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NEW YORK CITY'S HEALTHCARE TRANSPORTATION DURING DISASTER: A PREPAREDNESS FRAMEWORK FOR A WICKED PROBLEM

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16. Abstract

In disasters, victims with varied morbidities are located at incident sites, while capacities for care are distributed elsewhere in healthcare facilities with varied capabilities. Transportation serves an essential equilibrating role: it helps balance patients' need for care with the supply of care. Studying the special case of New York City, this project sets out the components as (1) incident morbidity, (2) transportation assets, and (3) healthcare capacity. The relationship between these three raises an *assignment problem:* the management of transportation within a dynamic and partly unpredictable incident-transportation-healthcare nexus, under urban disruption. While the routine *dispatch problem* can be tackled through better geographic allocation software and technical algorithms, the disaster assignment problem must be confronted through real-time mutual adjustment between institutions. We outline the institutional alternatives for managing the assignment problem and call for further research on the merits of alternative institutional models.

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In disasters in which there are mass casualties, healthcare facilities must be prepared to meet a surge of patients. Not only must patients be allocated to facilities with available beds and personnel, but also to those with the appropriate specialized services, such as pediatrics or burn beds. In some disasters, hospitals and other healthcare facilities are themselves internally disrupted, requiring reduction of operations or the transfer of patients.

Transportation then serves an essential equilibrating role: it helps balance patients' need for care with the supply of health care. But transportation management in the turbulent conditions found in disaster is exceptionally difficult. That was starkly illustrated in the wake of the Katrina disaster, during which there were tragic shortfalls in evacuation from healthcare facilities and in the transportation of patients.

As will be seen, the problem of healthcare transportation (HT) assignment during disaster is different from that of ambulance dispatch during normal conditions. This article sets out the elements of a framework for understanding the problem, in search of policy directions through which disaster HT can be made more effective. However, since there is no readily available way of comparing investment in disaster HT against other healthcare and disaster-abatement priorities, it is not reasonable to simply call for more funding. And it is also not reasonable to provide a counsel of perfection: to ask all parties to work harder and succeed better.

We study disaster HT with special reference to New York City (NYC), which serves as a very important case and not just because it is the country's biggest city. The hazards NYC faces include terrorism with explosives and biological weapons, radiological attack, pandemic flu and other infectious diseases, coastal surge from hurricane, heat wave, winter storm, earthquake, and technological hazards, such a large fire, blackout, hazmat release, plane crash, transit accident, and structural collapse [1]. The city has also had to learn from its HT experience in disaster, as from a review of its EMS performance during 9/11 [2]. For such reasons, NYC is in a position to set the example for other metro areas.

Three literatures converge on the present subject: emergency medicine and related prehospital research, transportation management, and disaster studies. Though our study has consulted some of all three, we have attempted to be exhaustive only with respect to disaster research and only since 2001. In addition, the authors benefited greatly interviews with key NYC informants, including medical practitioners with disaster expertise, who helped provide background and context. The most productive research databases were the *Homeland Security Digital Library* operated by the Naval Postgraduate School (www.hsdl.org); the *Lessons Learned Information Service* operated by the Department of Homeland Security (www.llis.dhs.gov); and the *International Security & Counter Terrorism Reference Center* accessible via the Memorial Institute for the Prevention of Terrorism (www.mipt.org) All three require registration for access.

Inferring and synthesizing from such sources, this article sets out the basics of the HT problem as (1) incident morbidity, (2) transportation assets, and (3) healthcare capacity. The relationship between these three raises an *assignment problem:* the management of transportation within a dynamic incident-transportation-healthcare nexus. We conclude that—if we do not call for large increases in funding or dramatic increases in human capabilities—the single best approach is through improvements in assignment efficiency. While the *dispatch problem* can be tackled through better geographic allocation software and technical algorithms, the assignment problem must be confronted through real-time mutual adjustment between institutions. We outline the institutional alternatives for managing the assignment problem, but call for further research on the merits of alternative institutional models. We also call for research on incident traffic management, a transportation logistics tool for hospital evacuation, tipping points in disaster HT, and on a proposed "Transportation Reserve Corps" to mobilize HT during catastrophic disaster.

REASONS FOR CONCERN

A basic reason for concern about disaster HT is that, even in relatively small-scale disasters, even when hospitals continue to operate as expected, the transporting of patients from incident sites to healthcare facilities encounters numerous difficulties. Victim locations and morbidity patterns vary starkly from that in daily EMS service. Large proportions of patients arrive at hospitals in private vehicles. Roads and bridges may be unavailable in ways unpredictable before the event. Burns, pediatric injuries, and hazmat contamination may require transport to specialized facilities. Throughout the event, the various agencies and response units are very likely to experience problem of communication, information retrieval, and inter-organizational coordination. While several documents warn about these problem and make suggestions for improvements ([3] [4], p. 31), there is much uncertainty about how HT assignment should be restructured.

Healthcare professionals are concerned about disaster HT also for another reason: many healthcare facilities are at or near capacity even under normal conditions. Because of "capitation" and other medical reimbursement rules, the number of hospital beds (and associated staffing and equipment) in the US has been in decline, leaving little to spare for patient surge [5]. According to one study early in this decade, 62% of all, and 79% of urban, hospitals are at their Emergency Department (ED) capacity or exceed it [6]. In 2003, 34% of U.S. emergency departments diverted ambulances originally assigned to them as primary destinations.[7] These strains already make emergency healthcare dependent on the transporting of patients among facilities. In disaster, healthcare facilities become all the more dependent.

In the immediate aftermath of Hurricane Katrina in 2005, 12 of the city's 15 hospitals had to be evacuated [8](p. 29). Besides being surrounded by flood waters, many experienced blackout, loss of communication, loss of water and sewer, and inadequate supplies. Nursing homes suffered similar problems. Though several entered into agreements with transportation companies, these companies may each have contracted with several hospitals, making them unable to serve multiple hospitals at once, even if drivers did arrive for work. [9], p. 18 Hospitals also faced severe problems evacuating because floodwater blocked access to the facilities; very few boats were available[10]. Until federal officials set up an emergency healthcare facility and mobilization center at Louis Armstrong Airport, many patients were transferred to a temporary staging area on an elevated highway[10]. In such devastating conditions, transportation becomes all the more critical as a way of allocating patients to surviving healthcare sites

Katrina was an unusually severe event, but not the only one in which the disaster harmed healthcare facilities. North American disasters requiring multiple hospital closures and patient relocation include the 1994 Northridge earthquake, Mississippi River floods of the 1990s, and several Florida hurricanes.[11] In the 1979 Mississauga (Ontario) train derailment, the entire city underwent precautionary evacuation to protect it from hazmat fumes. It is important to reiterate, however, that HT poses important challenges even in disasters of smaller scale than these.

