International Technology Scanning Program | July 2007

ACTIVE TRAFFIC MANAGEMENT: The Next Step in Congestion Management

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16. Abstract

The combination of continued travel growth and budget constraints makes it difficult for transportation agencies to provide sufficient roadway capacity in major metropolitan areas. The Federal Highway Administration, American Association of State Highway and Transportation Officials, and National Cooperative Highway Research Program sponsored a scanning study to examine congestion management programs and policies in Europe.

The scan team observed that transportation agencies in Denmark, England, Germany, and the Netherlands, through the deployment of congestion management strategies, are able to optimize the investment in infrastructure to meet drivers' needs. Strategies include speed harmonization, temporary shoulder use, and dynamic signing and rerouting.

The team's recommendations for U.S. implementation include promoting active traffic management to optimize existing infrastructure during recurrent and nonrecurrent congestion, emphasizing customer orientation, focusing on trip reliability, providing consistent messages to roadway users, and making operations a priority in planning, programming, and funding processes.

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International Technology Scanning Program

The International Technology Scanning Program, sponsored by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the National Cooperative Highway Research Program (NCHRP), accesses and evaluates innovative foreign technologies and practices that could significantly benefit U.S. highway transportation systems. This approach allows for advanced technology to be adapted and put into practice much more efficiently without spending scarce research funds to re-create advances already developed by other countries.

FHWA and AASHTO, with recommendations from NCHRP, jointly determine priority topics for teams of U.S. experts to study. Teams in the specific areas being investigated are formed and sent to countries where significant advances and innovations have been made in technology, management practices, organizational structure, program delivery, and financing. Scan teams usually include representatives from FHWA, State departments of transportation, local governments, transportation trade and research groups, the private sector, and academia.

After a scan is completed, team members evaluate findings and develop comprehensive reports, including recommendations for further research and pilot projects to verify the value of adapting innovations for U.S. use. Scan reports, as well as the results of pilot programs and research, are circulated throughout the country to State and local transportation officials and the private sector. Since 1990, about 70 international scans have been organized on topics such as pavements, bridge construction and maintenance, contracting, intermodal transport, organizational management, winter road maintenance, safety, intelligent transportation systems, planning, and policy.

The International Technology Scanning Program has resulted in significant improvements and savings in road program technologies and practices throughout the United States. In some cases, scan studies have facilitated joint research and technology-sharing projects with international counterparts, further conserving resources and advancing the state of the art. Scan studies have also exposed transportation professionals to remarkable advancements and inspired implementation of hundreds of innovations. The result: large savings of research dollars and time, as well as significant improvements in the Nation's transportation system.

Scan reports can be obtained through FHWA free of charge by e-mailing *international@fhwa.dot.gov.* Scan reports are also available electronically and can be accessed on the FHWA Office of International Programs Web Site at *www.international.fhwa.dot.gov.*

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European Bridge Structures (1995)

All publications are available on the Internet at *www.international.fhwa.dot.gov.*

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Abbreviations and Acronyms

AASHTO American Association of State Highway and Transportation Officials

ADT average daily traffic

ATM Active Traffic Management (United Kingdom)

CCTV closed-circuit television

DMS dynamic message sign

DOT Department of Transportation

ETC electronic toll collection

EU European Union

FHWA Federal Highway Administration

FTA Federal Transit Administration

GPS Global Positioning System

ITS intelligent transportation system

km kilometer

km/h kilometers per hour

LMS National Model System for Traffic and Transport (the Netherlands)

m meter

MCSS motorway control and signaling system

NCHRP National Cooperative Highway Research Program

NRM new regional model

NRTS National Roads Telecommunications Services (England)

NTCC National Traffic Control Center

PPP public-private partnership

RDS-TMC Radio Data System Traffic Message Channel

RTTI real-time traffic and traveler information

SHRP II Strategic Highway Research Program II

TCZ traffic control zone

TEN-T Trans-European Transport Networks

TIC Traffic Information Center (Denmark)

TMC traffic management center

VIS Road Sector Information System (Denmark)

VMT vehicle miles traveled

Executive Summary

The continued growth in travel along congested urban freeway corridors is exceeding the ability of transportation agencies to provide sufficient roadway capacity in major metropolitan areas with limited public funding for roadway expansion and improvement projects. High construction costs, constrained right-of-way, and environmental factors are pushing agencies to explore context-sensitive solutions, such as managed lanes, to mitigate the detrimental effects of congestion while optimizing the use of limited public funding.

