

# Communications of the IIMA

---

Volume 8 | Issue 4

Article 2

---

2008

## Geographic Information Systems, Evacuation Planning and Execution

Robert D. Wilson

*California State University San Bernardino*

Brandon Cales

*City of Victorville*

Follow this and additional works at: <http://scholarworks.lib.csusb.edu/ciima>

---

### Recommended Citation

Wilson, Robert D. and Cales, Brandon (2008) "Geographic Information Systems, Evacuation Planning and Execution," *Communications of the IIMA*: Vol. 8: Iss. 4, Article 2.

Available at: <http://scholarworks.lib.csusb.edu/ciima/vol8/iss4/2>

This Article is brought to you for free and open access by CSUSB ScholarWorks. It has been accepted for inclusion in Communications of the IIMA by an authorized administrator of CSUSB ScholarWorks. For more information, please contact [scholarworks@csusb.edu](mailto:scholarworks@csusb.edu).

# Geographic Information Systems, Evacuation Planning and Execution

**Robert D. Wilson**  
California State University San Bernardino  
USA  
wilson@csusb.edu

**Brandon Cales**  
City of Victorville  
USA  
calesb@csusb.edu

## ABSTRACT

*Evacuation planning has for decades relied on the results derived from mathematical modeling and scenario development. While there exist many mathematical and simulation models dealing with evacuation planning most lack one or more critical components needed by the individuals or agencies responsible for removing people from harm's way. Those critical components are real-time access to and representation of data to establish appropriate evacuation strategies.*

*All the pieces for a real-time centralized evacuation system exist but have yet to be integrated as a single point system. The focus of this chapter is the underutilization of geographic information systems (GIS). The contribution of GIS is its capability to serve as that single point platform incorporating all the components. Further, and perhaps most importantly, the focus means to reinforce the benefits of the visual analysis capabilities of GIS technology.*

## INTRODUCTION

A great deal of attention has been paid to how to move people away from danger especially since the events of September 11, 2001. Of course there had been significant research efforts on how to accomplish such a task prior to that event. Indeed the past decade produced a considerable number of studies that identified methods to model events and identify optimal routing strategies. Those strategies would, in turn, minimize adverse effects of natural or man-made disasters on the population. The transport systems in urban and rural areas are essentially networks. These networks function as the primary way to move people away from to danger and toward safety. GIS capabilities make it a natural for determining the best path along these networks during a man-made or natural hazard and/or disaster.

The primary objective of the authors' research has been to define, and ultimately develop, system architecture capitalizing on the visualization strengths of GIS. This architecture will permit the aggregation of disparate data from multiple sources in such a way as to provide direction for the evacuation of large numbers of people from areas of danger to safe areas. The main approach presented in this chapter is the identification of the 'pieces' of evacuation methodologies evident in the research and how to assemble those pieces into a single coherent system.

A review of the literature on emergency management of evacuation planning yielded a number of studies stressing mathematical modeling and scenario development. That area of research is well established and provides a number of frameworks within which to assess the benefits and shortcomings of various models. It should be noted that an initial decision was made to address models that purport to handle the movement of people from one area to another using existing transportation routes. Literature dealing with the evacuation of persons from buildings, public or private, was not included in our review.

## **TERMS AND SOURCES**

Common to nearly all studies related to evacuation planning is the issue of traffic congestion. Even without an event requiring evacuation, the public is well aware of the consequences of congestion. What is congestion? Simply put it is when a driver experiences a reduction in speed due to traffic volume exceeding the physical capacity of a roadway. The obvious result is that at best speed is reduced and at worst speed is zero.

An unintended result of large-scale evacuations using the road system is congestion. It is here that the use of GIS can prove exceptionally useful. One component of the system proposed by the authors are the sources used to collect congestion data. For example, the California Highway Patrol publishes incidents on its web site. These data can be obtained easily. Most state agencies maintain or could create and maintain databases containing information about accidents on interstate highways.

Another source for the authors is California Department of Transportation (Caltrans). It provides a database that contains information on, flow, occupancy and in some cases speed. Those sources are aggregated in a system designed and maintained through a joint effort by Caltrans, the University of California, Berkeley, and the Partnership for Advanced Technology on the Highways (PATH). The software that has been developed is a traffic data collection, processing, and analysis tool. The performance measurement system (PeMS) functions primarily to assist traffic engineers in assessing the performance of the freeway system. PeMS also serves as the data source for the system being developed by the authors which is presented later.

Congestion reduces the reliability of transport systems to manage large scale evacuations during a natural disaster or hazardous situation. Hence any system attempting to aid decision makers in managing the evacuation must accommodate the issue of congestion.

Congestion is generally placed in one of two classes: recurrent or non-recurrent. Recurrent congestion is of the type noted below, that is the result of holidays, time of day or week. Non-recurrent congestion is caused by such events as traffic accidents, lane closures or construction activity.

The amount of congestion on any given transportation route varies by time of day, day of the week, and holidays just to name a few of the variables. We know too that routes proximate to sports venues, malls, public schools, drive-thru restaurants affect traffic flows. People, over time, learn of these conditions and alter their route behavior to minimize delays. The issue is that dur-

ing evacuation situation people lack critical information necessary to select appropriate routes. Central problems are how this information be provided, in what form and to whom.

