Transportation Management Systems
Compiled by Adam Leigland

This report looks at the five primary Transportation Management Systems deployed in California.

According to the Intelligent Transportation Systems National Architecture developed by the US Department of Transportation [1], Travel and Traffic Management Systems encompass.

1. Pre Trip Travel Information
2. En Route Driver Information
3. Traveler Services Information
4. Route Guidance
5. Ride Matching and Reservation
6. Incident Management
7. Travel Demand Management
8. Traffic Control

This report looks at the five tools used to implement these principles in California.

1. Highway Advisory Radio
2. Changeable Message Signs
3. Ramp Meters
4. Road Weather Information Systems
5. Transportation Control Centers

Reference:
Highway Advisory Radio

Description of the Technology

Highway Advisory Radio (HAR) is a system of providing real-time traffic information to travelers by broadcasting on an AM frequency. Signs, such as seen in Figure 1, alert the motorist that he is entering a HAR zone. The HAR system can be permanent and located in high-congestion areas, or can be temporary and used in construction zones, during traffic incidents, or during special high-traffic events.

Figure 1. Typical HAR sign.

A HAR system comprises a network of low-power radio transmitters. Each transmitter typically broadcasts over a radius of 5 to 10 miles. The transmitters can be fixed or mobile, depending on the application. The information that is broadcast is stored in the transmitter, and can be updated either directly into the transmitter through a microphone --usually done for temporary HAR applications--or remotely via telephone.

Intended Benefits

Highway Advisory Radio is intended to give travelers accurate, up-to-date information so they can tailor their travel plans accordingly. If an accident has closed a lane up ahead, for example, the motorist will learn this from the radio and perhaps take a different route. This benefits both the motorists who choose a different route, and the motorists who are already “caught in the jam” by
preventing the jam from building up due to the arrival of more unwary motorists.

Applications to Date – Examples

Highway Advisory Radio systems are in wide deployment all over the country. CalTrans currently maintains 84 permanent HAR locations [1].

Barriers to Implementation

Smith, et al. has listed many problems with HAR in his home state of Virginia [2].

“Proper HAR operation is personnel-intensive. At present, VDOT operates HAR transmitters as isolated units. Linking them into a coherent traveler information system requires a concerted effort to consolidate information between multiple agencies. Moreover, updating broadcasts with information of value to motorists takes time. Updating HAR messages cannot be a secondary responsibility, yet field personnel generally have other, high-priority duties, especially in an incident.

Presently, information provided on HAR stations is of limited value to motorists. Motorists want specific, up-to-date information on congestion and incidents that affect their travel. Situations that can be communicated with other traffic control devices or that do not affect motorists do not warrant HAR broadcasts.

Motorists are not turning to HAR broadcasts. Many motorists do not understand when they are in an HAR broadcast area, and what information HAR offers them.

Motorists currently get most of their traffic information from commercial radio station traffic reports. Commercial traffic reports have decades of experience effectively providing regional traffic information in urban areas throughout the country. VDOT does not have the resources to provide this level of information, and should not attempt to compete in this market.

CMSs [changeable message signs] offer considerable advantage as advisory signing for HAR. Static HAR advisory signs offer a single, inflexible attention statement to drivers. Flashing beacon signs face the same problem, and are confusing to some motorists. CMSs can alleviate these problems, directing the message to the appropriate audience.”
References

1. Database provided by Caltrans Transportation Systems Management Program.
Changeable Message Signs or Variable Message Signs

The PATH web site (www.path.berkeley.edu/~leap) has extensive information on Changeable Message Signs. The information in this report comes from there.

Description of Technology

“Changeable Message Signs (CMS) or Variable Message Signs (VMS) are programmable traffic control devices that display messages composed of letters, symbols or both. They are used to provide information about changing conditions in order to improve operations, reduce accidents, and inform travelers. They may ask drivers to change travel speed, change lanes, divert to a different route, or simply to be aware of a change in current or future traffic conditions.

