U.S. Department of Transportation
Federal Highway Administration

Demonstrating Performance-Based Practical Design through Analysis of Active Traffic Management

PURPOSE OF THE TRANSPORTATION SYSTEMS MANAGEMENT AND OPERATIONS PERFORMANCE-BASED PRACTICAL DESIGN CASE STUDY SERIES AND SUMMARY OF CASE STUDY 5

As states and local agencies become increasingly challenged with addressing their system performance, mobility, and safety needs in the current era of financial limitations, Federal Highway Administration (FHWA) is providing guidance, delivering technical assistance, and sharing resources related to **performance-based practical design (PBPD)**. The FHWA Office of Operations is supporting the overall Agency PBPD effort by highlighting the role transportation systems management and operations (TSMO) alternatives and analysis tools can play in supporting PBPD.

To illustrate the range of TSMO strategies and tools and how they can be applied by transportation planners and designers in a PBPD context, five case studies were developed. This Case Study 5 illustrates how a PBPD approach be used to analyze and make tradeoffs when examining potential **Active Traffic Management (ATM) strategies** (as shown in Table 1) along freeways, as was done in developing ATM recommendations, a Concept of Operations and an ATM Implementation Plan for the New Jersey Department of Transportation (NJDOT).

Other case studies in this series include implementing of high-occupancy toll (HOT) lanes, urban freeway reconstruction/ modernization, regional performance-based planning, and the use of alternative intersections on arterials.

CASE STUDY BACKGROUND

ATM strategies have been receiving significant attention of late given the operational benefits that have accrued, coupled with their reduced costs and implementation timeframes relative to more traditional improvements, such as geometric enhancements to the roadway network. Furthermore, ATM operational benefits can help to achieve one or more regional, system, and project goals, such as safety, mobility, reliability, environmental, and accessibility.

Table 1. Active Traffic Management Strategies.

- Adaptive ramp metering
- Dynamic lane assignment
- Dynamic speed limits
- Dynamic shoulder lanes
- Dynamic junction control
- Queue warning

The Federal Highway Administration (FHWA) recently developed an ***Active Traffic Management Feasibility and Screening Guide (the Guide)*** to assist transportation agencies and planning organizations with making informed investment decisions by determining the feasibility of ATM strategies before committing significant resources towards any subsequent project development and design activities. The Guide presents a recommended process and series of steps for agencies to follow as they consider ATM deployment at the feasibility and screening analyses level. Following are key activities of the Guide:

- Identify ATM strategies that support regional goals and objectives and project performance needs.
- Use a data-driven approach to screen corridors and roadway segments for potential ATM deployment.
- Analyze and prioritize corridor segments for ATM deployment based on most appropriate strategies and associated benefits and costs.
- Evaluate potential design options to cost-effectively achieve desired performance options.

These activities strongly parallel the various PBPD concepts, including aligning the recommendations with regional and system goals, emphasizing needs and objectives when scoping and developing ATM projects, focusing on performance improvements and associated benefits, and using performance tools and analysis techniques to evaluate alternatives in terms of their value and return on investment (discussed in greater detail below).

The Guide was the basis for analyzing potential ATM strategies and identifying segments along NJDOT's limited access roadway network—comprising more than 700 directional miles—that would most likely benefit from the application of ATM strategies, resulting in recommendations and a Concept of Operations for initial ATM implementation projects that would be relatively easy to implement and provide the greatest possible benefits (i.e., "most bang for the buck"), thereby setting the stage for subsequent ATM deployments along other segments in the state.

CORRIDOR AND SYSTEM NEEDS AND OBJECTIVES

PBPD strengthens the emphasis on planning-level corridor or system performance needs and objectives when planning, scoping, and developing individual projects.

The initial activities of the ATM feasibility and screening process include aligning potential ATM strategies with regional (and statewide) goals and objectives, as well as project-specific performance needs. Table 2 was developed for NJDOT to show how the various ATM strategies addressed in the project would also support the transportation goals, and the associated needs and issues, identified in the Statewide Strategic Transportation Systems Management and Operations (TSMO) Plan. (Note: The ATM strategy of adaptive ramp metering was not included due to potential institutional issues.)