Congestion in the case of a catastrophe or natural disaster typically results in gridlock. This event is different from congestion and presents the decision makers with a significant problem. Irrespective of what computer simulations suggest as an evacuation route, the evacuees ultimately contribute to further congestion and often gridlock. What is needed by the decision maker is the ability to “see” the nature of problem. Whatever system is used should be able to model this event with the available data to provide decision makers with a visual representation.

Plainly, congestion is a function of the transport system ability to accommodate some number of vehicles. This is referred to as capacity. Physical capacity is measured by the maximum number of cars that can travel over a specific segment of an available traffic lane during some measured time period. Capacity then can be increased by adding lanes.

Other terms common to evacuation planning systems include variable or changeable message signs (VMS, CMS) and traveler information systems (TIS). These technologies exist in numerous locations and have proven beneficial to drivers. Another concept is that of traffic flow. This is defined at the PeMS site as “. . . the number of vehicles which have passed by the detector. The units are usually reported in terms of vehicles per hour. Freeways usually have a capacity of 2,200 vehicles per hour.”

The PeMS project serves mainly to process sensor/detector data on the freeways in California. It provides an excellent source of data for the creation of a single point system envisioned by the authors.

In summary, the following definitions of contributory factors serve to remind developers what information components must be available to decision makers.

- Physical Bottlenecks (“Capacity”) – Capacity is the maximum amount of traffic capable of being handled by a given highway section. Capacity is determined by a number of factors: the number and width of lanes and shoulders; merge areas at interchanges; and roadway alignment (grades and curves).
- Traffic Incidents – Are events that disrupt the normal flow of traffic, usually by physical impedance in the travel lanes. Events such as vehicular crashes, breakdowns, and debris in travel lanes are the most common form of incidents.
- Work Zones – Are construction activities on the roadway that result in physical changes to the highway environment. These changes may include a reduction in the number or width of travel lanes, lane “shifts,” lane diversions, reduction, or elimination of shoulders, and even temporary roadway closures.
- Weather – Environmental conditions can lead to changes in driver behavior that affect traffic flow.
- Traffic Control Devices – Intermittent disruption of traffic flow by control devices such as railroad grade crossings and poorly timed signals also contribute to congestion and travel time variability.

- Special Events – Are a special case of demand fluctuations whereby traffic flow in the vicinity of the event will be radically different from “typical” patterns. Special events occasionally cause “surges” in traffic demand that overwhelm the system.
- Fluctuations in Normal Traffic – Day-to-day variability in demand leads to some days with higher traffic volumes than others. Varying demand volumes superimposed on a system (Cambridge, 2005).

### Current Evacuation\Congestion Models

A comprehensive report dealing with evacuation planning and emergency management introduced a classification of the developments in this area (Jafari, Maher & Bakhadyrov, 2003). They categorized them by “approach, technology, and methodology.” Some of these are described below. Classification schemes are worthwhile and can be exploited for the design of certain components for a single point system.

Another popular approach is the use of linear programming and other mathematical models to aid in the removal of people from areas using existing roadways proximate to the event. Complex network algorithms, e.g., the Capacity Constrained Route Planner (CCRP) serve as the foundation for many researchers developing evacuation plans. That model, as well as others does not provide the information and recommendations needed to remove people from hazardous situations. Some models narrow the focus to evacuation problems occurring at intersections. A different strategy resulted in the development a model for lane-based routing to alleviate delays at intersections (Cova & Johnson, 2001). Again, that model provides another piece to be incorporated within the single point system.

As good as these models are one cannot escape the fact that, these models “. . . suffer from computational complexity . . .” and use “. . . naïve heuristic methods . . . and may not produce feasible evacuation routes” (Lu, Boedihardjo & Zheng, 2003). Nonetheless, those authors then proceed to produce two other heuristic algorithms. Still other authors discuss the further limitations of modeling and mathematical approaches (Kim, George & Shekhar, 2007). It is important to stress that modeling and scenario development are very useful as intermediate products or as data aggregators. They should, however, be seen as transforming data that is to be used by the visualization system.

Another accepted approach to evacuation planning is to derive mathematical algorithms to model evacuation processes according to a number of performance measures (Hobeika & Changkyun, 1998). The model, however, provides no visualization techniques and only applies to a particular class of disaster, i.e., problems at nuclear power plants. More frequent are the network models. One shortcoming of these type of models is typified in research on network flow analyses (Yamada, 1996). The central focus is on preparation in the event of some catastrophe. While there is nothing wrong with being prepared, these models lack the ability to provide real-time assistance during an actual evacuation. Once again though, they can become a component of an evacuation system.

## FUNDAMENTAL ISSUES

Any system that purports to be a single solution has certain criteria to meet. It must be able to handle data from multiple sources with multiple formats seamlessly. These data sources must be current, accurate and accessible. The hardware requirements while steep given the computational requirements exist and should not be a sticking point. Further it must produce output easily interpreted, provide real-time routing recommendations and react to user-provided parameter changes. As to the requirement for producing easily interpreted data this implies a visualization capability. Obviously GIS meets the visualization capability. The ability for a system to accommodate the other criteria remains problematic. Some of the reasons for this follow.