LIMITS OF THIS STUDY

As understood in this study, disaster HT is the process of getting patients to healthcare, including the transfer of patients between healthcare facilities. We came to focus on this topic after reviewing the general relationships between transportation and healthcare in urban disasters. There are four additional critical relationships between these two urban functions.

First, a disaster may impede the delivery of resources needed for the provision of healthcare. These include personnel, hospital supplies, pharmaceuticals, laboratory samples, and generator fuel (a study that considers alternative ways of conceptualizing supply lines in bioterrorist disasters is [12]). Though we mention this problem as a complicating factor, we do *not* examine it in detail. Our focus is on patient transportation.

Second, some disasters disrupt transportation on a grand scale, through collapsed highways and bridges, blocked streets, transit stoppages, and traffic jams. The situation impedes travelers' access to all destinations, not just healthcare. The travelers unable to reach healthcare include those with routine medical conditions unrelated to the disaster. In response, transportation planners should aim to make transit and road systems resilient so they can rapidly clear congestion, resolve blockages, and otherwise resume normal service (a study of this problem appears in [13]). Transportation officials should also seek out means of coordinating emergency operations with homeland security and emergency management agencies [14]. The present study does *not* investigate these general issues in disaster transportation management.

Third, transportation facilities may be sites and targets of disaster [15]. In NYC, this is a problem of utmost seriousness, because several terrorist plots have been directed against the city's ground transportation facilities. In fact, there have been eight such plots (some alleged) since 1993, not including airliner and airport plots.[16] Coastal surge could inundate the NYC subway system, as could structural collapses and subway accidents. The present study does *not* examine the special case of disasters in transportation facilities.

Fourth, transportation vehicles and transit stations (and airports), while not being sites of disaster, can become nodes for the spread of diseases such as SARS and pandemic influenza-- because transportation facilities are loci of human contact. The facilities may have to respond by conducting traveler screening and distributing travel advisories-- as anticipated in the New York City Pandemic Influenza Preparedness and Response Plan [17]. Vehicles and stations may also be maliciously targeted in a bioterrorist plot meant to disperse pathogens. By targeting a station or vehicle, the perpetrator can cause mass exposure and be able maximize geographic spread through infected passengers who are, in effect, being used as disease vectors. The present study does *not* investigate these particular threats.

Note that all concepts and lessons discussed here are for *preparedness*, referring to actions (before the event) to get technologies, human abilities, communications, coordination, and other capabilities ready for effective response (during the event). By contrast *mitigation* would refer to actions (also taken before the event) to reduce the likelihood or intensity of the event and reduce physical vulnerability to it. For example, planners may call for reduction of population in vulnerable areas, better-built hospitals, preventive inoculation of population against pathogens, and preemptive operations against terror groups. We do *not* investigate such mitigation policies. We also do not examine long term recovery from disaster.

The present study is focused on preparedness for disaster HT at the level of the city and its metro region—not at the state or federal level. In some disasters, state or federal assets become essential, as to provide airlift for patients. We do not consider the state or federal challenge of providing these assets.

A FRAMEWORK FOR DISASTER HT

Mass-casualty disasters generate a surge of deaths, injuries, illnesses, and the worried well. The problem of assigning them to medical resources can be divided into the following components:

- *Incident morbidity:* disaster-induced illnesses, injuries, exposures (as to toxins) and worried well, occurring in possibly chaotic conditions, focused at one ore more incident sites or dispersed broadly in the city.
- *Transportation assets:* the resources that take the patient from the incident site to appropriate healthcare facility (or take healthcare professionals to the field). These include ambulances, drivers, paramedics, and dispatch capability.
- *Healthcare capacity:* primarily at hospitals, assessed with respect to specialized services, such as trauma centers, decontamination facilities and isolation wards.

The greatly complicating factors are that, as the disaster begins, information on each component is subject to large uncertainties. The patterns of morbidity are uncertain until medical assessments can be made during the event. Transportation resources can decline (vehicles may be damaged, drivers may be unavailable), or increase (with help from, say, neighboring municipalities), or find their access to patients impeded by road damage. Healthcare facilities may be disabled, forced to reduce care, or may evacuate; alternatively, they may expand capacity to take in far more patients than normal; otherwise, new surge hospitals may be brought on line.

INCIDENT MORBIDITY

Disasters typically cause casualties that are geographically concentrated at one or more incident sites. The site may be a residential building, complex facility (school, airport, stadium, etc.), open field, bridge, street or highway, or underground location. The extreme event at the site may be a fire, explosion, hazmat release, hostage taking, shooting, airplane crash, public transit crash, structural failure, utility failure, or confined outbreak of infectious disease.

Multi-site incidents include synchronized terrorist attack on several facilities; isolated pockets of disease outbreak such as that of SARS and legionnaire's disease at nursing homes; and a weather event that leaves most of a city unharmed but severely damages a few buildings. Obviously, multiple sites complicate the transportation assignment problem.

Some disasters induce widespread destruction, disruption, and casualties through a city. Examples include earthquake, pandemic, hurricane, urban flood, and winter storm. Such events can force the dispersal rather than concentration of EMS resources. However, in such events, too, there are likely to be sites at which damage is concentrated. It is typical of earthquakes, for example, that, though an entire region shakes and injuries and deaths may be found throughout, a few buildings and infrastructures suffer disproportionate damage, causing concentrations of casualties. A great difficulty in HT assignment is the timely and accurate assessment of morbidity at incident scenes.

Incident Complexity

Routine EMS planning can rely on statistical regularities in types and locations of morbidity across large numbers of occurrences. By contrast, disasters are singular, distinctive events. They are typically characterized by information fog, confusion, and high uncertainty. Proper action on the scene requires communication across organizational divisions, under emotional and time pressures.

The Incident Command System (also known as Incident Management System or Unified Command) is now the national standard by which such situations have to be managed. In chaotic conditions, the command structures may take time to set up; further time is needed to make coherent sense of a situation. During the morning of 9/11, New York City EMS commanders frequently lost contact with each other because of communications overloads, had to move staging and command areas as the buildings collapsed, and underwent confusing shifts in command as EMS personnel tried to identify sectors for which they could be responsible. The EMS command in Southern Manhattan did not gain full coherence until late afternoon of 9/11 [2].

Disastrous incidents exhibit large variations in morbidity profiles, across event types (flood and hazmat) and within events of similar type (building collapses). Building collapse may lead physicians to expect high numbers of crush injuries. But the collapse of the World Trade Centers on 9/11 allowed for the rescue of only five victims from the rubble. Of 790 survivors who escaped just before the collapse and were treated during the first 48-hour period, the largest proportion presented inhalational injuries (almost 400) and ocular ones (about 200) [18]. By contrast, after the bombing of the Murrah Office Building in Oklahoma City in 1995, the most common diagnoses were lacerations, contusions, fractures, strains, head injuries, abrasions, and penetration of soft tissue by foreign bodies [18, 19].