Generally, VMS units consist of four components:

1) display board;
2) control center;
3) monitoring equipment;
4) communication network

The information for the VMS can come from any source that provide traffic information. Some systems have detectors tied directly to the VMSs themselves, while other systems have linked the VMS to a central control center (which could provide information to Highway Advisory Radio as well).

Intended Benefits

“VMSs provide information about: 1) recurring congestion, 2) non-recurrent congestion, 3) weather-related problems, 4) congestion due to special events, 5) routes, 6) speed restrictions, and 7) other changing conditions or requirements. The information displayed on VMSs can be classified as advice, warnings, and requirements.”

“The benefits of VMS system can be 1) a general improvement in routing choice, saving vehicle traveled miles and hours; 2) congestion reduced during peak hour; 3) improved routing during incidents and reduced accident costs; 4) travel time savings; 5) reduced environment effects: reduction in air pollution and 6) energy reductions.“
Applications to Date – Examples

Coordinated VMS systems have been implemented all over the world. The PATH web site list 26 specific existing systems (see www.path.berkeley.edu/~leap/travelerinfo/Driver_Info/message.html).

Barriers to Implementation

There are no particular barriers to implementing VMS, but there are a number of issues that can undermine their effectiveness. VMSs can have very specific applications, so it is important to consider both the objective and the contextual situation for the VMS. For example, a system that is meant to reroute traffic in case of an accident must take into account the network of both highways and surface streets or it could reroute traffic into a worse situation. It is easy to lose user confidence, so the information displayed on the sign must be accurate. It is better to have no information than incomplete or inaccurate information. Also there are safety and human factor concerns in sizing and spacing the signs and composing the message.

References

Partnership for Advanced Highways (PATH) web site accessed at www.path.berkeley.edu/~leap/travelerinfo/Driver_Info/message.html
Ramp Meters

Description of the Technology

Ramp meters are devices to control traffic entering a limited-access freeway. In almost all cases, they are red-green (no yellow phase) traffic lights, with one light for each lane on the entrance ramp. Ramp meters have varying degrees of responsiveness to mainline traffic conditions. At the simplest, a ramp meter can be programmed to turn on and off at a certain time and discharge vehicles at a fixed rate, while the most sophisticated meter completely tunes itself to the traffic over the whole network by varying its discharge rate and when it turns on and off.

The basic set of technologies needed for ramp meters includes some sort of vehicle detection system (see Fig 1 for a list of various detection technologies and some info about them), and some sort of microcomputer to control the process.

How it Works

Ramp Meters operate under the principle that by forcing cars to enter a crowded freeway in a controlled manner, it will be less disruptive to traffic. Figure 2 demonstrates how, without ramp meters, cars will all merge at once, forcing mainline traffic to slow. Ramp meters will carefully space the traffic entering the highway, allowing them to merge more smoothly with less disruption to mainline traffic. Figure 3 shows a typical layout for the various components.

Figure 2. Merging with and without ramp meters

Source: Washington State DOT
(www.wsdot.wa.gov/regions/Northwest)
Intended Benefits

Ramp meters are based on a simple trade-off: a short wait on the ramp allows drivers to save time overall while driving on the freeway. Ramp meters smooth

Figure 3  Ramp Meter Layout

Source: PATH web site
www.path.berkeley.edu/~leap/TTM/Traffic_Control/control.html#On-Ramp
the traffic flow, decreasing congestion and increasing the throughput of the system by increasing average speeds. Travel time reliability is also increased.

“In practice metering shortens the duration of congestion and improves overall traffic conditions. There is evidence that metering increases throughput, as many metered highways sustain peak volumes well in excess of 2,100 vph (flows up to 2450 vph have been achieved). By eliminating the stop-and-go behavior associated with congestion, metering can also result in up to 50% increases in speed and up to a 30% reduction in accidents. While diversion is an important metering concern, empirical results suggest no more than 5-10% of vehicles will be diverted” [1].