### *Interoperability and data standardization*

The US Department of Transportation Federal Highway Administration (FHWA) provides an excellent website representing the contemporary methods for managing demand via “Traveler Information Systems” (TIS). Under the section of “Unforeseen Catastrophic Events” (UCE) they state the following:

During unforeseen emergencies like earthquakes, hazardous material spills, or terrorist attacks, there is often no warning or precursors to the event and travel must be managed in stressful and uncertain conditions. In such situations, traveler information can play a key role in reducing uncertainty and stress among travelers and improving system throughput. Travelers need to be told about road closures, alternate routes, transit service disruptions, disaster recovery information, and safety information. Often, catastrophic events result in long-term disruptions to travel, and traveler information can be used to provide trip planning information such as construction schedules and road closures.

Clearly one difficulty is how to provide that information to different constituencies: the responsible decision maker, first responders and those immediately affected by the event (motorists). That website indicates that the data used in most TIS are typically collected for other purposes. These data are collected by public agencies for road monitoring (often providing public information via “Variable Message Signs” or VMS and Websites). In addition, private organizations are providing information to travelers through technological advances such as the Internet utilizing push technology to inform customers by PDA and or cell phone. As indicated on the website:

a prototype of a tool for personalized traveler information has been developed by Mitretek Systems using eXtensible Markup Language (XML) to gather and display web-based traveler information. Named TripInfo, the tool enables the traveler using a web browser to access the system which generates a route, determines relevant websites along the route, contacts each site, and extracts relevant information from the site. It organizes this information into a traveler report for the specified route.

Also found on the FHWA website is a description of a satellite based TIS that will be available through the private sector. Unfortunately this technology is more prevalent in Europe than in the United States at the present time. Other systems extant include radio data system and traffic message channel (RDS-TMC) along with products from commercial sources such as TrafficMaster,

e.g., Smartnav, an intelligent satellite navigation and traffic information service. That service currently provides traveler information to thousands of vehicles in the United Kingdom and other parts of Europe.

A survey of RDS-TMC users revealed that because of the information provided by the system, 50 percent of drivers changed plans, 87 percent saved time and reduced stress. It was noted that only 3 percent got the same information from another source. Drivers were reported to like having access to journey times, seeing the complete network and getting personalized information. Such a system has tremendous implications for the development of a central system. It is another piece of the system.

From the authors' perspective the European systems face many of the same issues of interoperability that systems in the United States do. There are national standards which if followed could mitigate the problems encountered when attempting to share data across different platforms. This issue is actually being addressed by ITS.

For example, some agencies maintain a centralized database wherein data are stored in flat files whereas others use hierarchical or relational data structures. Sharing data even with a given state remains problematic at this time. Yet another issue is the maintenance of the data and how often it is updated. Clearly in an emergency situation it is imperative that data be accurate and provided in real-time. Available systems in Michigan and Minnesota, for example have different hardware and architectures. While not a criticism of either approach this simply points out the problem of interoperability.

## **THE POLITICS OF EVACUATION**

An "ownership" issue seems to arise when the matter of control is discussed; exactly which government entity or regional group has power over any given unanticipated catastrophic event (UCE) or emergency management situation. Another issue centers on whether or not sufficient data sharing capability (interoperability enabling) exists where and when needed. Then too, there is some question as to how arguably 'real time' GIS solutions can be of benefit. And who provides this real time solution, the public or private sector. Commercial applications exist that can transmit information about the desired best alternative route to a backed up or blocked route. Should such private vendors be charged with a central role in evacuation planning? Or should such information come from a central control point, i.e., governmental agency, and widely disseminated to those affected?

On the other hand, should GIS function as a service for decision makers to simply model disaster preparedness planning, evacuation mitigation and damage assessment for the purpose of repair mitigation? That is, is the real role of GIS only strategic or is it the essential tactical evacuation management tool? It becomes clear that many models and simulations neither deal adequately with technical issues nor do they represent the real world challenges in using real-time GIS for emergency management or the inevitable UCE.

Moreover, the approach to the use GIS so far has indicated that traditional emergency management functions, e.g., mitigation, preparedness, response and recovery have been blurred or

merged. Cova has argued that the 'preparedness' and 'response' phases have effectively become the same with respect to current GIS evacuation solutions (Cova, 1999). Yet such an approach is wholly unacceptable since the response is produced, in the main, by static mathematical models. How then, one should ask, has the preparation phase been accomplished?

That same article cites other research wherein the conceptual framework of comprehensive emergency management is seen as ". . . applying science, technology, planning, and management to deal with extreme events . . ." (Drabek & Hoetmer, 1991). The reference book is a good source for the ins and outs of emergency management but is short on technological approaches.

Although it is worthwhile to keep this definition in mind as systems are developed for emergency managers it begs the questions of interoperability and delivery of information for the decision makers.

### CURRENT TECHNIQUES USING GIS

A common approach to evacuation planning that has been regularly explored is that of simulations using geo-spatial technology. A spatial decision support system (SDSS) was designed to assist in contingency planning (de Silva & Eglese, 2000). Its primary purpose was to interactively produce alternative routing for different contingencies. While important such systems are essentially after the fact models.