There may even be initial difficulty in confirming the causes of the incident. In the early hours of the sarin attack on the Tokyo subway system in 1995, there was great uncertainty about the cause of the illnesses [20]. After an explosion in a crowded place, the etiology of the event may be clearer, but the injuries are likely to be complex and technically demanding and to have occurred far faster than in a natural disaster, such as a flood ([21] p. 3.).

In biological, chemical, or radiological exposure, victims may initially not exhibit symptoms. Complicating the situation, those fearing illness (the worried well) may vastly outnumber those who are harmed. According the US Army Soldier and Chemical Biological

Command's estimates for civilian populations, the worried well in such disasters may outnumber the genuinely ill by between 5:1 and 15:1. This army command also estimates that 32,000 persons in the US sought healthcare after the 2001 anthrax attacks, though the numbers actually affected were in the tens [22].

It is standard procedure for EMS personnel to triage victims, but this turns out to be very difficult in large disasters. Crews often face particular difficulty in triaging pediatric patients.[23] An emergency physician interviewed for this study adds that after blasts, collisions, and collapses, persons who initially show no severe injury should be put under observation for internal bleeding, pulmonary disease, and other delayed effects or complications; EMS crews may have to persuade them to allow themselves to be transported to hospital.

A further complication is that patient behavior in disaster may be dissimilar to that in routine events: disaster victims have a high propensity to use alternative transportation modes [3]. In the 1993 World Trade Center bombing, one third of over 1000 victims sought medical help on their own. In the Oklahoma City bombing, most victims went of their own accord to the nearest hospital, overwhelming it. In the Tokyo sarin attacks, of about 5000 affected persons, 35% walked to the nearest hospital, 15% went by taxi, and 14% took private vehicles. Similarly after the 2001 attacks on the World Trade Centers, many victims left on their own, even though triage areas were established.[20] Other studies confirm the importance of pedestrian evacuation in U.S. mid-city disasters [24, 25], a phenomenon visibly illustrated by the large crowds moving away from lower Manhattan on 9/11.

Disaster research summarized by Auf der Heide indicates that much early search and rescue and patient transport occurs through immediate action by Good Samaritans present at the scene and by voluntary groups that organize themselves rapidly and get to the scene often before formal responders do [2]. Since much of this research appears to have come from studies of small disasters, such as tornadoes, in the US Midwest, there is some question about its applicability to large North American cities, where EMS, fire, and police are likely to be pre-positioned in the vicinity and to have rapid response rates to major incidents. On 9/11, which precedes the current round of intense investment in dispatch technologies and training, the first EMS crew arrived on the scene at 8:53AM, about seven minutes after first impact [2].

In almost all North American disasters, incident sites become foci for the "convergence phenomenon" ([26]pp.110-11, 215-216), in which excess numbers of persons and vehicles crowd the site. They include victims, police, fire, EMS units, humanitarian groups, and investigative officials, as well as volunteers, friends or family of victims, the media, and voyeurs. The scene can become chaotic, inhibiting all first response, including EMS. Though police have the critical role of securing the perimeter to prevent excess personnel and citizens from converging on the site, that often proves infeasible, because responders are drawn to helping victims (police officers may neglect perimeter control) and because large incident sites are difficult to secure. At almost all disaster sites, traffic management is essential [27].

Adding to the difficulties of the disaster scene are dangers to first responders themselves. In the three weeks after the collapse of the World Trade Centers, over 7000 first responders and relief workers sough help from health care providers [18]. Responders to the Oklahoma City bombing of 1995 faced grave risks from a severely damaged and unstable building while worrying about the possibility of a second bomb [28]. At sites of terrorist attack, the possibilities of additional bombs and booby traps have to be a persistent worry.

Note, however, that the convergence phenomenon, though very well documented and well known to responders, is not universal. The Katrina disaster was a revealing exception: the phenomenon did not occur, in the early days after the inundation of New Orleans, presumably because of the great geographic extent of the disaster, its catastrophically destructive impact, and the call for general evacuation of the city.

Incident Contingencies

As suggested above, the HT assignment problem—getting patients with given morbidities to appropriate facilities—begins at the incident site, where patients have to be identified and triaged. Leaving aside communication and coordination (crucial issues in all disasters, even in those in which the healthcare aspect is minor), we can state that HT effectiveness depends on some of the following incident contingencies:

- Site survey and stabilization
    - Search and rescue: removal of victims from immediate danger
    - Site survey: what caused this? Are there continuing dangers to victims and responders?
    - Fire fighting, hazard containment and isolation
- Incident command
    - Establishment of command and control
    - Establishment of site zones (such as triage staging areas, or concentric circles of hot, warm, and cold in hazmat events)
    - Incident perimeter control
    - Management of volunteers and emergent groups
- Incident medical care
    - Medical assessment: identification of types of morbidity
    - Patient stabilization,
    - First aid, prophylaxis, and treatment
    - Mental health care and support for the uninjured
- Transport and tracking
    - Accurate and timely reporting to dispatch centers
    - Incident traffic management
    - Triage
    - Patient identification for tracking (difficult to extend to patients who leave the site on their own or in private vehicles)
    - Loading of patients into vehicles; prioritize vehicles for site exit

To the extent that the site is more rapidly stabilized, EMS crews can better get to work. To the extent that medical assessment is more rapid and accurate, triage is improved, and patients can be more effectively matched to facilities. When medical treatment can be can be given on site, the flow of patients is slowed, allowing assigners to better allocate the highest quality ambulances and best trained paramedics in a congested setting. When patient information is recorded and organized, it can be better transmitted to dispatchers and receiving facilities.

However, such generalizations are subject to constraints and tradeoffs. Patients may be better served, even in highly unstable and critical medical condition, by rapid transport to a hospital than by rudimentary field treatment. And on-site attention to record keeping and patient identification can impede the speed of response. There may be a tradeoff between (a) rapidity of triage, treatment, and transport under incident conditions, and (b) efficient tracking and proper care when viewed longitudinally from incident through transport and treatment at a facility.

Special Case: The Healthcare Facility as Incident Site

A particularly difficult HT scenario arises when the hospital or nursing home is in itself a disaster site: when it undergoes an internal disaster. The internal disruption can occur because of an event in the hospital itself, such as fire, hazmat spill, utility failure, bombing, or hostage incident. Or the hospital may be disabled by a larger disaster, such as hurricane, coastal surge, flood, or earthquake [8, 29].

Hospitals and nursing homes are required to create and practice internal disaster plans--an especially good example is [30]. The sources of the mandate are The Joint Commission (a hospital accrediting body), the federal Center for Medicare and Medicaid Services, and some state laws. During internal disaster, the hospital has to weigh sheltering patients and staff in place, shifting patients and equipment within the facility, and lastly, partial or total evacuation. HT becomes relevant upon evacuation.