Cambridge Systematics, Inc, recently concluded a detailed study of the effectiveness of ramp meters in the Minneapolis/St Paul region. This study suggested the average travel times are reduced by 12-20% with ramp meters, that throughput increases by 20%, and that accidents are 26% higher without ramp meters [2].

Applications to Date – Examples

Ramp meters are in wide deployment all over the country. California has well over 1000 ramp meters in operation [3].

Barriers to Implementation

The following chart comes from the PATH web site [1]

<table>
<thead>
<tr>
<th><strong>Potential Cost</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversion</td>
<td>Diversion involves the diversion of trips from the freeway to alternate surface network routes. Factors which influence diversion include O-D patterns, trip length, ramp delays, and the quality of alternate routes. Conceptually, freeways were not designed for short trips, so diversion may be desirable if surface streets are under utilized. Even if alternate routes do not exist, experiences in Virginia, Chicago, and Denver indicate that metering</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td>Because ramp metering favors through traffic, metering benefits longer trips at the expense of &quot;local&quot; motorists. Trips may be diverted to local surface streets, and residents close to the CBD may be deprived of access given to suburban dwellers. In Milwaukee, where equity proved to be a delicate subject, metering rates were adjusted so that delay to the average motorist was the same on close-in ramps and on outlying ramps.</td>
</tr>
<tr>
<td><strong>Installation and Maintenance Costs</strong></td>
<td>Depending on existing ramp configuration and the size of the system, capital and maintenance costs can be sizable. Ramp metering systems typically have high costs associated with the communication medium connecting the ramps to the control center.</td>
</tr>
<tr>
<td><strong>On-Ramp Emissions</strong></td>
<td>Local emissions near the ramp may increase from stop-and-go conditions and vehicle queuing on the ramp.</td>
</tr>
<tr>
<td><strong>Promotes Longer Trips</strong></td>
<td>There is evidence that metering results in longer trips replacing shorter trips, as those trips taking up critical bottleneck capacity are also likely to use the long uncongested upstream or downstream freeway sections. Such catering to longer trips can have negative feedback effects, encouraging rather than discouraging commutes from further out.</td>
</tr>
<tr>
<td><strong>Ramp Delay and Spill Back</strong></td>
<td>Queues which back up onto</td>
</tr>
</tbody>
</table>
adjacent arterial streets can adversely affect the surface network. Those vehicles which use the ramp are delayed as they pass through the meter.

<table>
<thead>
<tr>
<th>Public Opposition</th>
<th>In addition to physical requirements of the ramp, the feasibility of implementing ramp metering control is dependent on public acceptance of ramp metering. The issue of public acceptance is critical, as the public is bound to be critical of a new installation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer of Land Values</td>
<td>Users who have been accustomed to ready freeway access may be rerouted in favor of new users, which can cause land values to change.</td>
</tr>
</tbody>
</table>

