Advanced Traffic Management Systems – Getting the Most out of Congested Freeway Corridors

Ransford S. McCourt, PE, PTOE, President, DKS Associates

Active traffic management systems (ATMS) have recently been deployed on a large scale in Seattle, Washington; Portland, Oregon and Minneapolis, Minnesota. Additionally, a major system is being planned for the San Francisco Bay Area in the East Bay. These systems have similar objectives to improve safety and operating performance of existing congested urban freeway corridors where funding is limited and environmental constraints are such that added capacity is not feasible for many years. This paper explores each of these systems with before and after data comparing both safety and performance results.

What is Active Traffic Management?

The best way to describe ATMS is as a "fix it first" and "get the most out of what you've got" strategy. ATMS brings to life numerous intelligent transportation systems (ITS) measures that were visualized over the last decade using technologies that make them cost effective and real time. These strategies are integrated in corridors between freeways and arterials and between modes (integrated corridor management – ICM). FHWA highlights some of the core operational strategies in Table 1.

Table1
ATMS Operational Strategies

Adaptive Ramp Metering	Dynamic Junction Control	Dynamic Shoulder Use
Adaptive Traffic Signal Control	Dynamic Contraflow	End of Queue Warning
Advanced Traveler Information	Dynamic Lane Use Control	Transit Signal Priority
Dynamic Advisory Speed	Dynamic Merge Control	Variable Speed Limits

Source: http://ops.fhwa.dot.gov/atdm/approaches/atm.htm

The objective of these systems is to reduce delay to all road users, reduce the number of collisions (which in turn reduces system delay through fewer incidents), and increase the options to travelers (in terms of route, mode, temporal, or choice of travel).

Who has Implemented ATMS?

The most full-scale deployment of ATMS is in the Seattle, Washington region on I-5, I-90 and SR 520 and includes ramp metering, lane use control, variable speed limits and traveler information, transit signal priority on arterials, and queue warning. Portland, Oregon has applied ATMS region-wide through adaptive ramp metering and has advanced dynamic advisory speed, lane use control, queue warning, and traveler information on OR 217, US 26, I-5 and I-405 (and is adding I-84 in the next year). Texas has experimented with variable speed limits on portable trailers in San Antonio on Loop 1604. Los Angeles has combined adaptive ramp metering and dynamic junction control (they are advancing a connected corridor initiative on the I-210 corridor). In the SF Bay Area a project has been in development for 10 years on the

I-80 corridor approaching the Bay Bridge (should be operational next year). Minneapolis, Minnesota has combined dynamic lane use control, variable speed limits and dynamic shoulder use on I-35W. Northern Virginia has used dynamic merge control and queue warning on I-66. There are several other isolation applications in Atlanta (I-285), Austin (I-35), Chicago (I-55), Colorado (I-70), Alabama (I-10), Delaware (I-495), Missouri (I-270), New Jersey, South Carolina (US 25) and Wyoming (I-80).

San Antonia Texas Loop 1604

What does it cost?

Congestion is back in today's freeway network and it continues to outpace transportation agencies and the public's ability to fund additional capacity. What once were million dollar projects are commonly now measured in billions of dollars due to the complexities of adding capacity. What the public sees many times for their investment in large projects is immediate relief followed by the return of congestion a short time later.

The cost of ATMS varies greatly depending upon legacy communication networks and infrastructure. Table 1 summarizes four project costs on a per-mile of highway basis. The need for gantries plays a significant role in construction costs. In any regard, the per-lane-mile costs of the projects in Table 1 are substantially less than any lane expansion (commonly $50-100M per mile) or interchange project in urban areas ($20-75M per spot, less than ½ mile of network). ATMS can cover many miles of regional highway network in terms of benefits (not to mention deliver crash reduction benefits that lane widening do not necessarily deliver).

Table 2
ATMS Project Cost Examples

Project	Year	Miles	No. DMS	Cost	Cost per Lane Mile
Minneapolis I-35W Smart Lanes	2010	16mi	174	$23M	~250K
Seattle ATMS I-5, I-90, SR 520	2010	23mi	276	$65M	~$500K
Portland ATMS OR 217, I-5, I-405	2014	10.5mi	56	$21M	~$500K
SF Bay Area ATMS I-80 Corridor	2016	18mi	~140	$87M	~$600K

How do you build it?