PERFORMANCE IMPROVEMENTS

PBPD focuses on performance improvements that benefit both project and systemwide needs. Projects are scoped to achieve the purpose and need.

ATM strategies, such as dynamic speed limits, dynamic lane assignment, and queue warning, have demonstrated performance improvements—particularly in terms of reduced crashes—in numerous deployments. Dynamic shoulder lanes and dynamic junction control strategies, by adding temporary capacity, are proven approaches for reducing congestion and may also enhance safety. However, these and other ATM strategies may not be appropriate to all roadway segments.

For the New Jersey limited-access roadway network, NJDOT conducted an initial screening to identify specific roadway segments where ATM strategies would likely provide the greatest benefits (and also helping to reduce the number of miles subject to a more detailed analysis). This screening included both quantitative and qualitative assessments using readily available data coupled with the local knowledge of several ATM stakeholders. The project area was first divided into 5- to 20-mile bidirectional segments, with major interchanges generally being the end and start points for each segment. These were evaluated and screened focusing on several performance considerations, including the following:

- **Existing TSMO/ITS infrastructure—**The Guide notes that an agency should <u>not</u> consider ATM strategies unless more basic and conventional operations strategies and supporting technologies, such as incident management and traveler information, are already in place and capable of more active management. Any segment that was not already managed to some degree were eliminated from further ATM consideration.

Table 2: Summary of the Extent to Which Active Traffic Management Strategies May Help Achieve the New Jersey Statewide Transportation Systems Management and Operations Goals and Solve Transportation Issues.

Goal	Issue/Consideration	DSpL/DLA	DShL	DJC
Safety & incident Management	High rate of crashes along roadway segments	●	◐	◐
	High rate of crashes in vicinity of interchange	◐	○	●
	High rate of secondary crashes	●	○	◐
	Improved incident and work zone management	●	○	◐
Mobility	Congestion along segment during peak period	◐	●	◐
	Congestion in vicinity of interchange	◐	◐	●
Reliability	Significant variation in average speeds	●	◐	◐
	Significant variations in traffic flows (special events)	●	●	●
Environment & Resiliency	Nonattainment area	●	○	○
	Concern with greenhouse gas emissions	●	○	○
	Supporting operations during major weather events	●	●	●
Economic Competitiveness	Improve operations on freight routes	◐	◐	◐
	Improve access to economic centers	◐	●	●

DSpL = Dynamic Speed Limits; DLA = Dynamic Lane Assignment
DShL = Dynamic Shoulder Lanes; DJC = Dynamic Junction Control

● = major improvement; ◐ = some improvement; ○ = neutral or not applicable

- **Safety—**The segments were scored based on their relative safety issues and crash experience, with highest score given to those segments where the crash frequency was the greatest. The safety scores were based on a review of geographic information system (GIS)-based maps showing the crash rates in New Jersey for the past 6 years. Those segments with the highest safety scores were selected for further analysis.
- **Recurring congestion and bottlenecks—**The segments were scored based on levels of recurring congestion and/or significant bottleneck locations, with the highest scores given to those segments with the worst congestion relative to other segments in the state. This scoring was based on a review of GIS-based maps showing congested commuter corridors and congested summer corridors and a review of GIS-based maps showing problem area interchanges and an impact ranking of state bottlenecks. Those segments with the highest congestion scores were selected for further analysis (and, not surprisingly, many high-scoring safety and congestion segments were one in the same).
- **Other considerations—**While existing TSMO, safety, congestion, and bottlenecks were primarily considered in this initial screening, other considerations were also assessed on a smaller numerical scale. These included whether the segment was a major freight route and/or serves a major economic area or intermodal facilities, serves special event venues and/or recreation areas, is used as an evacuation route, or will be undergoing

major reconstruction in the near future.[1] The potential of a segment being part of a future Integrated Corridor Management (ICM) system was also considered.