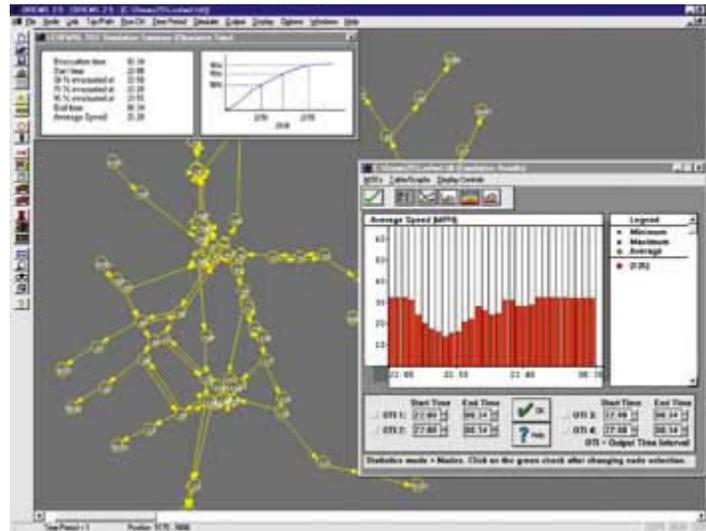
A somewhat different approach was to simply identify "neighbourhoods that may face transportation difficulties during an evacuation" (Cova & Church, 1997). Building on that work the authors demonstrated a method to integrate their "nonlinear, constrained optimization model" with geographic information systems (Church & Cova, 2000). Once again, such an approach simply produces maps that will identify for the decision maker the areas of concern. It is not dynamic. Indeed some researchers determined that perhaps there were just too many hurdles to the use of GIS as a real-time disaster decision support system (DDS), (Zerger & Smith, 2003).

Central to all evacuation models and simulations is the ability to direct people from an area of risk to an area of security. Many of the scenarios, simulation, and models reviewed dealt with the time it took to move people from a city under threat to an area of safety using the existing transportation routes. Fewer looked at how to direct people from threat to safety when it was the transportation route itself that posed the danger. This condition would occur when there was an overpass or underpass collapse or when there was a hazardous spill on a roadway. In such instances congestion leads to gridlock making most of the models and scenarios unresolved.

In those cases where such events were anticipated there were no extant real-time systems to deal with them. Nonetheless, there are systems that provide a 'piece' of the ideal system. The Oak Ridge Evacuation Modeling System (OREMS) has the capability to simulate the amount of time necessary to evacuate a particular area. In addition it can look at the effect of lane reversals and a number of other traffic control studies.

More importantly, from the authors perspective is its ability to provide visual information to the user (see Figure 1).

Figure 1: Visual Information.



Despite that particular benefit, its use is that of planning for an evacuation not how to evacuate during an event. This is a crucial distinction for the development of a real-time system. Following is an abbreviated discussion of some promising techniques.

In order to develop a single point system it is important that certain issues be considered. There are some key objectives to be met by a GIS-based system particular to the evacuation process: “1) clearly define evacuation routes for the evacuation area . . . and “2) determine, according to capacity constraints, an approximate egress time for the evacuation area (Fell, 2006). In addition to the system planning a re-route/evacuation path, an estimated time should be calculated based on those routes, the traffic counts and congestion, then provided by a visualization system.

The process that Fell used in setting up a similar system could be very useful to developers as he explains several steps in using a widely available desktop application: ArcGIS. He further identifies key data elements to calculate additional information to be used in the system. He, along with other, mentions that the system needs to include a mechanism to calculate alternative routes when initiated. In addition, there needs to be a method to manually block intersections or paths of travel. This would allow operations staff to control the flow, whether it is due to an effect on that path from a specific event, or just a management decision. In either case it provides the ability to deviate from the systems recommendations.

Based on a great deal of development activity one researcher, Yi-Chang Chiu has been in the process of developing a similar system for a few years and is completing a new revision. Chiu’s focus with the software is to react to a situation in real-time (ScienceDaily, 2007). Pulling in the real-time traffic data along with surveillance data, the software attempts to predict driver behavior. The next version of his software, called Multi-Resolution Assignment and Loading of Traffic Activities (MALTA), is anticipated to handle larger network systems and respond to real-time emergencies.

Again, in comparison to the system we are developing, there are many similarities. One of the key items it lacks is the ability to forecast events and propose ad-hoc re-routing as conditions change at the evacuation site as the need may occur. On a very simple scale the GIS evacuation system should inform staff of a congestion causing accident. Or with an event such as an earthquake, causing a bridge to be out of commission, the system should pick up on the fact that there was an immediate change in traffic speed and an increase in congestion. This predictive system could drastically increase the speed and efficiency of deploying the necessary response.

According to Intergraph, developer of the Hurricane Evacuation Decision Support System, traffic count data is the most critical. Intergraph had worked with the South Carolina Department of Transportation to assist in avoiding evacuation problems experienced during hurricane Floyd. Their system design efforts proved very beneficial during subsequent hurricanes.

They believed that in addition to the traffic count the next most important component was information on evacuation routes. With the traffic count information, they were able to analyze how many people were anticipated to be in the area, and how many were leaving (including days before, when voluntary evacuation was sent out). The system was able to show that traffic had come to a complete stop which enabled the decision makers to close the opposing lanes and reverse direction to allow twice as many vehicles leave the area in near real-time (Intergraph, 1999). With having access to detour maps, they were able to manipulate the decision process to work around them.