References

1. Partnership for Advanced Highways (PATH) web site.  
   www.path.berkeley.edu/~leap/TTM/Traffic_Control/control.html#On-Ramp
3. Database provided by Caltrans Transportation Systems Management Program
## Detector Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>One-lane ($)</th>
<th>Four-lane ($)</th>
<th>Pluses</th>
<th>Minuses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar</td>
<td>1500</td>
<td>4000</td>
<td>Good performance in inclement weather Direct measurement of speed</td>
<td>Requires narrow-beam antenna to confine footprint to single lane in forward-looking mode</td>
</tr>
<tr>
<td>Acoustic</td>
<td>3500</td>
<td>14000</td>
<td>Potential for identifying specific vehicle types by their acoustic signature</td>
<td>Signal processing of energy received by the array is required to remove extraneous background sounds and to identify vehicles</td>
</tr>
<tr>
<td>Laser</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VIP</td>
<td>17000-25000</td>
<td>26000-75000</td>
<td>Provides visible imagery with potential for incident management Single camera and processor can service multiple lanes Rich array of traffic data available</td>
<td>Large vehicles can mask trailing smaller vehicles Shadows, reflections from wet pavement, and day/night transitions can result in missed or false detections</td>
</tr>
<tr>
<td>Microwave</td>
<td>700</td>
<td></td>
<td>Good performance in inclement weather Direct measurement of speed</td>
<td>Requires narrow-beam antenna to confine footprint to single lane in forward-looking mode</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>2500</td>
<td>8500</td>
<td>Compact size, ease of installation</td>
<td>Performance may be degraded by variations in temperature and air turbulence</td>
</tr>
<tr>
<td>Magnetic</td>
<td>1500</td>
<td>3500</td>
<td>Can detect small vehicles, including bicycles Useful where loops cannot be installed</td>
<td>Difficulty in discriminating longitudinal separation between closely spaced vehicles</td>
</tr>
<tr>
<td>Loop</td>
<td>1000</td>
<td>3000</td>
<td>Standardization of loop</td>
<td>Reliability and useful</td>
</tr>
</tbody>
</table>
amplifier electronics
Excellent counting accuracy
Mature, well understood technology

<table>
<thead>
<tr>
<th>Source: New Mexico State University Vehicle Detector Clearinghouse (ww.nmsu.edu/~traffic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared</td>
</tr>
<tr>
<td>Pezoelectric</td>
</tr>
<tr>
<td>Bending plate</td>
</tr>
</tbody>
</table>
Road Weather Information Systems

Description of Technology

A Road Weather Information System (RWIS) consists of sensors installed in the travel lanes of the highway that measure the temperature of the pavement. Atmospheric sensors are placed adjacent to the pavement and measure air temperature, relative humidity, wind speed and direction, precipitation type, intensity and rate, and the driver's perception of visibility [1]. Often, the sensors are bundled together into a remote processing unit, which also sends the data to a central server. By applying models based on current and historical climatological data, technicians can determine the weather conditions at that road location and, more importantly, to determine the likelihood of ice forming on the road and the need to plow snow.

There are a myriad of technologies used in the actual sensors themselves, ranging from infrared spectral cameras to electric thermostats, but they are beyond the scope of this report.

Intended Benefits

This information can be used two ways. On the supply side, it lets roadway operators better manage snow removal and de-icing operations. For example, Nevada DOT was able to reduce road salting by 73%, which is important in environmentally-sensitive regions like Lake Tahoe [2]. It also lets them more effectively utilize manpower and equipment, especially during periods of harsh weather [3]. Conditions are monitored remotely, so a snowplow team based in, say, Placerville need not drive up to South Lake Tahoe to plow if there is no snow.

On the demand side, motorists can use the information to plan routes. The information can be broadcast on Highway Advisory Radio, displayed on Changeable Message Signs, or be available at telephone hotlines. Also, many agencies operate web sites with the information. Caltrans includes it with its road reports. A company called Surface Systems, Inc. has a web site with links to RWIS information in all states that have them (www.roadweather.com).

Applications to Date – Examples

Currently 27 states have implemented RWIS in some form [1]. Caltrans maintains 63 RWIS locations throughout the state [4]. Figure 1 shows the locations.
Barriers to Implementation

An Road Weather Information System is rather limited in application. It is best in climates that get a lot of snow. Also, current technology is very expensive. The remote processing units mentioned above cost on average $40,000 per unit, with a life span of 5 to 6 years [5]. Each individual RWIS location can have more than one remote processing unit, so it is easy to see how the costs can mount up. One problem with implementing RWIS at a new location is the development and tuning of the climatological models [5]. These models also require a lot of computing power to run, which drives up the cost. The Washington State DOT model, for example, required $700,000 of computer hardware [6]. Finally, since RWIS is primarily a supply-side management tool and doesn’t directly impact
congestion, it isn’t as “sexy” as other ITS applications and therefore might not garner as much support, though this is starting to change as travelers become more aware of the information available.