Disabled hospitals and nursing homes differ from other incident sites is that even persons (patients) unharmed by the disaster are likely to be injured, ill, or otherwise vulnerable. Some of the contingencies affecting this kind of HT are as follows:

- Ability to reduce or slow down building evacuation through internal patient movement to safe zones within buildings or among buildings on a medical campus. Capacity for organized, staggered ward-by-ward evacuation keeps evacuees in order.
- Spatial features of elevators, corridors, lobbies, and exit doors; extent to which elevator malfunction, corridor blockage, or fire serve as obstacles to patient movement
- Availability of crews and equipment for carrying non-ambulatory patients, especially down stairs; some of the equipment is reported to be unreliable or clumsy in large-scale emergencies [31]
- Patient triage for evacuation: in contrast to field triage, the most fit and ambulatory may go first, as suggested in [30] p. 16. Efficiency in dividing patients between those (a) who qualify for expedited discharge and (b) those who must be transferred to another facility. Those falling under the first category should be directed to a “discharge area” and those in the second category to a “staging area.” [30, 32]
- Availability of a patient census classified so that patients assigned for transfer can be matched to appropriate vehicles. Assignment of a “transportation unit leader” in staging and discharge areas to coordinate transport with receiving vehicles[30, 32]
- Availability of staff, medical records, and medications to accompany patients
- Management of the convergence phenomenon (relatives, extra staff, media, public officials, etc.); site traffic management

. Hospitals vary greatly in the extents to which they have these emergency management capabilities. Though staggered evacuation is simply a necessity imposed by staff, corridor, and elevator limits, it has the advantage—if patients can remain safe for the duration—that it slows the rate at which transport pick-up has to occur, thereby reducing the traffic congestion at the exterior loading areas.

TRANSPORTATION ASSETS

When disaster strikes New York, the agency responsible for bringing paramedical assistance to incident sites and moving patients to healthcare facilities is the Fire Department of the City of New York (FDNY). NYC is therefore among almost half of US municipalities that deliver EMS through their fire departments. Other cities do so through dedicated city or county agencies, health departments, police departments, or contracts with private firms.[33]

FDNY operates 388 municipally owned EMS units as of 2007. These units are designated Advanced Life Support and staffed by paramedics; or Basic Life Support, staffed by emergency medical technicians, who have a lesser level of training [34] The Advanced Life Support units are meant to transport the more acutely ill, such as those with asthma and acute cardiac problems.[35]

According to FDNY's strategic plan, the agency can in complex incidents supplement conventional units with specialized units that coordinate on-site triage, provide respiratory treatment, or manage aeromedical evacuation. [34] Unlike some municipalities such as Toronto, NYC does not operate ambulance buses. New York City's EMS resources are normally positioned throughout the city to deal with routine medical calls. As of 2007 in NYC, a GPS-based inter-agency "Automated Vehicle Locator" system is in effect, permitting the FDNY to claim greater dispatching efficiencies and maximization of unit assignments [34](p. 8). The system reflects the city's technological investments in disaster preparedness since 9/11.

New York City's municipal ambulances in 2007 are supplemented in part by about 200 hospital units, owned or commissioned by hospitals and dispatched through the FDNY's 911 system. An additional 590 proprietary units serve private customers who want healthcare transportation to the facility of their choice, and serve hospitals under contract to provide inter-facility patient transfer. A further 140 units are voluntary, operated by neighborhood groups, religious groups, or colleges. According to the Regional Emergency Services Medical Council of New York City, which coordinates these EMS providers, the city's residents were served by a fluctuating total of over 1300 municipal, hospital based, proprietary, and volunteer ambulances in 2007 (telephone interview with REMSA on Sept. 6, 2007).

In the vast majority of US disasters, the experience has been that an urban region can muster sufficient first-response resources, including EMS units, to meet the surge [26]. On 9/11, the FDNY was able to deploy 30% of its then 354 ambulances to the disaster [18]. According to a New York State Department of Health website, hundreds of additional EMS vehicles were put on standby from 59 counties to assist NYC. More vehicles were mobilized in Northern New Jersey. It can be generalized that in disasters of moderate or lesser scale (we are unsure of what the tipping point is, beyond which the disaster is no longer moderate), existing EMS transportation assets are sufficient to meet the need.

Disaster EMS Allocation with Municipal Assets

An initial EMS task during a severe incident is to reallocate municipal units (and units based in hospitals but operating via the city's 911 system) to meet the sudden surge in demand. Even in such moderate disasters, EMS allocation faces difficult decisions, such as the refusal of service to some routine calls, and complex contingencies.

One contingency is widespread disruption, as from earthquake, blackout, and nor'easters (large storms originating in the North Atlantic) worsens the municipal fleet's ability to respond. These events hamper EMS response times and also impede EMS personnel's ability to report to work. In epidemics, EMS personnel may have higher rates of infectivity than the general population, increasing absenteeism.

A related contingency is the extent of traffic disruption during disaster. To avert debilitating tie-ups, there have been calls to improve the coordination between transportation management officials and first responders. [14] However, it New York City, where traffic tie-ups occur daily, and may even be constant through the business day, the knowledge of traffic conditions provides limited advantage in EMS allocation. The city's traffic police, already assigned to choke points such as bridge ramps, are accustomed to giving precedence to emergency vehicles, without the necessity for complex central coordination. While it is customary to think of coordination as taking place high in an administrative hierarchy, it is important to also be aware that many important kinds of coordination occur through decentralized mutual adjustment.

Ramping Up EMS Assets

Beyond some tipping point (which we cannot estimate) in incident severity, or beyond some incident duration, when city's EMS units are operating near full capacity, FDNY would have to work with the city's Office of Emergency Management to increase resources. Some of the methods include the following:

- Extend EMS personnel workday: putting staff on 12-hour days instead of the normal 8 hours increases staff by 50%.
- Allow persons without emergency technician or paramedical certification to serve as drivers or to assist in vehicles—as for example fire personnel or nurses. Provide more medical personnel to conduct triage and emergency treatment at the incident site, freeing up EMS personnel for transport. Suspend some medical protocols, such as ones requiring paramedics to contact an ED physician (a time-consuming process) before leaving some categories of patients who refuse treatment.[36] pp. 46-47.
- Call in assistance from volunteer ambulance and proprietary units. However, response times and levels of staff training are reputedly lower than that of professional EMS and some operate lightly equipped "ambulette" vehicles. According to one informant, some qualified emergency management technicians and paramedics who work on the FDNY staff also moonlight in private EMS; if the FDNY called in these persons for 12-hour service, the ranks of emergency medical technicians and paramedics in private services would decline, limiting their ability to help supplement municipal EMS.
- Request assistance from other municipalities via "mutual aid" agreements. This is a large pool, but it brings its own assignment problems. According to our interviewees, some out-of-town units have to be dispatched by their home dispatcher. In NYC, many visiting units may face difficulties in navigating the city. Additional assistance may be requested from the New York State National Guard, a source that has depleted capacity to offer assistance during war.
- The city and state may also mobilize non-medical vehicles such as public buses. Buses would be especially valuable in catastrophic disasters when large numbers of the walking wounded have to be transported to hospital or when patients have to be moved from disabled facilities.

