assist in managing the flow of patients to regional network hospitals that have the capacity to care for them.

4. *Correctly aligned incentives, particularly sufficient funding, are critical to retaining the participation of designated trauma hospitals.* The included articles suggest that regionalized trauma care systems do not provide sufficient incentives for some hospitals to remain in the system. A bioterrorism response system is likely to benefit from clearly outlined mechanisms for reimbursement to hospitals designated to care for patients within a given regional network so that hospitals are less likely to refuse to participate or to drop their designations.

5. *Data registries contribute to continuous evaluation and improvement of trauma systems.* Ongoing evaluation of trauma care systems is important to identify areas for performance improvement. One source of data to conduct such evaluations is a standardized data registry. Such a registry allows comparison of one system's performance with similar systems, and facilitates identification of areas for improvement. A bioterrorism response system may benefit from periodic, region-wide evaluations. Such evaluations could be facilitated by the use of data registries.

Table 12. Selected Evaluations of Regionalized Trauma Care Systems

Study	Study Design	Components of Regionalization	Outcomes Evaluated	Special Population
Sampalis, et al.[509]	Prospective study evaluating trauma care effectiveness during each stage of the regionalization process (pre-during-post)	Designation of hospitals; triage and transport protocols; communication network; pre-hospital care through improved EMS training	Mortality rate during each stage of regionalization: Pre-implementation: 52%, Stage 1: 32%, Stage 2: 19%, Stage 3: 18%, (p<0.0001). Pre-hospital time decreased from 62 to 44 minutes (p<0.001); mean time to admission after arrival decreased from 151 to 128 minutes (p<0.001). A multivariate analysis showed that treatment at a Level 1 center, decreased pre-hospital time and direct transport to the tertiary center contributed to the decreased mortality	Not stated

Study	Study Design	Components of Regionalization	Outcomes Evaluated	Special Population
Mullins & Mann[37]	Systematic review of population-based studies evaluating the effectiveness of regionalized trauma care systems	Designation of hospitals; triage and transport protocols	15%-20% improvement in survival rate; early transfer from rural to tertiary centers; favorable volume-outcome association (>350 patients treated annually) and restricted number of Level I centers.	Rural areas
Nathens, et al.[38]	Review of literature to evaluate volume-outcome association for trauma care	None stated	Adjusted mortality: OR 1.3 times greater at low volume centers (<140 patients/two yrs) compared with high volume centers (>200 pts/two yrs); predictor of outcome was annual number of seriously injured patients per surgeon and the threshold needed was 35 pts/yr. Length of stay was lower in centers with high volume. Studied the relationship between volume and outcome in 31 academic trauma centers across the United States and found that there was a benefit in mortality rate when hospital volume exceeded 650; however, volume-outcome association benefit was restricted to severely injured patients	Not stated
Jurkovich & Mock[521]	Systematic review of studies that evaluated regionalized trauma care system effectiveness by studying registry-based data	Designation of hospitals	Improved survival after trauma center designation and improved infrastructure in trauma centers. Important to have standardized data registries to enable comparisons across different systems	Rural areas
MacKenzie[551]	Systematic review of panel studies evaluating regionalization of trauma care systems. Panel studies determine the preventable death rate where preventability is defined by physician review.	Designation of hospitals	The preventable death rate ranged from 22% to 86% before designation of hospitals, which dropped to between 10% and 40% after designation. There was a decrease in the percent of errors after implementation of regionalized trauma care systems	Not stated
Mann, et al.[523]	Systematic review of population-based studies, registry-based studies and panel studies evaluating regionalized trauma care effectiveness.	None stated	The findings consistently support regionalization of trauma care systems; although the quality of evidence considered to be relatively poor.	Not stated
Hulka[544]	Systematic review of studies evaluating pediatric trauma care systems	Designation of hospitals	Decreased risk-adjusted logistic odds of death in seriously injured children: Odds Ratio: pre-trauma system vs. post-trauma system: 1.17 vs. 0.68 respectively, $p<0.01$	Pediatric
Nathens, et al.[527]	Pre-post implementation study. Assessed change in motor vehicle crash mortality over time after the initial designation of trauma centers	Designation of hospitals; triage and transport protocols; pre-hospital care through improved EMS training.	Mortality decreased from 16.2 to 11.6 per 100,000 person-years. There was an overall 8% decrease in motor vehicle crash mortality 15 years after trauma system implementation.	Not stated
Miller & Levy[525]	Assessed the impact of regionalization on costs by comparing states with and without established trauma systems. Conducted multivariate regression analysis to account for potential confounding variables	Designation of hospitals; triage and transport protocols; pre-hospital care through improved EMS training	15.5% lower costs per hospital injury episode in states with trauma care systems. Analysis showed a savings average of $1025 per case. Also observed a high mortality rates in hospitals with low volume of trauma cases.	Rural areas

