Potential Use of Technology: Mitigating Disaster Evacuation

by

James T. Jarzab
Vice-President
Emtrac Systems
Western Regional--Pacific Rim Office
11501 Dublin Blvd, Suite 200
Dublin CA 94568
j.jarzab@emtracsystems.com
(p) 925-558-2763 (m) 925-895-5559 (f) 925-520-4850

Harvey Alexander
Manager, ITS Systems Support Branch
Transportation Operations Administration
District of Columbia Department of Transportation
2000 14th Street, NW, 6th Floor
Washington, DC 20009
harvey.alexander@dc.gov
Desk 202-671-1495 DDOT Cell 202-359-1478

James R. Jarzab
Assistant Planner
Emtrac Systems
Western Regional--Pacific Rim Office
11501 Dublin Blvd, Suite 200
Dublin CA 94568
jrjarzab.emtracwest@gmail.com
618-316-8643

Presented at the
5th International Social Science Research Conference
September 23-25, 2010
New Orleans, Louisiana
Hilton Riverside

Overview

The political philosopher John Locke proposed that the main purpose of establishing a civil government is to protect the freedom and security of all members of society. Few things exert such broad challenges to civil governments' achieving this role as natural- and man-made disasters. One of the tools of disaster mitigation is evacuation, as a diminished population allows for quicker infrastructure repair and a lessened demand on local public service delivery that, by the very nature of the event, is inevitably impaired.

However, the evacuation itself is fraught with problems. Even though motorized vehicle ownership rates in several major North American metropolitan areas approach or exceed one per registered driver, many households do not have a vehicle available; or, if available, many of these vehicles would not be viable transportation alternatives for an evacuation. Therefore, the management of public transportation resources and its coordination with private transportation is a major factor in the success of disaster mitigation programs.

A major tragedy of the 21st Century in industrialized countries is the inability of emergency services to evacuate at risk populations from the effects of man-made and natural disasters. Although advances in communication and data processing technologies have brought the costs of equipment necessary to marshal evacuation resources within reach of most First Responders, like a military doomed to fight the last war, today's emergency services continue to be hampered by inadequate investment in cost-effective emergency management systems. Traffic congestion and the resulting failure of the transportation system can lead to needless loss of property and/or life.

The advent of automated vehicle identification and location technologies (AVI/AVL), combined with radio communications, advance traffic control and monitoring systems provides opportunities for executing evacuation movements never before available. In application, First Responders are afforded emergency vehicle preemption (EVP), where the traffic signal halts all opposing vehicular flows; a variation—transit signal priority (TSP)--gives green time sooner to the transit vehicle, possibly holding the green cycle longer.

Because of their nature it is possible to develop "worst-case" scenarios for these evacuation events but difficult to predict occurrences. Therefore, it is essential to make risk-adjusted investment decisions with respect to disaster mitigation.

Recent Evacuations

Hindsight is 20/20. The purpose of this paper is to discuss possible technological applications that address some systemic difficulties captured in the following (and other) evaluations of evacuation efforts in North America—primarily, the use of public transit and First Responder equipment more effectively in addressing the needs of the evacuation and evacuees--not to critique the handling of those evacuations. Some subjectivity is inevitable; however one only needs to read the anguished words of helpless victims and public officials alike to sense the pain and frustration facing those incapable of doing more with the resources at hand.[1]

The events following the landfall of Hurricane Katrina is one of the most thoroughly publicized demonstrations of the need for improved planning and capital programming regarding the use of public transit resources in emergency evacuations. Hurricane Katrina forced many New Orleans metro residents to flee and caused severe damage to the structures and facilities throughout the Gulf Coast. Though many considered the evacuation of New Orleans during Katrina a relative success, it revealed many transportation infrastructure failures and the limitation of responders to evacuate groups like the elderly, low income, and chronically ill.