It is evident that NYC has access to extensive supplemental EMS resources. Viewed in terms of crude numbers, these resources are likely to be sufficient except in catastrophic events. When ramping up these additional resources, the challenge will be to effectively dispatch and coordinate them.

Inter-Facility Transfer

Once a disaster victim has arrived at the hospital, ED physicians often have reasons to then transfer him or her to another facility. Medical (as opposed to legal or financial) reasons for doing so are that the receiving hospital is overwhelmed with patients, while other facilities have spare capacity; and that another facility has the specialist capability for the patient's needs. Several administrative or legal obstacles may stand in the way of inter-facility transfer.

Physicians are subject to federal EMTALA (Emergency Medical Treatment and Active Labor Act of 1986 as amended and integrated with the Consolidated Omnibus Reconciliation Act) regulations, meant to stop the practice of "patient dumping," by which some facilities have divested themselves of patients unable to pay. On penalty of severe fines, physicians are expected to exercise due diligence to assure that patients are transferred for appropriate reasons and that the destination facility is ready to receive them. However, under the urgency of disaster, it may be very difficult and time consuming to fully fulfill EMTALA regulations, potentially putting physicians into a difficult legal bind.

As of mid-2007, the practice by the FDNY is that its EMS units are devoted solely to first pick up. Its units are not permitted to engage in inter-facility transfer, even if the units are present at the hospital from which the patient must be moved. This administrative prohibition applies even in disasters, as long as the initial receiving hospital remains operational. For inter-facility transfer, the hospital must deploy its own ambulances or call in vehicles under contract from private ambulance firms. As of 2007, this procedure was under review. According to our informants, New York City's public EMS vehicles may, however, provide inter-facility transfer to a hospital undergoing evacuation, since an incident is then considered to be in progress.

Special Case: Assets for Evacuating a Healthcare Facility

If a New York City hospital has to evacuate, and it is the sole disastrous incident in the city or one of a few moderate incidents, there will be more than enough EMS units available to transfer the patients. Even in these moderate conditions, the challenges are great. Hospitals must have an evacuation plan, but plans vary in quality; there is as of yet no agreement on best practice.

Hospitals will have to be ready for stringent on-site traffic management. They should know the rate at which ground vehicles can pull up and depart with evacuees, and should also consider aeromedical evacuation. They should know the types of vehicles to be matched with pediatric, neonatal, and maternity patients; patients with ventilator needs; patients with ambulatory, semi-ambulatory, and non-ambulatory conditions; and patients suffering from morbid obesity. Though it should be possible to have at hand a tool or worksheet by which to match patient census to vehicles, no such worksheet exists to our knowledge.

In hospital internal disaster as contrasted with other kinds of disastrous incidents, it is expected that physicians or other healthcare staff (rather than EMS dispatchers) will be the ones identifying transfer destinations. As long as the hospital evacuation is the only incident in the city, it should be possible to coordinate in real-time contact with a dispatch center. However, if the hospital is isolated, as by communications failure or overload on the dispatch system, and receiving hospitals are themselves stressed by a disaster, the sending hospital may not be well equipped to direct drivers toward destinations or to redirect them en route. In a widespread urban emergency with multiple hospital closures, the hospital may face the possibility of tragedies similar to those in New Orleans.

Transportation under Catastrophic Disaster

It should be noted that under severe earthquake, bioterrorist attack, multiple bombings, and coastal surge, when major population movements (possibly urban evacuation) are required, the HT challenges rise by orders of magnitude. One study of New York City evacuation in response to a coastal surge, which would flood large parts of the city, saw enormous difficulties, though it considered mainly residential evacuation, and did not assess the evacuation of the ill and disabled.[37] In catastrophic conditions, the surge transportation assets on which the EMS system relies may simply be unavailable, as after Katrina. While NDMS provides surge medical personnel (as do other organizations) and aeromedical evacuation, it does not assist in local healthcare transportation.[9]

HEALTHCARE CAPACITY

As compared to other regions of the US, NYC has a large number of trauma centers for its geographical area: 17 of them plus 2 pediatric trauma centers. There is likely to be one close to almost any NYC incident. For most emergency calls under normal conditions, EMS units are expected to bring patients to the nearest hospital ED or nearest trauma center.

It is, however, quite common even under normal conditions to have to then transfer the patient. A patient with traumatic injuries may arrive at an ED that it not a trauma center, requiring the patient's rapid transfer. Even trauma centers--according emergency physicians interviewed--can manage only a few specialized surgeries, perhaps up to four, at any one time; additional patients are often better served by being sent to a more distant facility. HT has the double function of getting patients the first hospital and then if necessary diverting or transferring to a second. The assignment problem is more complex to the extent that the patient must be matched to a specialized facilities, such as those described below.

Disasters pose the additional challenge that hospital capabilities can undergo substantial flux: some hospitals successfully ramp up their capacities, while others may suffer deterioration. Some facilities may have to close entirely and evacuate patients, while new facilities may be established.

Capacities of Specialized Facilities

The scarce specialized facilities to which patients may have to be transported in disaster include the following:

- Trauma care, providing complex surgery, resuscitation, and life support for severe injuries
- Intensive care, which monitors and treats critically ill patients with expensive equipment and high staff-to-patient ratios of specialized healthcare staff
- Radiology suites, which are essential after bombings, because victims may have to undergo multiple studies. On the day of the Madrid train bombings in 2004, 350 radiological studies had to be performed, stressing the city's capacity. [21], p. 9
- Decontamination facilities, which isolate the patient while removing radioactive, hazardous, or infectious material, usually in a sealed facility equipped with showers and located just outside hospital or, if inside the building, near an entrance. Negative air pressure rooms are meant to isolate infectious patients, by assuring that airborne pathogens do not spread to the rest of the facility.[38] The numbers of such facilities are sufficient for normal use but become scarce under some scenarios.
- Ventilators are devices used in emergency and intensive care to help patients breathe. Concern about ventilator availability during pandemic influenza has led to the establishment of a New York State working group examining ventilator allocation [39].
- Pediatric care in disaster raises grave issues both because of the emotional concern for children, and because of the special attention and facilities these patients require. One study anticipates deficiencies in decontamination and isolation, intensive care, mass prophylaxis, mental health care, and mortuary affairs in mass pediatric emergencies[23]
- Burn beds, some of which are in burn centers, require specially trained professionals, temperature-controlled rooms, and special equipment such as tubs, along with other features. Explosions can cause a drastic increase in numbers of burn patients. Emergency physicians who served as our informants were especially concerned about limited numbers of burn beds in the NYC area. In a large-scale event, aeromedical evacuation may be needed to distribute patients to burn beds in the US.