In addition to segments that had the highest scores for safety or congestion, all scores noted above were summed and identified a few additional segments for more detailed analysis.

A more detailed data-based analysis was conducted on roadway segments identified during the initial screening process to define the specific links (i.e., mileposts and interchanges) and associated ATM strategies to be deployed on these links. This was accomplished by analyzing time-space plots of recurring congestions and crash history tables, with the latter focusing on rear-end and sideswipe crashes. The data analyses were supplemented by field reviews (e.g., could the existing roadway footprint accommodate temporary use of the shoulder as a travel lane, sight distance considerations for ATM signage visibility).

GREATER RETURN ON INVESTMENTS

By scrutinizing each element of a project's scope relative to value, need, and urgency, a PBPD approach seeks a greater return on infrastructure investments.

Implementing ATM strategies can involve significant capital costs—such as frequently spaced gantries and dynamic message signs—followed by ongoing operations and maintenance requirements. As such, some ATM strategies may not be cost effective for certain segments and links of the surface transportation network. A benefit-cost analysis was, therefore, performed for those roadway links and ATM strategies where likely performance improvements had been identified. Several ATM options were analyzed:

- **Full gantry approach—**Gantries (with a small dynamic message sign (DMS) over each lane to display speed limits and lane control symbols and larger DMS to the right side of the roadway for queue warning) located nominally every 0.5 mile—the approach taken for initial ATM installations in England, Washington, and Minneapolis. The New Jersey analysis assumed five gantries every 2 miles, considering project area horizontal and vertical curves.
- **Hybrid approach—**Gantries placed every mile, with side-mounted dynamic speed limit signs—located on both sides of the roadway—installed between each set of gantries. This is a variation of the approach currently being used in England.
- **Shoulder use considerations—**Two sets of costs were developed for dynamic shoulder lanes: a "best case," assuming minimal work is required to prepare the shoulder for traffic (i.e., mostly repaving), and a "worst case," assuming complete shoulder reconstruction, including minor widening and drainage and guiderail relocation.[2]

Benefits were estimated based on conservative assumptions of the percent decrease in crashes and congestion resulting from implementing ATM strategies. These assumptions were based on the results from other ATM implementations, with the hybrid approaches resulting in slightly less benefits relative to the full gantry approaches. Benefits and costs were calculated using a 15-year life-cycle.

While the resulting benefit-cost ratios were an important factor in identifying the optimum segments for initial ATM deployment in New Jersey, other considerations were also addressed, included the following:

- **Freight—**Additional emphasis was placed on those segments identified as priority highway

[1] Including ATM infrastructure during a roadway reconstruction effort can help reduce overall costs. Additionally, ATM strategies may also effectively provide work zone traffic control benefits on the segment undergoing reconstruction as well as alternate routes.

[2] This information was not readily available without drilling cores to determine the actual construction of the existing shoulders.

corridors in the New Jersey Statewide Freight Plan.

- **Constructability—**There were a number of constructability-related considerations. For example, installing gantries and supports along a roadway built on structure is often more problematic when compared with an at-grade stretch of roadways. Alternatives involving dynamic shoulder lanes have significant uncertainty that can impact a project's schedule and cost, such as the ability of existing shoulders to handle traffic (with only minimal reconstruction), impacts on drainage, and potential environmental impacts and the associated processes.

The final recommendation for the initial ATM projects in New Jersey were to implement dynamic speed limits, dynamic lane assignment, and queue warning on along I-287, I-80, or both, using a hybrid approach. These segments generally have the highest benefit-cost ratios (Table 3) and positive ratings in other considerations. Dynamic shoulder lanes could be added at a later date.

Table 3: Recommended Segments for Initial Implementation of Active Traffic Management in New Jersey.