Study	Study Design	Components of Regionalization	Outcomes Evaluated	Special Population
Smith[532]	Review of published articles that evaluated patient outcomes after trauma care regionalization	Designation of hospitals; triage and transport protocols; communication network; pre-hospital care through improved EMS training	Found high mortality rates in hospitals with a low volume of trauma cases	Not stated
Abernathy, et al.[536]	Pre-post implementation study. Assessed outcomes after the implementation of a voluntary trauma care system	Designation of hospitals; centralized communications center	Lower mortality rates: OR 0.48 (95% CI: 0.32-0.71); Shorter length of stay: 16.5 days vs. 19.5 days, (p<0.05); Decreased mean costs: $29,795 vs. $34,983, ($p$<0.05) after implementation of system	Not stated
West, et al.[571]	Pre-post implementation study. Reviewed autopsy records to determine the preventable death rate where the rate was determined by physician review	Designation of hospitals; triage and transport protocols	The preventable death rate decreased to 9% after implementation of system compared with 71% and 73% before implementation. The rate of appropriate care after implementation was 89% compared with 20% and 14% before implementation	Not stated
Mullins, et al.[36]	Compared outcomes between two states with trauma centers at different stages in the implementation of system. Also had a pre-post implementation comparison within a state. Conducted multiple logistic regression models to determine effect of a regionalized trauma system	Designation of hospitals; triage and transport protocols	Adjusted mortality rate OR=0.80 (0.7-0.9). An overall 20% reduction in mortality after implementation compared with another state in pre-implementation period.	Rural areas
Mullins, et al.[34]	Assessed change in mortality rates during the pre-implementation, early implementation and established phase of a regionalized trauma care system	Designation of hospitals; triage and transport protocols	Adjusted risk of death: in adults: OR 0.65 (95% CI: 0.51-0.81) and in children: 0.47 (0.26-0.84) after establishment of trauma system	Not stated
Mullins, et al.[35]	Pre-post implementation design. Assessed adjusted risk of death	Designation of hospitals; triage and transport protocols; pre-hospital care through improved emergency medical services training.	Adjusted risk of death: OR 0.82 (95% CI: 0.73-0.92) after implementation of regionalized system	Rural areas
Cales[569]	Pre-post implementation design. Assessed the preventable death rate. Preventability determined by physician review of records.	Designation of hospitals; triage and transport protocols; pre-hospital care through improved emergency medical services training.	The preventable death rate decreased from 34% to 15% after implementation. Average prehospital time increased one minute and transport time to hospital increased two and a half minutes after implementation; Appropriate pre-hospital care increased from 34% to 75%; Appropriate emergency department care increased from 38% to 90% after implementation.	Not stated

systems have evolved as well. Several state-of-the-art systems strip away individual-level information, utilizing these data only when an abnormal disease pattern has been identified.[68]

Lessons Learned From Regionalization of Surveillance Systems

Regionalization of surveillance systems has important implications for key processes related to data collection, analysis, and decision making and response.

1. *There is a need for evaluations of regionalization of surveillance data collection and analysis.* Although numerous syndromic surveillance efforts in local areas are promising, there has not been an evaluation of the tradeoffs in terms of costs and benefits of regionalizing some components of bioterrorism surveillance (e.g., costs of data collection, analysis and reporting, false positive and false negative rates). Given this lack of evaluative data, we developed a simulation model to evaluate some of these costs and benefits. This model is presented in the next section.

2. *Local data collectors may not be incentivized to collect surveillance data, particularly if they are analyzed regionally.* If a regionalized surveillance system is based on a model of local data collection with regional analysis, considerations of means to reduce costs of data collection and to share relevant analyses with local data collectors may enhance local participation.