In any GIS evacuation system, it is clear that traffic data are important to functionality and output. The addition of data sources identifying road construction or other detour information could be crucial as well – this assuming the GIS doesn't contain it already. Equally important is the incorporation of a predictive model similar to the one developed by Intergraph. That component allowed them to quickly change the flow for the opposing lanes, which helped alleviate congestion. With the Intergraph system South Carolina personnel also located mobile traffic counters to provide insight as to how many cars were leaving the area.

As with many of the articles on this subject there are very few that describe or are in the development process of an actual system. While it is obvious that a lot of work has been done, much of it is over 5 years old. In addition most articles refer to mathematical calculations and simulations. They generally fail in actual situations.

Having said that, a promising system from the University of Illinois at Chicago (UIC) provides a description of a preventative model "Real Time Change Detection and Alerts from Highway Traffic Data" (Grossman et al., 2005). Its' goal is to provide real-time detection of changes in traffic conditions, focusing on the interesting changes.

Four challenges were tackled with the project including the following:

- Identifying changes in large, complex data sets
- Detecting changes in real time
- Keeping algorithms current for data updates
- Extracting features from different sources

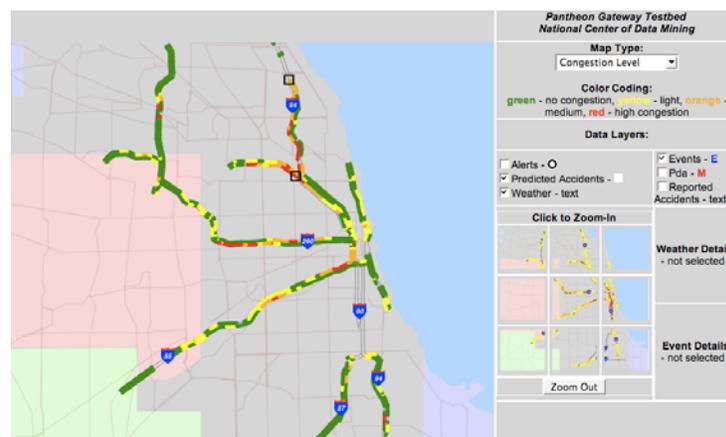
With the first challenge they determined the need for many separate baselines for comparison against. This included one for each hour, day, and region. Overall there were approximately 42,000 baselines utilized allowing for optimal change detection. The second challenge would be met by including a scoring mechanism that would decrease the time needed for processing. Alerts could then be sent out with the score exceeding set thresholds. The last two challenges were with real time data updates, specifically the inconsistent formatting. This relates to the interoperability issue noted earlier. To ameliorate this they used the standard for XML and developed an initial conversion from the source to a more common layout in XML. This allowed them to compile all the data at once.

They developed a demonstration of the system. The reader is directed to the Pantheon Gateway Testbed (<http://highway2.lac.uic.edu/index-js.html>). The site accommodates the archived data from all sources such as highway sensor, meteorological, special events, and traffic accidents. The data utilized for this application included the various characteristics for traffic, such as speed, volume and occupancy. Due to restrictions from the data sources, they were only allowed to acquire updates every six minutes – this frequency seeming to be adequate for the predictive nature of the technique. Other data gathered included weather and RSS feeds regarding special events.

The creation of data baselines was crucial in their version of the software, allowing for better change detection. As the data was processed through a scoring mechanism, if it exceeded the threshold alerts were sent out. Using tree-based classifiers the system makes decisions to isolate situations that are most likely weather caused or accident related.

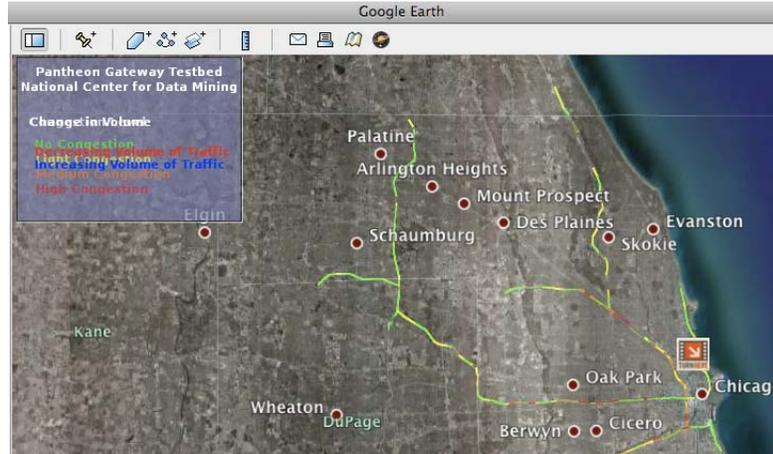
Unfortunately the use of visualization technology seems to be only a small piece of their system. It does, however, provide the most effective interpretation of the data. Using scalable vector graphics (SVG) and JavaScript it outputs a map of the region, satellite imagery, and the real time detections in traffic patterns (Figures 2 and 3).

**Figure 2: Real Time Image.**



Real-time satellite imagery is possible as opposed to simply overlaying road networks and other data on a static image as was done in the figure below.