As project manager, principal-in-charge, and quality control director, my role in the Seattle, Portland and SF Bay Area ATMS projects provides some unique insights into the construction of ATMS. These projects were built using both design/build (Seattle) and design-bid-build

(Portland and SF Bay Area). WSDOT chose to use a design/build procurement method to install the ATM equipment for this project and DKS was the lead transportation engineer. Given this was one of the first widespread, automated ATMS projects, there were some clear advantages of this type of procurement and implementation. First off – it goes fast. Typical project development, design and construction can take years of time. In the case of the I-5 corridor, the notice to proceed occurred in July 2009 and the ATM signs were up, tested and ready for WSDOT to complete system software development testing by the end of 2010 (nearly 900 plan sheets, with the first signs up in less than one year).

Second, the design/build process helped to advance innovative systems. At the time, high-density LED matrix signs for freeway operation and management had not been readily available. By using the Alternative Technical Concept (ATC) approach, new technologies were applied in real-time. With about 300 new technology dynamic message signs, it may have been more difficult with a design-bid-build approach (as has been experienced with the I-80 project that has been slower to implement). Now that the technology is more mature and on many QPLs (qualified product lists), both design-bid-build and design-build are approaches that can be effective.

One key lesson learned in the subsequent installations in Portland is that equipment testing and burn in can pay off. In Seattle, detailed test plans and equipment burn in got many of the bugs out (like LED failures) before installation. ODOT did not use this approach and had to replace several LED panels in live traffic after “go live.” Cost, time, public perception, and maintenance worker safety should be considered in making these choices.

ATMS design requires several unique activities:

- Sign vertical clearance (unique strategies to analyze each gantry and sign)
- Sign spacing (Analysis is required when placing signs to meet the variety of design, environment, and driver needs)
- Sign side clearance (narrow medians or shoulders provide limited space for signs to avoid strike potential)
- Sign visibility (analysis of horizontal and vertical curvature as well as obstructions – trees, sound walls, poles – as well as optics are needed to optimize the viewing capacity for drivers)

- Maintenance walkways (providing access to the signs under live traffic after construction)
- Anti-graffiti strategies for signs (materials and access affect design and matrix signs present new and different situations)
- ITS Cabinet applications (ATMS is a great application of ITS cabinets – double wide – where numerous controller elements can be consolidated in the field)
- Mainline fiber conduit communication strategies

What are the benefits?

Safety – ATMS focuses on reducing the rear-end collisions that occur on the nation's urban freeway network during peak times. Additional reduction in rear-end collisions can also occur during off-peak times such as weekends when infrequent users may be present on the system.

Travel Time – Travel time, delay reductions, and vehicle speed increases can be attributed to improving the relative proportion of vehicles in the optimal 45-60mph, above 1500 vphpl zone and reducing incident related delays. To complement these, we have created an additional metric by analyzing the speed/volume fundamental diagram to assess the amount of activity in the optimal speed/volume conditions.

Reliability – The buffer index, which measures travel time variability, can be reduced. This index adds the time needed during peak travel that a person would need to add to their trip to be sure to arrive on-time.

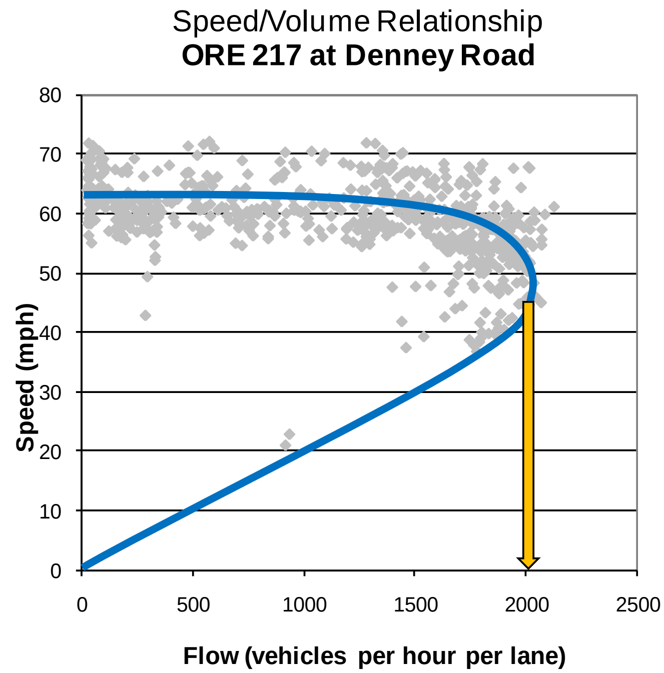
SOURCE: WSDOT

Weather Travel Information – WSDOT and ODOT are providing traveler information regarding roadway conditions of rain/ice with the objective of reducing incidents during inclement weather.