In mass casualty disasters, HT assigners face the problem of matching patients to specialized facilities that may already be at their capacity.

Surge Capacity in Hospitals

In normal conditions, when an ED reaches its capacity, patients can be redirected *en route* or transferred soon after arrival. However, in disaster, it is incumbent on a hospital to ramp up to receive a surge in patients.

Surge capacity is only in part indicated by a hospital's available "beds," understood as physical objects. Many hospitals store spare beds that under duress can be set up in hallways, lobbies, and cafeterias. It's more difficult to ensure that there are sufficient resources to serve the patient in those beds. As the list below suggests, hospital surge capacity is not a fixed figure that can be confidently predicted but rather a shifting capability dependent on various contingencies. In preparing the list below, we have omitted training, communication and inter-agency coordination, because they are critical contingencies in all disaster response, whether there is a large healthcare component or not. The surge contingencies include

- Staff availability, especially nurses and on-call specialists, who may be in short supply in trauma centers even under routine conditions. Early steps in surge may include the recall of off-duty staff and the transferring in of medical practitioners from affiliated hospitals, such as ones in the same municipal or private hospital system.
- Availability of personal protective equipment, medicines, sanitary supplies, food, water, and other supplies. To maintain the emergency flow of goods and services to the hospital, the facility should have entered into prior contracts with suppliers.
- Expedited discharge of ambulatory patients or patients waiting for elective procedures. In rapid-onset disaster, there may be no time for discharge procedures, so the hospital may instead temporarily shift ambulatory patients to less impacted wards or waiting areas [32]
- Administrative capacity to handle additional burdens for triage, registration, vaccination, dietary service, mortuary service, lab and diagnostic service, custodial service, and disinfection.[40] Availability of building security to manage uncontrolled surges of patients and visitors and to alleviate staff and patient fears during crowding.[36] Some facilities can call on non-medical volunteers, who may help with patient care tasks like feeding and bathing.
- Alterations of standards of clinical care, as with less frequent checking of vital signs, refusal to admit ED patients with minor symptoms, and reductions of lab testing.[36] p. 67; also [4] Establishment of a tiered approach to mass critical care can multiply the reach of critical care physician: for example, a critical-care physician supervises four other physicians (not specialized in critical care) who each manage as many as six critically ill patients[21], p. 13. Critical-care nursing care can be similarly extended.
- Access to medical and nursing volunteers who have registered their readiness to serve in disaster and have had their credentials verified.
    - A potential source is the Medical Reserve Corps, which assembles and provides training for volunteer physicians, nurses, pharmacists, dentists, and other professionals, all pre-credentialed. NYC's unit is large, with over 6000 members, including over 1300 physicians (www.medicalreservecorps.gov, consulted August 2007). However, the Corps is primarily intended for mass

vaccinations, medical evaluation, public education, triage, and distribution of medicines, not for in–hospital service.

- Coordinated by the Department of Homeland Security, but with participation by several federal agencies including the Defense Department, the National Defense Medical System (NDMS) assembles medical assistance teams that can be dispatched to civilian disasters sites. It has around the US about 7000 volunteer medical professionals organized into teams and can assign them to disaster sites [9] It appears from program documents that its mission does not include direct assistance to badly stressed hospitals.

Capacity Deterioration in Hospitals

Contingent factors can also have the pernicious effect of reducing a hospital's capacity to provide service during disaster. An example is the August 15, 2003, Northeast blackout, which caused no physical destruction and very few casualties (and does not qualify as a "disaster" by some definitions), but still had deleterious effects on healthcare facilities. Nursing homes had difficulty obtaining delivery of fuel to run emergency generators because of traffic delays; they faced staff shortages, because of transit delays that held up staff members. Hospitals underwent increased stresses, as from dialysis patients who could no longer receive care from free-standing dialysis centers, from members of the public seeking prescription drugs because drugstores were closed, and even from non-patients who simply wanted to be in a place with electricity [41].

Alongside bad weather, infrastructure failure, and transportation disruption, a critical factor undermining the hospital is infectious disease. One review finds, from studies of the SARS outbreaks in Hanoi, Hong Kong, and Toronto, that in reaction to the large number of infections of healthcare workers, many workers quit or failed to report to work, causing staff shortages just when selected hospitals were trying to ramp up to confront the epidemic [12] p. lvii.

Diverting Patients from Hospitals

As disaster patients begin to exceed the region's hospital capacities, still another assignment option is to divert patients with less acute symptoms from hospitals. They may be diverted to primary care physicians, neighborhood clinics, home care, and for those who are dying, palliative care centers. Such diversion in itself can impose very difficult dispatch problems. Hospitals can more readily achieve a reduction of patient inflow, without further putting demands on HT, by informing the public to stay away in all but the most urgent cases. This can be done by communicating with the city's Emergency Operations Center's public information officer, who can in turn inform the media. Simply the knowledge that hospitals are overflowing may disincline potential patients from reporting.

Closing Some Hospitals, Opening Others

The HT assignment problem reaches a higher order if some hospitals have to close part of all of their operations—a subject already discussed—with the dire result that patients have to be evacuated, possibly at the very time when disaster victims are seeking hospital care.

In large-scale disasters, the opposite scenario can also take place: new "surge hospitals" may be established. According to a Joint Commission study, they fall into several categories: (1) shuttered hospital buildings that are reopened, (2) nonmedical "facilities of opportunity" (airport hangars, arenas, veterinary hospitals) adapted for medical use, (3) mobile medical units situated on trucks, and (4) portable self-contained units sometimes known as "hospitals in a box" set up near mass-casualty incidents. [42] The Joint Commission report does not include military-type medical tents, once considered prototypical field hospitals.

The surge facility may have limited functions. It may serve as a triage point where patients can be observed to ascertain which ones require transfer to a conventional hospital. It may also serve as clinic for ambulatory patients, point at which to distribute medications or give vaccinations, or site for low-acuity patient care, to which conventional hospitals my transfer patients to make room for more urgent patient care.[36], p. 81. Some self-contained portable units are designed to serve as trauma centers serving small numbers of patients. Whatever the type of surge hospital, each requires elaborate preparation, including staffing and supplies—none is likely to be ready in the early hours after a sudden-onset disaster.