Figure 3: Google Earth.



The authors system replicates almost every aspect of the example from the University of Illinois but with important additions, chief among them real-time visualization any additional data sources. While their focus was for the Chicago area and the authors focus on Southern California, it simply shows the need to develop a more universal system. This is not a trivial problem.

For example with an initial agency in Southern California, the data sources would be say the state and the county. One difficulty is that in many if not most situations, the data are proprietary when you drill down to the city and/or county levels.

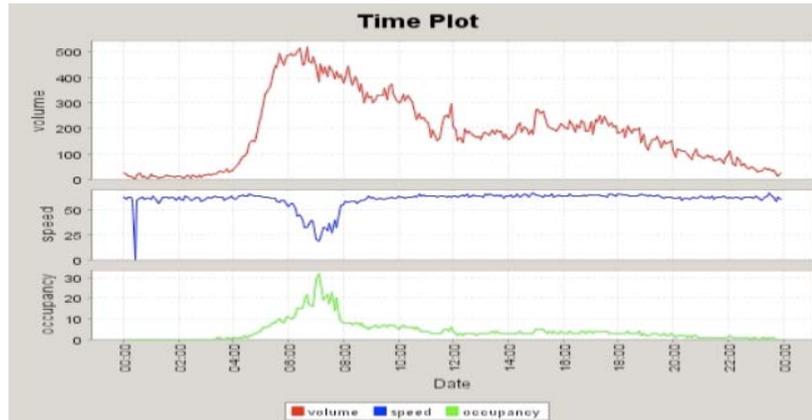
This type of system must be expanded, even for the optimal use by a single agency. The data sources should extend beyond the specific boundary as to provide better calculations and detection within the jurisdiction. To improve upon the UIC system the authors added the acquisition of more data sources such as cell-phone call logs to 911 (an increase in calls within the cell towers of the focus area, primarily along highway routes could indicate a concern), freeway cameras, and real-time satellite imagery. The separation of data that UIC employs is central to its functionality. Anomalies need to be identified. On the other hand normal congestion should not lead to its identification as an adverse event. By separating the data integration and scoring engine functions the system is able to differentiate the types of traffic incidents using the time of day. Taking this a step further a reference to a calendar year to rule out the common traffic issues surrounding annual events like holidays.

This seems to be the best approach to integrate the various data types into a single format before processing. The classification engine should be further refined to include scenarios for large-scale weather like tornadoes or earthquakes could provide to be useful.

Another use of the GIS technology came from Virginia Tech. Figure 4 below represents the content of most of the visualizations produced by the system: time based plots. Little visualization actually focused on the spatial aspect. Those that were generated by the system were adequate as shown in Figure 5.

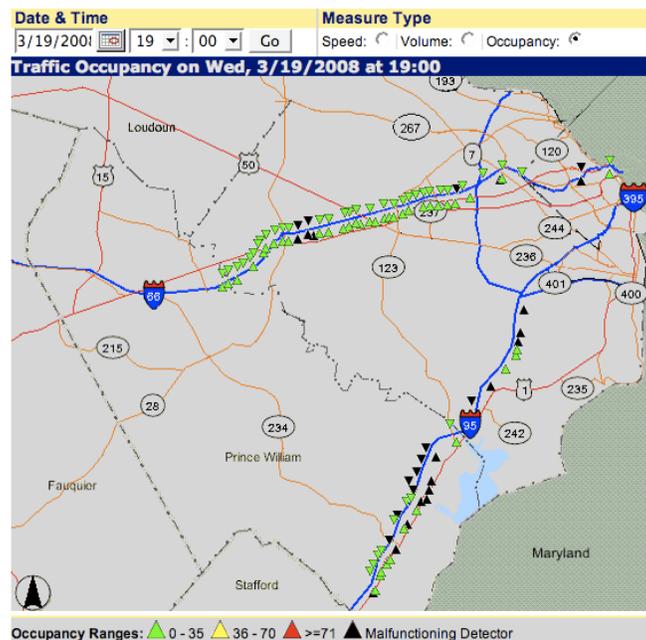
Their system is called Advanced Interactive Traffic Visualization System (AITVS). ([spatial.nvc.cs.vt.edu/traffic/](http://spatial.nvc.cs.vt.edu/traffic/)). Although the time plots can be useful to technical staff, the map view is optimal for management. This system isn't too complex, as it is limited to traffic congestion and prediction based on historical data rather than interpretation of current data.

**Figure 4: Time Plots.**



Their representations using time plots are valuable and should be included in any system even if only as an add-on. Even with the primary visualization being a map, these additional graph types are useful when utilizing the right set of data.

**Figure 5: Traffic Occupancy.**



It is noted, however, that the interface is less user friendly and appealing to management than that from UIC. This raises a key factor for any system – the display of spatial information is arguably the most important design consideration.

## CONCLUSIONS

The overriding finding is that GIS is either underutilized or used to produce static maps of events, routes or congestion as opposed to providing real-time data to decision makers. As noted, all of the essential components of a single point system exist in one form or another. What remains is how to tie them all together.

Overall the system we are developing is geared to those who manage the evacuation process and first responders using real-time in motion maps as the optimal solution. Taking the ideas that UIC used in their system and expanding them to make it more universal and enable it with more data sources seems to be the best approach.

