Active Transportation and Demand Management

U.S. Department of Transportation
Federal Highway Administration

ATDM Analysis Brief #4: Example Application (Ramp Metering and Demand Management) of ATDM Capacity and Operations Analysis

Overview

The Federal Highway Administration (FHWA) Office of Operations sponsored a research project to develop new and updated methodologies, data sets, and content for the Highway Capacity Manual (HCM) that will better reflect the demand and traffic flow behavior that results from the application of Active Transportation and Demand Management (ATDM) concepts and strategies. This project was completed in June 2013.

This is the fourth in a series of informational briefs on ATDM analysis:

- ATDM Analysis Brief #1 introduced this project.
- ATDM Analysis Brief #2 described the technical analysis method.
- ATDM Analysis Brief #3 provides an example application of the analysis method for converting a high occupancy vehicle (HOV) lane to a high occupancy toll (HOT) lane with dynamic congestion pricing.
- ATDM Analysis Brief #4 (the subject of this brief) illustrates the application of the method to travel demand management (TDM) for incident management.

These analysis briefs as well other ATDM program briefs are available at: http://ops.fhwa.dot.gov/publications/publications.htm#atdm.

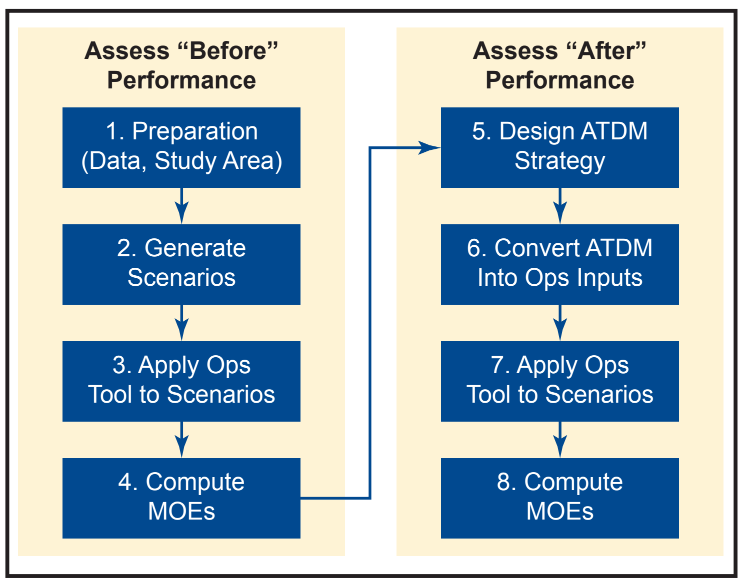
Source: Minnesota Department of Transportation

Applying the HCM to ATDM Analysis

The ATDM Analysis framework uses modest extensions of conventional Highway Capacity Manual methods combined with SHRP 2-L08 reliability analysis methods to develop estimates of the effects of ATDM investments on facility demand, capacity, travel time, and travel time reliability. These conditions will fluctuate throughout the year and ATDM strategies will generally have their greatest benefits under non-typical conditions. The analysis is performed twice on 30 possible demand, weather, incident, and work zone scenarios for the facility. (The reason for selecting 30 scenarios is that it keeps the amount of effort to develop input data manageable while capturing the major sources of variability in performance.) In this way, the performance of the facility over time is replicated by accounting for the factors that cause travel times to vary from day-to-day. This variability is captured in performance measures related to reliability. The first round of analysis evaluates "before ATDM" conditions. The second round evaluates "after ATDM" conditions. ATDM Analysis Brief #2 provides more details on the methodology.

A pair of spreadsheet based computational engines, implementing Visual Basic routines, have been developed to research and demonstrate the analysis method. The core engine is an extended version of the HCM 2010 FREEVAL software (FREEVAL-ATDM) for evaluating peak period freeway facility operations. A second engine, the ATDM Analyzer, generates the scenarios and the ATDM investments to be tested in FREEVAL-ATDM.