References

1. www.roadweather.com/wbpublic/RWISOverview.htm
4. Database provided by Caltrans Transportation Systems Management Program
Transportation Management Centers

Description of Technology

“The Traffic or Transportation Management Center (TMC) is the hub of a transportation management system, where information about the transportation network is collected and combined with other operational and control data to manage the transportation network and to produce traveler information.

It is the focal point for communicating transportation-related information to the media and the motoring public, a place where agencies can coordinate their responses to transportation situations and conditions.

The TMC links various elements of Intelligent Transportation Systems such as variable message signs, closed circuit video equipment, roadside count stations,...enabling decision makers to identify and react to an incident in a timely manner based on real-time data” [1].

The TMC is itself not a technology but rather a place for managing all other components of a transportation management system. In one sense, it is a building, housing all the computers, monitors, and communications equipment. In another sense, it is the various personnel from different agencies who operate in the TMC.

Intended Benefits

“TMCs can help reduce incident response times, lower incident rates (mainly secondary incidents), disseminate traveler information and hence reduce congestion and enhance safety. To date there is little data quantifying the exact benefits resulting from TMCs. One study conducted by MnDOT reported decrease in accident rates by 25 percent, 20-minute reduction in response time, 35% increase in average speeds (34 mph to 46 mph) during rush hours and 22% increase in capacity of freeways, after the implementation of their TMC.” [1].

The PATH web site lists the following benefits.

1. Faster incident response and reduction in incident rates.
2. By broadcasting traveler information and coordinating their activities with the State Patrol, etc, TMCs have been successful in reducing congestion in freeways and arterials.
3. Increases traffic safety by effective incident response and clearance techniques. By providing traveler information regarding incidents it minimizes the likelihood of secondary incidents.

4. Enhanced communication in all aspects of transportation management (planning, design, implementation, operation, maintenance).

5. Monetary savings by sharing responsibilities between fewer staff, achieved by co-location of participating agencies at the center.

6. Agencies working closely together in a TMC typically produce a more consistent, unified response to a situation, increasing the overall effectiveness of the transportation resources.

Applications to Date – Examples

The TMC concept can be implemented at various levels. The borough of Queens TMC monitors 6,000 computerized signal lights, 58 traffic video surveillance cameras, and 7 variable message signs [2]. The Central Valley TMC in California handles an area covering Madera, Fresno, Tulare, Kings, and Kern counties, including Yosemite National Park, and monitors 2030 miles of highway [3]. In between lie large cities such as Seattle, Minneapolis/St Paul, and San Diego, counties such as Bay County, Florida and Montgomery County, Maryland, and regions such as the Research Triangle of North Carolina. Rhode Island DOT has a TMC for the entire state.

Barriers to Implementation

Implementing a TMC entails considerable cost. Some costs include conception, design and implementation of TMCs and the capital costs associated with the facility. The Houston TranStar is located in a $11.5 million, 52,000 sq. ft. building [1]. In addition, there are substantial operational costs. For example, the yearly operation budget for the Seattle TMC is in the range of $1.4 million, and that for San Antonio ranges from $700,000 to $1 million [1].

Not surprisingly, an entity touching disparate governmental agencies as well as various areas of the private sector is subject to daunting organizational challenges. Roles must be clear and communication and coordination is vital. Of course, this is easier said than done. The TMC might be seen as a way of optimizing efficiency by the engineering community, but the law enforcement community might see it as an extra patrol car on the road. Further, there are challenges in managing a complex technological environment.

References
1. Partnership for Advanced Highways (PATH) web site.
   www.path.berkeley.edu/~leap/TTM/Traffic_Control/tmc.html
2. Borough of Queens Traffic Management Center web site.
3. Caltrans District 6 Central Valley Transportation Management Center web site.
   www.dot.ca.gov/dist6/tmc/tmcresc.htm