Roadway	Segment (mile post)	Capital Costs (million)	B-C Ratio
I-80: both directions	52.5 to 62.5	$ 38.7	5.4
I-287: both directions	0.5 to 14.5	$ 50.3	3.6

DESIGN STANDARDS AND REGULATORY REQUIREMENTS

PBPD can be implemented within the Federal-aid Highway Program regulatory environment using existing flexibility.

Figure 1 shows the recommended gantry layout for New Jersey, incorporating dynamic speed limits (actually advisories rather than legal limits), dynamic lane assignment, and queue warning strategies—a full span over one direction of the roadway, with speed and lane control displays situated over each travel lane. Another display can be added over the shoulder if and when using the shoulder as a travel lane is implemented. Speed displays are also installed on the gantry support poles on both sides of the roadway.

As the speed advisory and lane assignment displays (specifically the yellow diagonal arrow shown in Figure 1) do not conform to the Manual on Uniform Traffic Control Devices (MUTCD), it will be necessary for NJDOT to request approval from FHWA of an "experiment" to use the nonstandard sign displays. According to the MUTCD, "a successful experiment is one where the research results show that the public understands the new device or application, the device or application generally performs as intended, and the device does not cause adverse conditions."

OTHER DESIGN CONSIDERATIONS

ATM strategies, and TSMO in general, may be used to support other PBPD-related activities. One example is the "design exception" process whenever a recommended design—identified as part of a PBPD approach—deviates from

Figure 1. Graphic: Recommended Active Traffic Management Gantry Layout for New Jersey.

nationally recognized critera such as the American Association of State Highway and Transportation Officials (AASHTO) "Green Book[3]." When the minimum (or maximum) values of any controlling criteria are not met, the recommended alternative must be documented as a "design exception" and evaluated for formal approval by FHWA. For example, a design exception will likely be required if the PBPD-based analysis results in a recommendation that involves adding capacity by narrowing freeway lanes to less than 12 feet in width and/or narrowing shoulders to less than 10 feet in width. Under these circumstances, ATM strategies such as dynamic speed limits and queue warning may be included in the recommendation (and in the design exception documentation) as a means to reduce speeds and provide warnings in advance of freeway segments with narrow lanes, limited shoulder widths, or reduced sight distance.

Another potential example is including dynamic lane assignment when designing and operating part-time (or full-time) shoulder use. The signs can be used to dynamically close the shoulder under several scenarios, such as debris or disabled vehicle in the shoulder or a closed shoulder (and perhaps other lanes) to permit emergency vehicles to more quickly reach a crash scene (from either direction) and subsequently to support on-scene operations.

PERFORMANCE-BASED PRACTICAL DESIGN

PBPD encourages evaluating the performance impacts of highway design decisions relative to the cost of providing various design features. PBPD can be articulated as modifying a traditional design approach from a "top-down," standards-first approach to a "design-up" approach where transportation decision-makers exercise engineering judgment to build up the improvements from existing conditions to meet both project and system objectives. Following a PBPD approach can help make more efficient use of scarce resources so that a greater number of improvements can be made. Notable attributes of PBPD include the following:

- Focuses on performance improvements that benefit both project and system-wide needs.
- Uses performance tools and analyses—scrutinizing each element of a project's scope relative to value, need, and urgency—to promote a greater return on investments.
- Strengthens the emphasis on planning-level corridor and system performance needs and objectives when scoping and developing individual projects.
- Can be implemented within the Federal-aid Highway Program regulatory environment using existing flexibility (e.g., design exceptions).
- Does not eliminate, modify, or compromise existing design standards or regulatory requirements.

CONTACTS

George Merritt
FHWA Resource Center Safety and Design Team
404-562-3911
George.Merritt@dot.gov

Jim Hunt
FHWA Office of Operations
717-221-4422
Jim.Hunt@dot.gov

Robert Mooney
FHWA Office of Program Administration
202-366-2221
Robert.Mooney@dot.gov

[3] American Association of State Highway and Transportation Officials (AASHTO). 2011. *A Policy of Geometric Design of Highways and Streets.* Sixth edition.