Public Acceptance – Better information about the travel conditions on congested highways appears to resonate positively with travelers. This also affords political support for projects in limited funding conditions.

ATMS is cost effectively targeted to address the near epidemic levels of rear end collisions that plague many of our congested urban freeways due to rapid end of queue formation. While freeway widening projects typically claim safety benefits, it is difficult for widening projects to reduce rear end collision potential. Congestion returns and the result is there are now more lanes, creating more opportunities for rear end collisions. Using ATMS to reduce rear end collisions, the delays associated with incidents and their clean-up can be reduced allowing existing capacity to better service demand at peak times.

One of the by-product benefits of ATMS has been theoretically claimed to be “harmonization” of traffic flows, which should result in improved speeds during the most congested periods. To measure this we have used detection data from the ramp meters to create a “speed-volume fundamental diagram.” Analyzing the prior conditions of the fundamental diagram for the optimal speed-volume combinations (above 55 mph and greater than 1500 vphpl) has created a method to determine if we are indeed improving “harmonization.” Using the ODOT OR 217 corridor at its critical bottleneck we were able to determine that an increase of over 7% of the points in this critical area of the “fundamental diagram” occurred with ATMS.



Case Studies – Benefits

Seattle, WA[1]: ATMS elements were placed on I-5, I-90 and SR 520 in late 2010 and early 2011. This system entailed gantries placed over the freeway at ¼ to ½ mile spacing with lane use control signs for variable speed limits and lane controls plus dynamic message signs (DMS) – over 275 in total. In addition, detection and fiber optic communication systems were added and modifications were made to ramp meters. Funding for the project was supported by ARRA funds and targeted as part of a long-term construction management system in the Seattle region as several major transportation improvements will be underway for over a decade (SR 520 floating bridge expansion, LRT on I-90, Alaska Way Viaduct replacement, and I-5 rehabilitation).

After five years of operation some clear trends have emerged. Using I-5 as a comparison corridor to other Seattle region corridors without ATMS, a 4.1% reduction in collisions occurred on I-5 northbound while other corridors in the region were experiencing a 2-4% increase in collisions. Most evident was the reduction in weekend collisions (infrequent drivers) where a 14% reduction in collision was experienced on the heavily congested I-5 northbound corridor approaching downtown Seattle. Each crash that does not happen has a net capacity benefit on the system as the impact of the crash on traffic flow (lane blockage, delay, queuing) is avoided. Just assuming the value of crash reduction alone (assuming no residual value for delay reduction, communication system enhancement, traveler information,…) the cost of the Seattle system would be exceeded by benefits in around 10 years.

SOURCE: MNDOT

Minneapolis, MN[2]: Smart Lanes is the brand name of Minnesota Department of Transportation's (MnDOT) ATM system on I-35W in the Twin Cities Metro Area. The original system covered 16 miles of I-35W south of Minneapolis starting in 2009, and was extended by two miles in 2011. Additional ATM equipment was installed on an eight-mile section of I-94 between downtown Minneapolis and downtown St. Paul in 2012. The annual operational cost of Smart Lanes is about $300,000 plus about $60,000 in utility costs. This has led to a "minimal" signs approach in future applications.