Federal Aeromedical Evacuation

The National Disaster Medical Service (NDMS) is primarily known for organizing medical teams that can be flown to disaster sites. NDMS also has missions of mass evacuation and the provision of "definitive care," referring to actual medical care. The Katrina disaster was the first in which NDMS was called upon to provide both its aeromedical evacuation and definitive care functions.[9]

When regional hospitals are overwhelmed, NDMS can provide definitive care by airlifting patients to hospitals around the US that have voluntarily affiliated with NDMS or to federal Veterans Administration hospitals. As of 2007, much programmatic material has been removed from the NDMS website, so description has to be assembled from older program documents that may no longer be accurate. In general, to get ready to airlift patients, NDMS has to create mobilization centers at airports for temporary medical treatment and eventual embarkation. The establishment of an aeromedical mobilization center serves as still another complicating contingency for disaster HT assignment.

HT ASSIGNMENT UNDER GREAT UNCERTAINTY

In summary, HT assignment takes place in an incident-transportation-healthcare complex. Decisions made in this complex help or hinder transportation from playing its equilibrating role in getting disaster victims to treatment facilities.

In view of these systemic features of this complex, analysts may hope to improve HT allocation decisions through better information systems, simulation modeling, and decision-support systems. Such technical progress is indeed important—and we suggest one direction below. However, technical solutions confront limits beyond which they are ever less incrementally helpful. The limits arise because disaster HT is a "wicked problem,"[43] which means it is in part resistant to algorithmic systematization.

Several features make it a wicked problem. In the sudden onset of a disaster, information about causes, morbidity, mortality, severity and distribution of injuries, and site risks are difficult to assess. Incident data collection takes up responder time and complicate incident command, possibly detracting from triage, treatment, and transport. It may be worth accepting errors in handling some patients for the sake of faster treatment in fully equipped facilities for most patients. There is at disaster incidents a tradeoff between more on-site assessment and quicker response. There may be no way to know at what point that tradeoff lies. Under uncertainty, it is best to rely on the informed, rapid-fire judgments of experienced people on the scene. The proper planning direction may be as follows: to develop capabilities to clearly communicate on-site judgments to the range of decision makers in the incident-transport-healthcare complex.

For the allocation of EMS vehicles, global positioning systems and routing algorithms have already reached a high-degree of sophistication and are ever more widely deployed in the US. Improvements in such information systems should still be sought, but their accuracy will always be subject to the inadequacy of the input data. Busy with caring for patients, navigating traffic, and communicating, EMS crews and dispatchers (who are under intense stress during disaster) may have to take away from these immediate duties to convey data about patient movement. Also, EMS has no information on disaster victims who forgo the wait for an ambulance and arrive independently at hospitals. Vehicle routing systems that work under normal conditions may perform less well under the unusual disruptions caused by disaster. Sometimes the EMS unit is better off making a highly localized routing decision with traffic officers than with central dispatch. An important but neglected planning approach is to facilitate decisions made in decentralized form; though based on partial knowledge, the sum total of decisions may be made more efficient than that achieved through central control.

Healthcare facilities may become crowded and discharge excess patients; or successfully ramp up operations to meet the surge in demand; or otherwise, find they are so impacted by disaster that their capacity to deliver care deteriorates. Some facilities may undergo internal disaster and evacuate; but new surge hospitals or aeromedical mobilization centers may open up. During the wrenching and all-consuming effort to make such changes, healthcare decision makers may well not be able to take the time to supply data to a central information system. It may be wiser to quickly communicate qualitative information to an Emergency Operations Center, which can convey the information to other groups, without the attempt to systematize the information.

There are indeed systemic relationships at work between incident morbidity, patient transportation, and healthcare facility capacity. But relationships cannot be sufficiently divided into distinct, with well defined variables having calculable functional relationships. Factors interrelate in ways that are dynamically nonlinear; critical information may be unavailable (and it may be irrational to collect it under the time pressure); and the situation is subject to very large numbers of surprising contingencies, as from various kinds of infrastructure failure. For all these reasons, the main way to make HT assignment more efficient is through institutional set-ups that foster versatile, real-time learning among decision-makers in interacting organizations.

HT ASSIGNMENT AS AN INSTITUTIONAL PROBLEM

Coordination breakdowns occur in part because incident commanders (often fire or police commanders), EMS dispatchers, and hospital executives have their distinct responsibilities in disaster and can adjust only with difficulty to the needs of other officials. In disaster, even within their own realms of responsibility, these officials have to face conditions very different from ones they face in normal daily routine—they confront problems of coordination in situations that are already difficult and stressful, and characterized by information-overload in some respects and information dearth in others.

As always in disaster, agency and jurisdictional fragmentation can undermine cooperation. This is to be expected: the various officials work daily within their organizations' rules, reporting lines, and customs; it is exceptionally difficult to break out of such practices suddenly. There is too long a history of organizational fragmentation in disaster to expect that the problem can be easily or substantially resolved.

According to a review of emergency management research in the 1980s and 1990s by Tierney and Lindell, the lesson from past disasters is that "transportation for disaster victims to hospitals is almost invariably uncoordinated" ([26]p. 129). After the 2001 attack on the Pentagon, reviewers of Arlington County's response still found that communication between EMS and hospitals was deficient. Reviewing medical response to nine major terrorist attacks, researchers reported that none had a central database of victims from all responding medical sites.[20],p. 12. According to Tierney and Lyndell, the lack of coordination is further exacerbated by conflicts and differences of mission between public and private hospitals, low-status and high-status hospitals, and various medical professions. The researchers find in the HT assignment problem the jurisdictional fragmentation and inter-organizational complexity that bedevil disaster response in general ([26]p. 129).

Our interviewees also mention the differing financial motives of hospitals in normal versus disaster conditions. In normal conditions, a hospital may vie for EMS delivery of patients, because of the importance of keeping healthcare staff occupied and receiving reimbursement. In disaster, when staff is overwhelmed or backlogged, the same hospitals may prefer to receive no more patients.

In disaster, hospital EDs may be inclined to underestimate the number of additional patients they can handle. This is less a matter of misrepresenting facts (and not primarily an ethical matter of lying or distortion), and more a subjective matter: the extent to which the hospital can successfully go into surge mode. Hospital surge capacity is relative. It depends on the decisiveness with which the hospital discharges non-acute patients, speeds up of patient care beyond routine standards, considers cots in the hallway to be acceptable crisis measures, and decreases quality to care to patients who are less at risk.

EMS dispatchers, too, may be subject to conflicting motives. They may not be sure how many additional patients are at incident sites, of the relative seriousness of their injuries, and of the reasonableness (in terms of the patients' conditions) of bypassing the nearest hospital to ones that report additional capacity. Also, from a dispatcher's point of view, if an EMS vehicle delivers a patient to the nearest ED, even if that ED is overcrowded, the vehicle can more quickly turn around to pick up the next victim. At least in New York City, it is on the number and rapidity of pick-ups that EMS services are normally evaluated.

Such practices need not reflect individuals' ethics: in disaster, healthcare professionals may be too busy caring for patients even to be able to pay attention to the ensuing logistical complications. Instead of blaming, if we are to succeed at improving HT assignment, we need to recognize the institutional pressures under which improvements have to be made. The guiding question then is: What are the reasonably achievable institutional reforms through which a region can improve disaster HT assignment?