Thousands of residents, particularly those from lower income communities, were unable to evacuate the urban area using personal vehicles. According to the plan, these population segments with few transportation options were to be directed by officials to make their way toward "refuges of last resort" in order to be removed using higher capacity transit services. However, this part of the evacuation plan ran afoul of numerous logistical and strategic problems when it came to moving such large numbers substantial distances in such a short period of time. It is estimated that over 100,000 people were left behind in New Orleans as a result of the evacuation and most of these had very few options for evacuating.

Two glaring problems in the design and implementation of emergency planning contributed to logistical inefficiencies and obstacles in the evacuation: the overall minor role mass transit resources played in the evacuation and the resources committed to evacuating population segments with few transportation options. First, there was not a dedicated use of all available mass transit vehicles to help efficiently evacuate residents in the evacuation plan. Though some local jurisdictions used regional transit buses to evacuate, these plans were not coordinated with their surrounding regions and had little communication between district and jurisdictions; furthermore, there was little use of plentiful school buses. In fact, the evacuation plan for New Orleans called for the use of transit services to move population segments with few transportation options from the city but was never initiated. Instead, the Regional Transit Authority was ordered by the Mayor to evacuate residents to the established "refuges of last resort," such as the Superdome, instead of outside the danger zones. Consequently, the residents in these refuges--the majority of which were mobility-limited or low-income residents--were not evacuated until almost three days later.

The second problem--the lack of response to population segments with few transportation options--is unsurprising considering the atmosphere of evacuation planning in New Orleans. Much of the

[1] Because of the extensive numbers of primary and secondary sources of information available about the Hurricane Katrina and the September 11, 2000 attacks, this paper forgoes traditional citation as the breadth of the information renders such sourcing unenlightening; the fact that these sources are not presented in no way reflects a lack of respect for the scholarship exhibited by countless commentators with regard to these events.

planning that occurred before the storm to accommodate population segments with few transportation options relied heavily on "neighbor helping neighbor" policies that were of limited success. The Victoria Transport Policy Institute describes New Orleans's public transport evacuation as follows: *"…bus deployment was ad hoc, implemented by officials during the emergency* *without a detailed action plan… Katrina's evacuation was relatively effective for people with automobiles but failed transit-dependent residents"*[2]. Those regional evacuation plans that did contain the use of bus or transit services to move people from the city were heavily focused on local efforts and only minimally coordinated with local evacuation plans. Also, many of the local transit resources were committed to multiple groups that placed heavy strain on already heavily taxed transit resources. As a result, thousands of low mobility residents were stranded in the several refuges and not successfully evacuated until days later.

The disaster of September 11th is one of the major tragedies to strike the United States in the last 50 years. As part of a coordinated attack on multiple targets, two hijacked commercial passenger jets crashed into twin towers of the World Trade Center destroying an important landmark of New York. The attack occurred as the City's transportation network was operating at its peak morning rush hour capacity, which forced transportation officials to make critical decisions for the protection of the traveling workers and residents. During the attack, the region's transit network operated as the primary support system for the evacuation of refugees and the reinforcement by emergency services. Using the complex and widespread system of public and private transit, millions of New York workers and residents were evacuated from the island of Manhattan in less than 24 hours.

By 11:02 am, over 3 hours after the attack, 1.2 million workers and residents were ordered to evacuate Lower Manhattan, to be followed hours later by an overall evacuation of the rest of Manhattan's work force of 2.6 million. However, due to New York's subway, bus, and rail services being suspended mere hours after the attack and local streets becoming clogged with abandoned vehicles, millions of workers and residents were initially instructed to leave on foot. Residents south of Canal Street were asked to flee northward, while the New York Port Authority opened up bridges along the east river for pedestrian to walk across into the neighboring burrows.