3. *Decision-making and chain of command must be clear to all stakeholders.* Decision-making and response could occur at the local, state, regional, or national level, and would depend on outbreak characteristics and the level of response needed.

4. *A common technology platform may facilitate the collection and analysis of surveillance data.* This common platform may be composed of new technologic infrastructure or translation tools that enable existing legacy systems to communicate with one another.

5. *Privacy issues are a key concern as increasingly detailed surveillance data is collected and disseminated.* Collection and analysis of surveillance data must be able to protect individual privacy while being sufficiently detailed to detect new outbreaks.

Table 13. Syndromic Surveillance Systems

System	Geographic Area Under Surveillance	Participants	Data Sources/Types
Connecticut Hospital Admissions Syndromic Surveillance[64]	Connecticut	Connecticut Dept of Health, 31 acute care hospitals	Non-scheduled hospital admission data

System	Geographic Area Under Surveillance	Participants	Data Sources/Types
Denver Center for Public Health Preparedness[65]	Denver, Colorado area	Denver Public Health Dept, one hospital, one ED*, EMS, ~24 community- and school-based clinics, poison/drug center	Chief complaint data (nurse advice line, ED, EMS), ICD-9 data (ED, hospital, clinics)
Electronic Surveillance System for the Early Notification of Community-based Epidemics I (ESSENCE I)[66]	All military installations worldwide	104 DoD primary care and emergency clinics, 121 Army, 100 Navy, 80 Air Force, and two Coast Guard installations	ICD-9 data
Electronic Surveillance System for the Early Notification of Community-based Epidemics II (ESSENCE II)[67]	Northern Capital Area (Washington, D.C. area)	Military and civilian data from area emergency rooms and clinics, local pharmacies, nurse hotline, school system local veterinaries, area laboratories	ICD-9 data (clinics), chief complaint data (ED), over the counter drug sales, nurse hotline calls, school absenteeism reports, veterinary reports, laboratory reports
Indianapolis Network for Patient Care[65]	Indianapolis, Indiana area	Five health systems, Indiana University School of Medicine, Regenstrief Institute, 11 hospitals, county health dept, MD practices	Chief complaint data, coded diagnoses and procedures, immunizations, medications, allergies, electrocardiogram tracings, echocardiogram data, radiographic images, vital signs, demographic data
National Bioterrorism Syndromic Surveillance Demonstration Program[68]	National, although data from five health plans based in four states	CDC, American Assoc of Health Plans, Harvard University, five health plans based in Massachusetts, Minnesota, Colorado, and Texas	Ambulatory care data – focus on aggregated data rather than encounter level data
New Hampshire ED Syndromic Surveillance System[68]	New Hampshire	16 sentinel EDs	Data manually collected on four syndromic categories
New York City System[69]	New York City metropolitan area	EMS data	EMS data, pharmacy sales data
Real-Time Outbreak Detection System[65, 70, 71]	Pittsburgh, Pennsylvania area	17 hospitals, University of Pittsburgh	ICD-9 data, chief complaint data
Syndromic Surveillance for Bioterrorism[72]	Minneapolis/St Paul Minnesota area	HealthPartners Medical Group, Minnesota Dept of Health	Pt encounter data, ICD-9 data
Syndromic Surveillance Information Collection System[73]	Seattle, Washington area	Four health care systems, University of Wash, three EDs, 10 clinics, EMS, school system	ICD-9 data, demographics, chief complaint data, school absenteeism reports, EMS dispatch data

Key Question 1. What are the key tasks of local responders during a bioterrorism event?

Key Question 2. What resources do local responders require to perform the tasks identified in Key Question 1?

The preceding sections in this chapter have discussed the regionalization of supply chains; existing infrastructure for regional response to bioterrorism; actual regional responses to the 2001 anthrax attacks, naturally occurring outbreaks, and natural disasters; regionalization of emergency trauma care; and regionalized surveillance systems. From the literature described in each section, we abstracted information about the tasks of local responders during a bioterrorism response (Key Question 1) and information about the resources required to perform those tasks (Key Question 2). In this section we synthesize all of the information about the tasks of local responders during bioterrorism-relevant events. We present our response to Key Questions 1 and 2 in Table 14.