Exhibit 1: Flow Chart of ATDM Analysis Process



Source: Cambridge Systematics, Inc.

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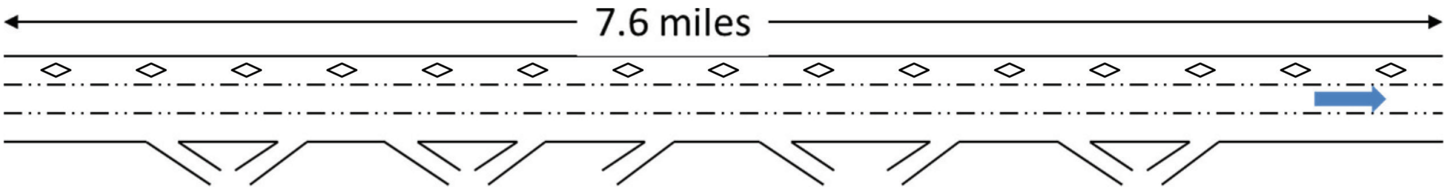
Example Application – ATDM Program with HOT Lane, Metering, and TDM

The selected study freeway is 7.6 miles long with three through lanes. It currently experiences relatively little recurrent congestion, but it is operating very close to the margin. Work zones, weather, and incidents can have significant effects on congestion. The left most lane is currently dedicated to HOV 2+ during weekday PM peak periods. The HOV lane is currently slightly underutilized, carrying at most 1,350 vehicles per hour.

The agency recently completed an analysis of an investment in converting the HOV lane to HOT operation with dynamic congestion pricing during the weekday PM peak period and found significant performance benefits (see the exercise in ATDM Analysis Brief #3), but observed that there was still significant recurring and incident related congestion on the facility. So the purpose of this analysis is to determine the incremental performance benefits (e.g. Speed, delay, productivity, reliability) of adding dynamic ramp metering and employer based travel demand management (TDM) to the agency's program of ATDM investments for the facility.

The steps to conduct the analysis are presented below. (Note: for more detailed discussion of each of the steps, please see ATDM Analysis Brief #2).

Exhibit 2:



Source: Cambridge Systematics, Inc.

1. Preparation

Data is assembled for the selected study facility and time period for a traditional HCM freeway facility analysis. (This HCM data becomes the "seed file" for the reliability analysis and generation of scenarios.) Data is then assembled on the day-to-day variability of demand, the historic frequencies of adverse weather, the frequencies of incidents and crashes, and the frequencies of work zones by type. These are used to reflect how the facility currently performs under varying conditions presented throughout a year.

2. Generate Scenarios for "Before" Condition

As noted in the description of the methodology in ATDM Analysis Brief #2, the method allows for the following ranges of conditions: 7 possible levels of demand; 16 weather subscenarios; 13 incident subscenarios; and 7 work zone subscenarios. These conditions can vary independently resulting in 10,192 combinations (or scenarios) for analysis. The probability of any given scenario is estimated by multiplying together the probabilities of the individual subscenarios and demand levels. From these 10,192 scenarios, 30 scenarios are selected for detailed analysis of the effectiveness of the proposed ATDM strategies. The ATDM Analyzer generates the scenarios and creates the input files required by FREEVAL-ATDM to evaluate the unique demand, capacity, and free-flow speed characteristics of each scenario.

3. Apply Operations Tool to Scenarios for "Before" Condition

A conventional HCM analysis (with SHRP 2-L08 extensions to predict capacities and speeds for adverse weather, incident, and work zone conditions) is applied to the 30 scenarios. This analysis is fully automated within the FREEVAL-ATDM software. The methodology uses capacity and speed adjustment factors for weather, work zones, and incidents from the HCM in order to model these disruptions. In this example, since an incremental analysis is desired, the HOT lane that was previously determined to be cost-effective is included in the "before" case.