After the security of the transit network was established, New York authorities deployed the mass transit of the region to speed up the evacuation process. Four and a half hours after the attacks, regional transit services were partially resumed, avoiding the extensively damaged lower Manhattan lines, to assist in the evacuation of residents and deployment of emergency crews. By evening Coast Guard forces began mobilizing several public and private water ferry companies to provide additional evacuation routes to New Jersey, Queens, and Brooklyn, further evacuating over 160,000 people. By nightfall, as a result of the quick response by local authorities, over 2.6 million people were evacuated from Manhattan despite an early shutdown of most transit services and the extreme limitations of the geography.

---

[2] Litman, T., *Lessons from Katrina and Rita, Victoria Transport Policy Institute,* Victoria, B.C., 2006, p. 18.

The government and regional response to the terrorist attack on September 11th highlights the advantage of using multiple transit options for the emergency evacuation of residents. Despite the loss of emergency command centers of the Federal Emergency Management Agency (FEMA), the NYC Office of Emergency Management (OEM), and the Port Authority--all of which were located within the World Trade Center complex--millions of NYC resident and workers were able to evacuate safely and speedily. New York's heavy focus on pedestrian and mass transit services to evacuate the city showcased the advantages of including such services in the regional emergency plans of at-risk urban areas. Unlike the evacuation of New Orleans during Hurricane Katrina, the use of private vehicles to evacuate residents was not given priority, as we can see from the Port Authority's total shut down of all tunnels and bridges to residents fleeing Manhattan. Instead, New York's response in regard to all spheres of socio-economic groups and their shift from more typical "neighbor helping neighbor" strategies of other high risk urbanized areas enabled a quick and efficient evacuation of Manhattan through multiple modes of transit.

Following the terrorist attack in New York City, a third hijacked commercial airliner struck the Pentagon in Arlington, Virginia (outside Washington D.C.) at 9:43 am. The regional transit and municipal authorities responded rapidly to the attack on the Pentagon; however, the overall complexity of the highway network and transit system in Washington D.C. lead to serious congestion and communication issues that made the movement of workers from the metropolitan area difficult. Despite a paucity of accurate information and the absence of a mandatory evacuation of Washington D.C., hundreds of thousands of workers and residents were able to leave the city by the end of the day.

The lack of information and reliance on piecemeal deployment of evacuation plans contributed heavily to a series of independent public and private decisions to evacuate the city at the end of the morning on September 11th. Similar to the evacuation of New York City, the communication between the separate planning agencies and civil authorities were sporadic, especially regarding the warnings and information distributed to the public. However, unlike the actions taken by New York authorities, the evacuation procedures of the Washington D.C. area relied heavily on the use of private vehicles and less upon the use of public transit. This problem was compounded by misinformation to residents about the operation of local rail and bus facilities, leading many to believe that they were completely or partially shut down. Local transportation agencies also responded to the evacuation by closing key transit facilities near the Pentagon and other important locations--presumed to be terrorist targets in the capital--by redirecting traffic and transit assets. These events caused heavy backups and travel time delays during the partial evacuation and highlight a serious obstacle in the execution of the disaster plan for the D.C. area.

The strategies employed in the partial evacuation of Washington D.C. show the adverse effects that can arise from a lack of communication and regional coordination when moving such large numbers of people relying on automobiles. Despite the relative timeliness of decision-making, regional transportation agencies ran into major roadblocks as the main arteries leading out of the D.C metro area became overcrowded from residents attempting to flee. Additionally, misinformation regarding the operation of the mass transit utilities led to increased difficulty safely and efficiently evacuating workers and residents from the capital. Though the loss of life and damage was much more concentrated in Washington D.C. than in New York City, and the size of the evacuation was much smaller, evacuation and emergency planning minimized the potential contribution of public transit resources.

For a successful evacuation to occur and to avoid the complications from a single mode-dependent transportation system, at-risk metropolitan areas should take advantage of the transit resources of the region to safely and efficiently remove the general population from evacuation zones. Investment in the support of effective and efficient functioning transit assets as they interplay with general traffic are exceptionally important.