The included articles describe nine main task categories: preparedness planning, field assessment and triage, diagnosis, management of the acutely ill, prevention of the spread of disease, surveillance, outbreak investigation, communication, and emergency management. For each of these main tasks, we considered the subtasks responders are required to perform. For example, subtasks of surveillance include collection, analysis, and reporting of surveillance data.

Broadly, the resources required for these tasks and subtasks are described by three main categories: personnel, material, and information. Additionally, for each task, financial resources are required to train and employ the relevant personnel and to procure and maintain the relevant materials and information.

We conclude that a bioterrorism response requires numerous, heterogeneous tasks requiring a complex array of trained personnel, material, and information. We define these three categories broadly. For example, material resources include any of the physical resources required for a bioterrorism response ranging from vaccines and pharmaceutical supplies to hospital beds and isolation rooms. The performance of these tasks and the delivery of these resources are potential targets for regionalization.

Table 14. Examples of Tasks, Subtasks, and Resources Required for a Bioterrorism Response

Main Task	Example Subtasks	Example Resources
Preparedness planning	• Planning for distribution and dispensing of prophylactic antibiotics • Relationship development (partnering) among responder groups • Pre-event vaccinations of first responders and health care workers • Planning, execution, and evaluation of preparedness drills	Personnel • Decisionmakers from hospitals, emergency management, and public health (e.g., CDC) • Representatives of relevant government agencies (e.g., FEMA and HRSA) • Representatives of relevant non-government bodies (e.g., Joint Commission on Accreditation of Healthcare Organizations, American Hospital Association) • Logisticians Material • Necessary vaccines and supplies for pre-attack vaccination • Guidelines for preparedness planning

Main Task	Example Subtasks	Example Resources
	• Determination of local capacity (e.g., hospital and laboratory capacity) and planning for surge capacity	Information • Understanding of relevant organizations and their scope of responsibility at each regional response level • Understanding of the regional and national resources in place to assist a local community in the event of a bioterrorism event • Familiarity with preparedness plans through drills and other training exercises • Understanding of changes needed to guidelines based on real-time feedback from bioterrorism affected areas (e.g., revisions to treatment protocol based on what is working in field during an attack)
Field assessment and triage	• Transportation of victims • Use of portable diagnostic and detection equipment • First responder protection • Determination of probability of exposure to biothreat agent • Environmental testing for biothreat agents	Personnel • Local first responders and those obtained through mutual aid agreements • Logisticians Material • Transportation equipment • Decontamination equipment • First responder protective gear • Portable diagnostic detection equipment Information • Sensitivity and specificity data for portable detection equipment • Updated information about emerging outbreaks and necessary personal protective equipment
Diagnosis	• Ordering of appropriate diagnostic tests • Interpretation of diagnostic test results	Personnel • Clinicians • First responders Material • Decision support systems to facilitate diagnostic decision making • Sufficient laboratory surge capacity for large increases in test requests Information • Test result data • Updated information about emerging outbreak updates to inform assessments of pretest probability of disease • Information about the natural history of bioterrorism-related diseases, their clinical presentation, and relevant diagnostic tests
Management of acutely ill	• Provision of definitive medical care • Fatality management • Distribution of supplies, equipment, and pharmaceuticals	Personnel • Clinicians • Security personnel to maintain security of hospitals • Mental health professionals • Pharmacists • Logisticians Material • Inventories of pharmaceuticals • Negative pressure isolation facilities • Critical care equipment: ventilators, chest tubes, oxygen delivery systems • Morgue facilities • Hospital surge capacity Information • Management guidelines from public health officials for clinicians • Information systems to manage the flow of patients through the hospital • Radiographic, laboratory, and clinical data