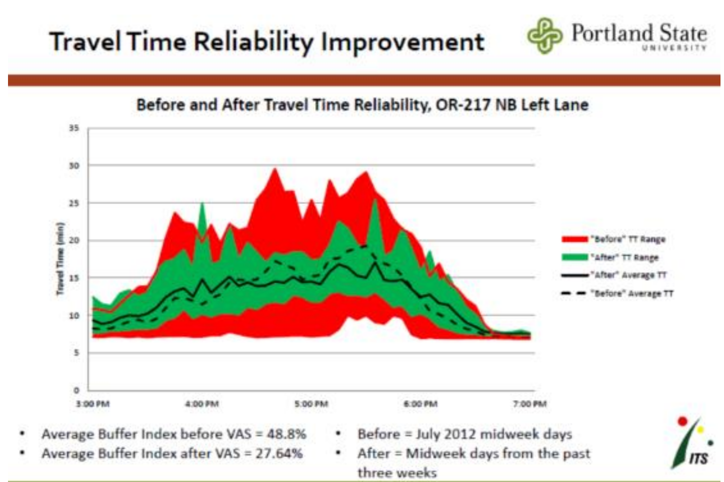
In Minneapolis, MnDOT converted a segment of the left shoulder on I-35W from bus on shoulder (BOS) operations to a priced dynamic shoulder lane open to all vehicles. Opened in 2009 as part of MnDOT's Urban Partnership Agreement project, the section of I-35 between 42nd Street and downtown Minneapolis is open to buses, carpoolers, and MnPASS users during certain times when traffic is congested. Overhead gantries are spaced every ½ mi and include static signs and DMS inserts indicating price and lane control signals. The variable speed limit (VSL) system did appear to positively impact the most severe congestion (speeds below 10-15 mph). Specifically, the instances and spread of extreme congestion waves (speeds bellow 10 mph) have been reduced after the VSL system activation. Property damage only crashes were statistically significantly lower by 25%.

Portland, OR: Two significant projects were undertaken on OR 217 and I-405/I-5. Turned on in 2014, this system took a slightly different approach by using an advisory speed rather than a variable speed limit. While legislative authority existed for VSL, it was decided for public perception and enforcement reasons to pursue the advisory speed limit approach. This award-winning $21 million project includes an innovative, low-cost approach to improve the corridor's safety, travel time reliability, and mobility. While the region had plans for a $1B corridor widening, it was estimated that it would take 75 years to obtain the funding for improvements. Instead of waiting for such funding to deliver public benefits, the ATMS strategy was developed and implemented in a short time frame. It entailed the following elements:

- Advisory speed signs that change based on current traffic and weather conditions
- Traveler information signs that alert drivers to crashes, congestion, road conditions, closures and other traffic-related information
- Travel time signs that display estimated travel times to key destinations
- An adaptive ramp metering system that adjusts rates based on traffic conditions
- A queue warning system that warns drivers of stopped or slowed vehicles ahead

Since the upgraded ramp meter and ATMS system was implemented in 2014, average PM travel times have been reduced by 7 percent, total delay reduced 33%, and travel time reliability has improved by 19 percent, while traffic volumes have increased by 9 percent. Public opinion has also been positive[3].

Reliability is a key benefit that was measured in the OR 217 project by Portland State University researchers[4]. They found that the travel time extremes tightened up, providing a more reliable travel time. One measure of this is the buffer index. This index represents the additional time that would be needed to assure on-time arrival (for example a 10 minute travel time with a 48.8% buffer index equals a 15 minute buffer time (i.e. 10m + 10 x 0.488 = 15m). For OR 217, initial (honeymoon) results show the buffer index dropped from 15m to 13m, a 13% improvement.



One of the interesting findings was provided from the emergency service provider in the corridor (Tualatin Fire and Rescue). They monitor all incidents on the freeway (OR 217) and log about 300 per year. Initially they have observed a 7% reduction in incidents in the same six months since the beginning of ATMS operation year over year[5].

Conclusions

For years transportation engineers have identified safety and getting the most out of existing capacity as objectives for travel in urban areas. ATMS provides new technology and management strategies at a much lower cost than adding lanes to address these objectives. The initial results from several metropolitan areas are very encouraging. ATMS decreased rear end collisions (5-10% reductions), improved performance (measured in speed, travel time and volume by 7 to 12 %), and improved corridor reliability by over 13%. As more lessons learned from the early adopters emerge, lower cost ATMS methods will be applied in other congested corridors to achieve similar benefits.

There are substantial resources available on the US DOT website. The following link has several useful background documents[6].

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[1] ATDM Operations and Implementation, WSDOT, Morgan Balogh, April 2015.

[2] http://www.ops.fhwa.dot.gov/publications/fhwahop14022/chapter5.htm; and

Urban Partnership Agreement: Minnesota Evaluation Report, US DOT, FHWA-JPO-13-048, January 2013

[3] Oregon Department of Transportation flyer, June 2015, 217 benefits.

[4] Downey, Matthew, *Evaluating the Effects of A Congestion and Weather Responsive Advisory Variable Speed System in Portland,* Portland State University, 2015

[5] Tualatin Fire and Rescue Highway 217 Motor vehicle incidents, February 2015.

[6] http://www.benefitcost.its.dot.gov/its/benecost.nsf/SingleTax?OpenForm&Query=Freeway+Management