Effect on Travel Patterns

As the summary of evacuations show, the very act of evacuation is disruptive. It is common that commuting declines significantly as the bulk of the population disperses and remaining residents prepare to protect possessions and shelter in-place. At least temporarily, normal travel patterns cease to exist and no longer require active support from the transportation infrastructure.

This tends to minimize the effectiveness of centralized traffic control systems designed to facilitate "typical" travel patterns. Because of the relative difficulty in predicting the resulting evacuation traffic flows of any particular disaster, infrastructure that allows for distributed decision-making is most effective in application. This especially holds true for the efficacy of EVP and TSP, both highly desired traffic system attributes in dealing with a disaster, its advent and aftermath.

In an organized evacuation, private transportation is generally directed to collection points for accessing evacuation corridors. Reversing the flow of some freeway lanes is a common transportation tactic of emergency preparedness, significantly increasing directional highway capacity for evacuations. Functionally, entrance ramps for reversed lanes must be blocked and attended by uniformed personnel, with exit ramps temporarily converted to entrance ramps. After opposing traffic has been halted and changes have been made to the ramp flow, pilot vehicles must clear the route of opposing traffic; this entire process is time and resource consuming. Because these collection points may be chosen based on availability rather than traveler convenience, it is likely that coordinated traffic signals and other well established fixed infrastructure controls may not support the resulting travel patterns. The inevitable consequence is traffic congestion and, in the worst case, gridlock as private vehicles pursue assumed "best available" paths to safety.

It is not surprising to find that recent evacuees with the means to support their own transportation often traveled great distances to avoid evacuating to areas of perceived housing, food or fuel shortages. Conversely, the more transportation constrained populations generally traveled to nearby areas in the initial phases of the evacuation. That nearby evacuations were often by public transit was understandable; what was less understandable is why in some evacuations transit vehicles—after making their initial trips—were not recycled to remove additional impacted individuals.

Much of the deficiency has been attributed to the shortage of personnel necessary to more effectively use these vehicles effectively and, in some cases, legally or otherwise without personal liability. Because trained personnel are the scarcest essential resource during an evacuation, it is not only logical but also essential that technology—capable of functioning 24 hours a day, seven days a week—be employed to the greatest extent practicable to facilitate the evacuation.

Economic Efficiency

Circumstances make a disaster and consequential evacuation a stochastic event, at least from the perspectives of the victims. Furthermore, the exact nature of the threat is imperfectly known, often until well after the event has ceased to be a direct threat. Because infrastructure is expensive, it is important that investments that support emergency evacuation have a more predictable cost-benefit profile that arises from regular use. That is, investing scarce resources in support of a function that may never be used is not an attractive investment strategy. Corps of Engineer levee construction is an example of a multi-functional investment. Clearly, while levee reinforcement seems prudent there is no guarantee that the levee will be needed in the future; for this (and other) reason(s), most levees are also used as roadways that facilitate "everyday" travel and may in doing so provide a public benefit that exceeds the insurance value of the levee in terms of flood prevention.

Due to the limited inability to forecast the need for evacuation, it is important that the tools used to facilitate the evacuation have other, more predictive benefits; preferably, these benefits arise from every day use. Inevitably, these benefits will arise from a function important both during an evacuation as well as during "normal" activity. This is particularly important because infrastructure is virtually impossible to install on short notice.

Recent enhancements in technology have afforded First Responders and public transit operators the opportunity to significantly alter their functional economies. This is possible through the use of emergency vehicle preemption (EVP) and transit signal priority (TSP). Note that these technologies have a history of development that has culminated in the current generation of products that have characteristics necessary for reliable, accurate functionality in a variety of disaster environments.