This is what the authors are currently using as the jumping off spot for their single point system. The GIS Evacuation Assistant is a real-time traffic collaborator and forecasting system. It is designed to reside on a network with a direct Internet connection to continuously download real-time data from transportation related agencies. It currently uses the Freeway Performance Measurement System (PeMS) developed at the University of California – Berkley using input provided by the California Department of Transportation (Caltrans).

The system receives data and processes it immediately through a series of predictive spatial and analytical filters and models. Presented in a web-based dashboard format, these data are shown as meters and real-time maps. The system calculates irregularities, based on predefined thresholds, and then data are sent through a secondary set of spatial models. These models automatically plan out rerouting and or evacuation paths and present them on the dashboard for review.

The system is able to propose three separate paths: preemptive – warning system for distant roadway systems: re-route – allowing traffic egress at closest exists to incident; and immediate – reversing direction of traffic at the event location. The calculated recommendations can be presented visually. In addition, the information can be transmitted to on-site individuals.

It should be recalled from earlier comments that this system relies on embedded sensors, the California Highway Patrol CAD System as well as the data provided by Caltrans as stated earlier. PeMS was selected for a number of reasons, not the least of which is the fact that it could be modified to capture and maintain data from other state wide systems. There are similar systems in Washington, Detroit Michigan, Minnesota, and these counties in California, Maricopa and King.

The fundamental difference between the proposed system and those presented here is in the presentation of the critical data required for successful evacuation planning. In an actual UCE decision makers face a situation not unlike military strategists. That is, decision makers can now draw on plans created by mathematical models and/or various scenarios.

However, the decision makers soon discover what the generals have long known: no battle plan survives intact after the first shot is fired. While some of the research reviewed shows that there are models purporting to predict driver behavior during emergencies, this is akin to herding cats.

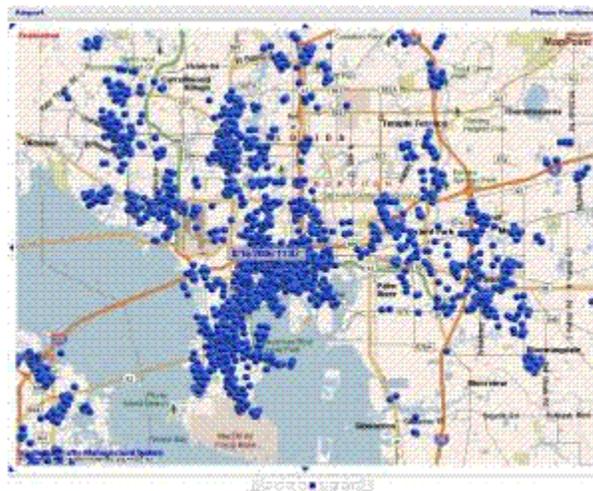
Drivers (people) act out of self-interest and will not behave according to some planner's model. Consider a situation in which an overpass collapses across eight lanes of traffic. Those drivers still able to use their vehicle will attempt to leave the area. Not according to some predetermined plan but rather by conditions on the ground at that time.

The event is only now being recorded by most of the systems currently under development. Those systems provide the decision maker with a reasonable plan based on some heuristic or predefined scenario. The obvious difficulty and shortcoming is that during the time the transmission of the incident takes to research the decision maker profound changes have occurred.

That is why real-time visualization is imperative and one of the data sources must be route cameras and/or satellite imagery. Real-time camera images need not come only from existing free-way monitoring equipment. Law enforcement vehicles (including aircraft) are equipped with cameras. These cameras can transmit the data to the system.

While not yet ubiquitous, personal cell phones can serve as an important data source. Most cell phones possess GPS capability and many have camera capabilities. These data can be transmitted wirelessly to the system from those in the affected area (see Figure 6).

**Figure 6: Cell Phone and GPS.**

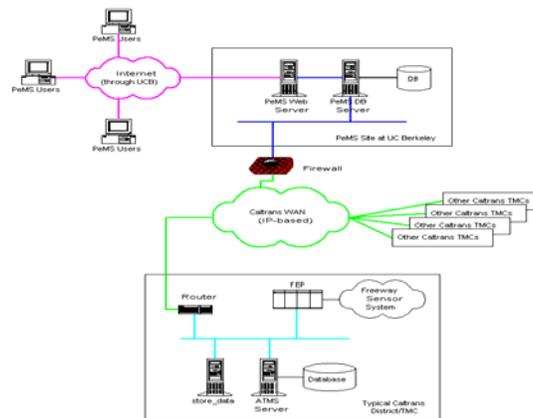


(Credit: IntelliOne Technologies Corporation)

In the above figure the dots represent the location of active cell phones subscribing to one particular carrier. These data become invaluable to the decision maker and must be integrated within the system.

As presently constituted our system would be seen as one of the PeMS users as shown in Figure 7.

Figure 7: PeMS.



Once the requisite data are acquired they are stored locally. To the data provided through PeMS are added traffic incidents from cell phone vendors and image data from Caltrans cameras. Anticipated will be the addition of sources noted earlier, i.e., mobile cameras. These data are aggregated and run through filters then displayed. As events change, the coordinates of the changes are run through predictive systems to initiate system recommended routes away from the event. These recommended routes can be overridden by the system manager who can supply alternative events and regenerate routes.