With dynamic congestion pricing, the assumption is that the toll for the HOT lane will be dynamically set as low or as high as necessary to fill the HOT lane to its target operating capacity of 1,600 vph. Allowing for some latency in the tolling/demand cycle, it will be assumed that a target maximum volume of 1,500 vph will be achieved. Thus volumes in the HOT lane will be limited in the HCM analysis to 1,500 vph, where demand on the facility is sufficient to reach those levels.

4. Compute MOEs for "Before" Condition

FREEVAL-ATDM generates the MOEs for each scenario as well as combined summary results for the 30 scenarios. (See exhibit following Step 8.)

5. Design ATDM Strategy

While the HOT lane was found in the prior analysis to relieve recurring congestion for the low and medium demand levels, there was still predicted to be significant congestion on the facility during an upcoming major work zone as well as during adverse weather and when major incidents occur. Consequently, two additional strategies will be added to the ATDM program for evaluation: dynamic ramp metering and an employer-based TDM program. The dynamic ramp metering would be sensitive to expected and unexpected variations in demand and capacity conditions on the freeway. The employer-based TDM program would be targeted to the times when the work zone is expected to cause major disruptions, a major incident has occurred, and during forecasted major weather events. During these times, employers will allow a certain percentage of their employees to telecommute and will implement staggered work hours. In this example, agency management expressed concerns that implementing ramp metering and TDM could be counterproductive to the investment in the HOT lane strategy by diverting demand from the freeway facility. This ATDM analysis is being performed to determine if the effects of these three operations strategies working together. The modeling of ramp metering is handled by several steps:

- The mainline capacity is increased, which is at the discretion of the user. We are suggesting 3 percent, unless the user has better data.
- The effect on ramp volumes delivered to the freeway is handled by setting the capacity of the ramp equal to the ramp metering rates.
- Ramp metering rates are specified by the user, but can also be automatically generated using a local optimal method roughly based on the ALINEA algorithm. (ALINEA is the basis for ramp metering for this example.) The local optimal method generates ramp specific metering rates for each 15 minute analysis period.

6. Convert ATDM Strategy into Operations Tool Inputs for "After" Condition

Locally optimal dynamic ramp metering is emulated in the HCM analysis by comparing the predicted total demand (ramp plus mainline) for the on-ramp merge section to the target maximum desirable flow rate for the freeway. (For this example the target is set at 2,100 vehicles per hour per lane for the general purpose lanes.) The difference between the target merge section volume and the upstream freeway mainline input volume is the ramp metering rate, subject to these constraints:

- the maximum ramp metering rate is set at 900 vph/lane;
- the minimum ramp metering rate is set as 240 vph/lane; and
- if, during the course of the analysis, the number of vehicles stored on the ramp hits 40, then the meter rate is set to the maximum rate until the queue drops below 40 vehicles. (This storage threshold is set by the user.)

The analysis is automatically repeated for each ramp for each 15-minute analysis period within each scenario. The computed ramp rates become the ramp capacities input into the HCM analysis tool.

The capacities of the ramp merge sections are increased by 3 percent to account for the capacity increasing effects of ramp metering.

Examination of the ramp volume data suggested that single lane metered on-ramps would be inadequate to accommodate the expected ramp demands under medium demand conditions. Consequently it was judged that the ramps would have to be expanded to two metered lanes each, for metering to work on this facility.

Various TDM strategies are considered for reducing recurring demand. A program of strategies that increase as demand increases is adopted. For example, a special program to contact cooperative major employers in the area is put in place for activation when PM peak period demand levels are expected to be greater than normal. Based upon an independent assessment of the likely effects on facility demand, it is estimated that this program will reduce freeway demands by 1 percent for low demand levels, 2 percent for medium demand levels, and by 4 percent for high demand levels.

A TDM plan for dealing with long-term work zones, major incident, or severe weather events can also be developed in order to model the effects of reduced demand. Major employer participation and information dissemination is ramped up when a long-term work zone is in effect, a major incident has occurred, or severe adverse weather is predicted.