Perhaps most encouraging is the estimate of return on investment (ROI) of EVP and TSP in everyday use. Depending on application and purchase price, the equipment pays for itself in operating savings within five years. In a city where transit is a priority the payback was under three years with a return on investment of 36%.[3] It should be noted that EVP savings have been more difficult to document due to

[3] Shilpa, Gorde,"Transit Signal Priority for San Francisco Municipal Transportation Agency" M.S. Thesis, San Jose State University, San Jose, California, May 2010, p. 41.

the lack of uniformity in EVP service calls and the subjectivity in determining avoided costs for collisions and attributing the value of human life saved by First Responders. Even so, there is a consensus that benefits from improved operation exist; since EVP and TSP can often be provided using equipment in common, much of the benefits are cumulative.

Operational Efficiency

Not all EVP and TSP technologies have state-of-the-practice functionality. While signal control systems have benefited overall from improvements in backup power supplies, once power supply issues are normalized older generation EVP and TSP technologies exhibit severe functional shortcomings. Most optical and infrared systems—the predominant EVP technology in the industry developed 25 years ago—rely on analog approximations of distance affected by ambient environmental conditions, and basic pseudo-encryption to provide communications with traffic signal control devices. These primitive applications are also adversely affected by the reduced levels of traffic signal maintenance caused by the industry shift to light emitting diode (LED) signal heads. In key areas like distance-to-signal call and release accuracy as well as signal selectivity (false calls), the older technology leaves much to be desired. Loop detection provides more accurate point detection but is susceptible to wire breaks (from multiple causes) and electrical shorts from high water tables or other standing water conditions. Furthermore, earlier generations of equipment lack any but the most rudimentary encryption, allowing inconsiderate citizens—or, in the worst case, terrorists—the opportunity to disrupt proper First Responder or transit use of EVP and TSP. At this juncture GPS-based AVL/AVI communicating with frequency hopping spread spectrum (FHSS) radio offer state-of-the-practice positional information as well as secure communication for EVP and TSP applications.

Apart from technology, system design also affects operational functionality. The more centralized a command and control structure is, the more likely that a communication deficiency will be encountered. During an evacuation it is likely that transit agencies will lose some communication capacity to FEMA as a condition of their radio license; this will of necessity make centralized control more difficult. In an environment where communication is unreliable, it is important to have viable de-centralized operations. That is, vehicles eligible for EVP and TSP need to negotiate the granting of pre-emption or priority directly with the intersection in order to minimize response time and maximize benefit.

An effective increase in operating speed can only occur with a good match between detection technology and signal control hardware and software. Gains of up to 30% in operating speed have been modeled.[4] While it is difficult to replicate results from an ideal modeling exercise in the field,

---

[4] Parr, Scott, "Transit Signal Priority for Emergency Evacuation: Mitigating Disaster" M.S. Thesis, Florida Atlantic University, Boca Raton, Florida, May 2010, p. 70.

gains of 20% or better have been reported.[5] TSP has consistently improved operating speeds of transit, with little or no adverse impact on general traffic operation. In general, patronage gains have also been associated with services benefiting from TSP.

Conclusion

EVP and TSP technologies are a cost-effective means of mitigating evacuations. Since First Responder resources and public transportation are in short supply, investments that enhance their operation improve the cost-effectiveness of their provision on a daily basis as well as during emergency evacuations.

To date no "Magic Bullets" have been identified that restore disaster-impacted metropolitan areas to their prior states. However, EVP and TSP can help the preservation of lives and property when properly implemented in advance of the disaster event.

[5] Jarzab, James T., et.al. *BUS SIGNAL PRIORITY IN SANTA CLARA COUNTY, CALIFORNIA,* ITS America Annual Meeting, Washington, D.C. 2009, p. 4

ACKNOWLEDGEMENTS

The contents of this paper reflect the views of the authors, who as individuals are solely responsible for the facts and accuracy of the information presented herein. These views do not necessarily reflect those of Emtrac, the District of Columbia or any other institution under whose sponsorship such activities were undertaken. The authors wish to thank Tunde Balvanyos of Pace and Brendon Hemily of Brendon Hemily and Associates for their interest and advice. This paper is dedicated to those First Responders who risk their lives for the safety of others.