HT ASSIGNMENT MODELS

Through the research and review we have conducted, we can cannot answer the question just posed, but can set out the options to be studied. The list below lays out the alternative organizational arrangements. It will be seen that New York City stresses the first, but can in disaster switch to a combination of them.

- <u>Combined "911" Assignment:</u> This is primary arrangement used in NYC: A "911" dispatcher directs EMS units to incident sites and to hospitals. The dispatcher is expected to coordinate with emergency departments but has the discretion to impose patients on hospitals. Hospitals have limited authority to opt out of receiving patients.
- <u>Assignment Hospital</u> also known as "Clearinghouse Hospital" or "Regional Coordinating Hospital": A state-designated hospital coordinates a coalition of hospitals to monitor ED capacity, inventories of supplies, epidemiological data, and command and control. An example is the Metropolitan Hospital Compact in Minneapolis-St. Paul.[36]
- <u>Central Assignment or EOC Assignment</u> uses an independent organization to coordinate. It should be led by an umbrella group that brings together hospital, public

health, EMS, and emergency management representatives. (In NYC disasters, the city's Office of Emergency Management, through its Emergency Operations Center (EOC) may serve as a clearinghouse on hospital capacities.) Though central assignment is intuitively the most appealing, it can suffer from the enormity of the information problem: centers must consider or even fuse so much information that they risk causing confusion and missing critical links.

- First Hospital Assignment. In view of the difficulties of making medical assessment at the incident site, this method stresses the importance of quickly moving patients from the incident site to the nearest ED. There, upon physicians' examination, the patient is either admitted or sent on to the most appropriate facility. This method derives from the assumption that it's better at all costs to get the patient to a well-resourced facility. The method is also preferred when there are fears of multiple terrorist attacks on the same site—it's thought best to remove victims and first responders from the scene as fast as possible. An important difficulty is that the physician who must make patient transfer decisions may, in disaster, have limited knowledge of transportation assets and capacities at other hospitals.
- Specialized Assignment. Electronically connected assignment groups interact for specialized care. There may be groups for burn, pediatrics, ventilation, and isolation. This method may work jointly with any of the previous assignment methods. For example, as explained by one of our interviewees, it may take a specialist to determine whether a patient with a certain pattern of burns needs to be transported to a burn center. The decision may have to be delayed until the patient arrives at the first ED, where the emergency physician can consult with the specialist assigner and decide where to transfer the patient to a burn center.
- Assignment through Decentralized Mutual Adjustment. This method notes that centralized services are subject disruption in disaster. They are also subject to information overload and information bottlenecks. In response to complex conditions, on-site medical responders, EMS crews, transportation officials, and emergency physicians sometimes bypass the dispatch center or EOC. For example: an on-site physician or nurse calls a burn specialist to decide how to handle a patient before transporting him; EMS crews negotiate with a traffic officer to bypass traffic jam or get permission to cross a closed bridge; physicians at a hospital waiting for disaster victims call affiliated EMS crews on cell phones to find out the situation at the incident site. Such decentralized mutual adjustment can generate its own efficiencies, but they must be weighed against the inefficiency caused by not having an overall picture of resource constraints. This mutual adjustment method is compatible with Specialized Facility Assignment and First Hospital Assignment.

CONCLUSION AND FURTHER OBSERVATIONS

Disasters that generate problems of mass healthcare transportation are rare. Their future likelihoods are not at all clear. The risks of such events cannot be reasonably compared with the risks of other disastrous scenarios. Therefore, recommendations for improved HT that simply call for more investment or better practice (counsels of perfection) are not helpful. What is more critical is to identify improvements that can be made without extravagant expectations for additional funding.

From our review, we conclude that a very important policy direction for improving disaster HT is the reform of institutional assignment methods--but within the constraints of our research, we cannot say which of these institutional assignment models is most appropriate for which conditions. We conclude, rather, that these assignment procedures, and the institutional frameworks in which they take place, *make up the single most important research question for the better planning of urban HT in disaster*. Our review also allows us to make four further calls for research: on (1) incident traffic management, (2) a transportation logistics tool for evacuating hospitals, (3) tipping points and (4) a transportation reserve corps.

We observe a dearth of information about site traffic management for health care. Under standard incident command rules, responsibility for transportation falls under the incident commander's logistics chief, who may appoint a subordinate specifically for transportation management.[32] However, this person's roles and needed skill sets are—to our knowledge—undocumented. We have seen no investigations of the advantages, if any, of ambulance buses versus conventional vehicles. Though there are reports that stress the importance of incident traffic management[27], we have found none that investigates traffic management under various disaster scenarios, say bombings as compared to winter storms. We recommend research on this subject.

Hospital evacuations are rare events. When they do occur, they raise severe challenges for which many hospitals are not well prepared. One of these challenges is on-site transportation logistics. Hospitals should know rates of rates at which evacuation vehicles can pick up patients and depart, consider access for air ambulances, and know how to match vehicles to specialized patients, including neonatal patients, patients with ventilator needs, and patients with various ambulatory capacities. Through research, it should be possible to prepare a tool or worksheet by which to match patient census to vehicles.

Though we do not recommend efforts at comprehensive systematization of the HT assignment problem, we do think important headway can be made. One way is to identify tipping points affecting the assignment problem. Beyond what number of victims (in varied geographic distributions of incidents, under varied rates of disaster onset) does the EMS system encounter limits to its transport capabilities? Beyond which number of victims of which morbidity types do city's general (trauma center, ED) and specialized (burn, decontamination) healthcare facilities exceed their capacities—both routine capacity and reasonable surge capacity? Research on tipping points can help answer the question so that, as the tipping limits are approached, they can be anticipated more quickly, permitting ramp-up procedures to get underway more expeditiously.

As we have stated, the city along with mutual-aid assistance has extensive capability to ramp up healthcare transportation assets for up to moderate disasters. However, under catastrophic urban disaster and urban evacuation, transportation assets and dispatch capability will be inadequate. Though federal and military sources have extensive assets, there appear to be no established procedure for civilian-military cooperation for local transportation assistance in catastrophes.[21], pp. 8, 19. Though the NDMS can provide surge medical volunteers and aeromedical evacuation, it has no local transportation function.[9] What is more, for a city as large and complex as New York, where a general evacuation would cause enormous disruption, it would make little sense to import additional transportation resources, an effort that would be too slow and would add to congestion and confusion.

We note that, while there is a Medial Reserve Corps that can assemble thousands of medical volunteers from the metro New York area, there is no equivalent for transportation professionals. We propose research into the feasibility of a Transportation Reserve Corps, though which buses would be given communication equipment, and drivers would receive training and certification, to supplement capabilities for mass healthcare transportation during catastrophic events.

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