7. Apply Operations Tool for "After" Condition

A conventional HCM analysis (with SHRP 2-L08 extensions to predict capacities and speeds for adverse weather, incident, and work zone conditions) is applied to the 30 scenarios. This analysis is fully automated within the FREEVAL-ATDM software using capacity and speed adjustment factors from the HCM.

8. Compute MOEs for "After" Condition

FREEVAL-ATDM generates the MOEs for each scenario as well as combined summary results for the 30 scenarios (see exhibit below). Results of adding dynamic metering and employer-based TDM to a freeway with a HOT lane are shown below. Note that VMT after implementation is lower because of the TDM strategy. Implementing ramp metering and TDM improves both total delay and average speed, and also improves travel time reliability (as shown in the reduction of the Planning Time Index).

Exhibit 3:

Measure of Effectiveness	Before (with only HOT)	After (with HOT, metering, and TDM)	Difference (After-Before)	Percent Difference
Vehicle-Miles Traveled Demand (VMT-Demand)	25,847,488	25,390,134	-457,354	-1.8%
Vehicle-Miles Traveled Served (VMT-Served)	25,847,488	25,390,134	-457,354	-1.8%
Vehicle-Hours Traveled (VHT)	561,258	482,868	-78,390	-14.0%
Vehicle-Hours Delay (VHD)	192,009	120,152	-71,857	-37.4%
Average Speed (mph)	46.05	52.58	6.53	14.2%
Average Delay (secs/mi)	26.74	17.04	-9.70	-36.3%
Planning Time Index (95^{th}% TTI)	3.36	2.54	-0.82	-24.4%

TTI = travel time index, ratio of actual travel time to free-flow travel time.

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Conclusion

Adding dynamic metering and employer-based TDM to the previously selected ATDM strategy of converting the HOV lane to HOT lane operation with dynamic congestion pricing is estimated to reduce vehicle-hours of delay by an additional 37 percent (across all lanes), increase average speeds on the facility by an additional 14 percent, and improve reliability of the facility (as measured using the planning time index) by an additional 24 percent. It should be noted that some of the reduced delay across all lanes is due to the lower demand caused by the TDM strategy.

Rather than detracting from the effectiveness of the HOT lane conversion, dynamic metering and employer based TDM further support the agency's objectives for improving the performance of the freeway facility.

The table below shows the relative contributions to facility performance of the various components of the total ATDM investment program for the freeway facility.

Exhibit 4:

Measure of Effectiveness	Before with HOV	Convert HOV to HOT	Add In Dynamic Meter	Full ATDM Program (HOT + Meter +TDM)
Average Speed	42.8	46.1	48.6	52.6
Average Delay	32.6	26.7	22.6	17.0
Planning Time Index	3.92	3.36	2.99	2.54

It is likely that the order in which the strategies are applied influence the change from one strategy to another. If the incremental benefits of adding a strategy to another are desired, then the analyst should conduct multiple runs of the procedure, varying the sequence in which the strategies are applied.

ATDM Project Informational Briefs

This informational brief is one of the ATDM briefs in the Analysis category of the FHWA ATDM Brief Series. ATDM briefs are or will be available in the categories of:

- ATDM Program: **Yellow**
- ATDM Planning: **Purple**
- ATDM Analysis: **Orange**
- ATDM Design: **Green**
- ATDM Operations: **Red**

In addition to this overview brief of the ATDM/HCM Analysis method, FHWA is releasing additional project briefs to provide high-level descriptions of the various components of the ATDM/HCM methodology and its application.

FHWA ATDM Program

The U.S. Department of Transportation (U.S. DOT) is advancing the development of guidance, planning, case studies, and research in the application and design of active transportation and demand management approaches. In addition, the ATDM program will provide lessons learned, standards, and best practices on key underlying ATDM planning, evaluation, analysis techniques and design elements that serve as a foundation for ATDM implementation.

For more information on this project or the FHWA ATDM program efforts, please contact:

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FHWA ATDM web site: http://www.ops.fhwa.dot.gov/atdm/index.htm

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