Main Task	Example Subtasks	Example Resources
Prevention of the spread of disease	• Prophylaxis of the exposed • Mass immunization • Isolation of infectious patients • Evacuation • Quarantine • Crowd and traffic control • Vector control	Personnel • Clinicians • Public health officials • Other public employees to serve as non-medical staff at dispensing sites • Members of the media to inform the public about prophylaxis and quarantine policies • Logisticians • Pharmacists to sort, re-package, and dispense medications • Security personnel to enforce quarantine and evacuation, maintain social order, manage traffic near hospitals and distribution sites • Vector control professionals Material • Pharmaceuticals and supplies for prophylaxis (e.g., vaccines, antibiotics, needles, and dressings) • Negative pressure isolation facilities • Sites for mass vaccination (e.g., schools and military facilities) • Parking • Supplies for mass care in the event of a large-scale evacuation (e.g., tents, food, portable toilets, etc.) Information • Prevention guidelines from public health officials for clinicians • Statutes and regulations relevant to quarantine decisions • Contraindications for prophylactic treatment • Home-care instructions for patients receiving prophylaxis and home treatment • Information regarding characteristics of infectious agent for decision making about quarantine, isolation, and evacuation
Surveillance	• Collection of surveillance data • Analysis of surveillance data • Reporting of surveillance analyses to relevant decisionmakers	Personnel • Clinicians, laboratory personnel, vector control professionals, animal control professionals, pharmacists and others for collection of bioterrorism surveillance data • Public health officials to collect, analyze and interpret surveillance data Material • Environmental detectors • Collection equipment for taking environmental samples in the field Information • Baseline data for bioterrorism-related syndromes • Sensitivity and specificity data for portable detection equipment
Outbreak investigation	• Contact tracing • Verification that the cases identified from the surveillance data represent an outbreak	Personnel • Epidemiologists and other public health officials • EIS officers Material • Laboratory capacity to verify suspected cases Information • Information about the characteristics of the exposure • Information about the person-to-person transmissibility of the biothreat agent used
Communication	• Communication system development • Clinicians' reporting of information about suspicious cases to public health authorities	Personnel • Public health officers • Clinicians and first responders • Members of the media • Trained personnel to staff information hotlines • Public health officials at all response levels

Main Task	Example Subtasks	Example Resources
	• Public health officials communicating news of outbreak to clinicians • Distribution of protocols for hospital preparedness planning; for field detection, triage, and management by first responders and clinicians • Communication with the public and prevention of mass panic	Material • Secure Web site to allow the rapid and safe electronic transmission of data and guidelines • Hotlines • Secure Web site to allow the rapid and safe electronic transmission of data and guidelines Information • Information regarding the nature of the biothreat agent, its potential for harm to first responders and clinicians, and its natural history • Guidelines for personal protection • Guidelines for the management of the acutely ill, the exposed, and family members of both • Guidelines for the public to protect themselves, or to seek care when appropriate
Emergency management	• Declaration of emergency • Command/Control • Crowd and traffic control • Shelter and feeding of evacuated/displaced persons • Process for continuous evaluation of needs and resources • Mental health services for responders, victims, caregivers, and their families • Volunteer management	Personnel • Emergency management professionals • Elected officials to declare emergency • Security personnel (e.g., police and military) • Mass care professionals (e.g., American Red Cross) • Mental health professionals • Logisticians Material • Command/control center • Supplies for mass care in the event of a large-scale evacuation (e.g., tents, food, portable toilets, etc.) Information • Information about capacity and need for services • Understanding of command control protocols, such as Incident Management System and the Hospital Emergency Incident Management System

Key Question 3. Which existing regional systems of delivery of goods and services could be relevant to supplying the resources identified in Key Question 2?

We found numerous systems and organizations with regionalized infrastructures engaged in the timely delivery of bioterrorism-relevant material, personnel, and information. These systems and organizations can be broadly categorized in two ways: by the level at which they primarily operate (local as opposed to regional) and by the type of response task they perform.

For this Evidence Report, we define a local response to bioterrorism as occurring under the jurisdiction of the local health officer. However, many relevant local responders and response organizations (such as clinicians, first responders, hospitals, and emergency management professionals) may not organize themselves in relationship to the local public health jurisdiction in which they work. Thus, if an article used a different definition of local, we deferred to their definition.

Regional responses fall into three broad categories: sub-state, multi-state, and federal. Most states utilize sub-state regions (often drawn according to county lines) for disaster planning. For example, in California (where regions encompass up to ten counties) these regions are an integral organizational element of the state's mutual aid agreements. Multi-state regions are typically defined by one or more federal agencies. For example, there are ten FEMA regions, each made up of between four and eight states. These same regional designations are also used by other federal agencies, such as HRSA and HHS. The Department of Homeland Security, which has