The user interface is currently being developed. It is based on the concept of business intelligence dashboards. This will permit the presentation of temporal, spatial and volumetric information in a near real-time display. The most difficult issue is the capture, analysis, and presentation of 'camera' data.

The promise of GIS has not yet been fully realized. It may be due to a misapprehension of its capabilities as noted earlier. Whatever the reason, it is hoped that with the completion of this system that others will improve upon it and put GIS technology in the forefront of evacuation support systems.

## REFERENCES

- Cova, T. J. (1998). GIS in emergency management. *Geographic Information Systems: Principles, Techniques, Applications, and Management*. Longley, P., Goodchild, M. F., Maguire D. & Rhind D. (eds), 845-858.
- Cova, T. J., & Church, R. L. (1997). Modeling community evacuation vulnerability using GIS. *International Journal of Geographical Information Science*, 8(11), 763-784.
- Cova, T. J. & Johnson, J. P. (2001). A network flow model for lane-based evacuation routing. *Transportation Research Part A: Policy and Practice*, 37(7), 579-604.
- Cova, T. J. & Johnson, J. P., (2002). Microsimulation of neighborhood evacuations in the urban wildland interface. *Environment and Planning A*, 34(12), 2211-2229.
- Church, R. L., & Cova, T. J. (2000). Mapping evacuation risk on transportation networks with a spatial optimization model. *Transportation Research Part C: Emerging Technologies*, 8, 321-336.
- DeSilva, F. N. & Eglese, R. W. (2000). Integrating simulation modelling and GIS: spatial decision support systems for evacuation planning. *Journal of the Operational Research Society*, 51(4), 423-30.
- Fell, J. W. (2006). Implementing a Traffic Assignment Heuristic in GIS: *Exploring the Evacuation Problem*.
- Grossman, R., Sabala, M., Aanand, A., Eick, S., Wilkinson, L. & Pei Z. (2005). Real Time Change Detection and Alerts from High way Traffic Data. [www.ncdm.uic.edu/publications/files/proc-091.pdf](http://www.ncdm.uic.edu/publications/files/proc-091.pdf)
- Hobeika, A. G. & Kim, C. (1998). Comparison of traffic assignments in evacuation modeling. *Engineering Management, IEEE Transactions on Engineering Management*, 45(2), 192-198.
- Jafari, M., Maher, A. & Bakhadyrov, I. (2003, March). Technological Advances in Evacuation Planning and Emergency Management: Current State of the Art Report Prepared for the U.S. Department of Transportation, Federal Highway Administration Center for Advanced Infrastructure & Transportation (CAIT) Department of Industrial and Systems Engineering The State University Piscataway, NJ 08854-8014.
- Kim, S., George, B. & Shekhar, S. (2007). Evacuation route planning: scalable heuristics. Proceedings of the 15th International Symposium on Advances in Geographic Information Systems ACM GIS.

- Lu, Q, Huang, Y. & Shekhar, S. (2003) Evacuation planning: a capacity constrained routing approach. Symposium on intelligence and security informatics. Tucson, AZ. 2665, 111-125.
- Lu, C. T., Boedihardjo, A. P & Zheng, J. (2006). Towards an advanced spatio-temporal visualization system for metropolitan Washington D.C. [www.teachamerica.com/VIZpdf/VIZ05b\\_Lu.pdf](http://www.teachamerica.com/VIZpdf/VIZ05b_Lu.pdf)
- National Science Foundation (2006, September 6). Real-time Traffic Routing From The Comfort Of Your Car. *ScienceDaily*. [www.sciencedaily.com/releases/2006/09/060901163455.htm](http://www.sciencedaily.com/releases/2006/09/060901163455.htm)
- Drabek, T. E. & Hoetmer, G. J. (1991). Emergency Management: Principles and Practice for Local Government.
- Science Daily (2007). Evacuation software finds best way to route millions of vehicles. *ScienceDaily*, 20.
- Virginia Technical Institute (2005). Towards an Advanced Spatio-Temporal Visualization System for the Metropolitan Washington D.C. [spatial.nvc.cs.vt.edu/traffic/](http://spatial.nvc.cs.vt.edu/traffic/)
- Yamada, T. (1996). A network flow approach to city emergency evacuation planning. *International Journal of Systems Science*, 27(10), 931-936.
- Zerger, A. & Smith, D. I. (2003). Impediments to using GIS for real-time disaster decision support. *Computers, Environment and Urban Systems*, 27(2), 123-141.

### **Other Sources**

- Traffic Congestion and Reliability: Trends and advanced strategies for congestion mitigation, prepared for the Federal Highway Administration prepared by Cambridge Systematics, Inc., September 1 2005
- Intergraph Corporation Real-Time GIS Assists South Carolina in Managing Hurricane Floyd Evacuation. [spatialnews.geocomm.com/features/floydgeomedia/index.html](http://spatialnews.geocomm.com/features/floydgeomedia/index.html)
- Federal Highway Administration,  
[ps.fhwa.dot.gov/publications/manag\\_demand\\_tis/travelinfo.htm](http://ps.fhwa.dot.gov/publications/manag_demand_tis/travelinfo.htm)

**This Page Intentionally Left Blank**