Purpose

The purpose of this scanning study was to examine the congestion management programs, policies, and experiences of other countries that are in the planning stages, have been implemented, or are operating on freeway facilities. This scan sought information on how agencies approach highway congestion, actively manage and operate freeway facilities, and plan for and design managed lanes at the system, corridor, and project or facility levels. It builds on two other scans that focused on travel demand management and traffic incident response. While demand management and incident response relate to the purpose of this scan and are components of congestion management, the scan's primary focus was on agencies' use of managed lanes to provide additional roadway capacity and flexible operating strategies to respond to changing traffic conditions. In addition, the scan assessed European experiences to determine how agencies can integrate managed lane strategies into their congestion management program, network, and corridor planning and how managed lanes fit into the development of highway improvement projects.

Planning for the congestion management scanning study began in November 2005 with a desk scan that recommended Denmark, England, Germany, and the Netherlands as the four countries to visit. The initial team meeting occurred in December 2005 in Washington, DC, and the trip took place June 2–18, 2006. The 11 team members—all with expertise in planning, designing, and operating transportation facilities—included individuals from four State transportation agencies, the private sector, and the Federal Highway Administration (FHWA). During the 2-week trip, the team participated in the First International Symposium on Freeway and Tollway Operations in Greece and visited representatives in Denmark, England, Germany, and the Netherlands.

The initial desk scan did not indicate that managed lane facilities, as defined in the United States, are operating in many places in Europe nor are they in the planning phases in most European countries. Acknowledging this fact, the team decided to visit the selected countries to assess their policies, programs, and commitment to proactively managing and operating their highway facilities. Moreover, the team wanted to learn about the operational strategies the countries use and their positions on the use of managed lanes as part of their overall approach to operations and traffic management. The intent was to identify key issues for agencies to consider when developing a proactive congestion management program, including planning for, designing, and operating managed lane facilities, and how an agency can integrate managed lane operational strategies into the various decisionmaking processes related to roadway infrastructure investment.

Active Traffic Management

The scan team arrived in Europe with the intent of examining congestion management programs, policies, experiences and how the countries plan for and implement managed lanes. What the team uncovered during the trip was that and more: a complete package of strategies that make up the broader concept of active traffic management. This approach to congestion management is a more holistic approach that can include the current U.S. application of managed lane strategies to congested freeway corridors. It is the next step in congestion management.

What is active traffic management as the scan team envisions its application in the United States? It is the ability to dynamically manage recurrent and nonrecurrent congestion based on prevailing traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility. It increases throughput and safety through the use of integrated systems with new technology, including the automation of dynamic deployment to optimize performance quickly and without the delay that occurs when operators must deploy operational strategies manually. This congestion management approach consists of a combination of operational strategies that, when implemented in concert, fully optimize the existing

infrastructure and provide measurable benefits to the transportation network and the motoring public. These strategies include but are not limited to speed harmonization, temporary shoulder use, junction control, and dynamic signing and rerouting. Managed lanes, as applied in the United States, are an obvious addition to this collection. In addition, various institutional issues essential to the successful implementation of active traffic management include customer orientation; the priority of operations in planning, programming, and funding processes; cost-effective investment decisions; public-private partnerships; and a desire for consistency across borders.

The scan team saw the European approach in action in each of the countries visited: Denmark, England, Germany, and the Netherlands. Through the deployment of these strategies, agencies in these countries have control over entire facilities and are able to fully optimize the investment in the infrastructure to meet customer needs. Depending on the location and the combination of strategies deployed, specific benefits Europe has measured as a result of this congestion management approach include the following:

- An increase in average throughput for congested periods of 3 to 7 percent
- An increase in overall capacity of 3 to 22 percent
- A decrease in primary incidents of 3 to 30 percent
- A decrease in secondary incidents of 40 to 50 percent
- An overall harmonization of speeds during congested periods
- Decreased headways and more uniform driver behavior
- An increase in trip reliability
- The ability to delay the onset of freeway breakdown

These countries have been able to implement active traffic management and gain acceptance from the public and policymakers because they are seeing real results. For this reason, the scan team firmly believes that active traffic management is the next evolution in congestion management in the United States and we have much to learn from the experiences in Europe to make it a reality at home.

Recommendations

Europe faces similar mobility challenges as the United States, including an increase in travel demand, growth in congestion, a need to improve safety, and the reality of limited resources to address these challenges. Given these similarities, the scan team identified nine key recommendations related to congestion management that have the potential to help ease congestion if implemented in the United States. The purpose of this scan was to examine the congestion management programs, policies, and experiences of other countries and to seek information on how agencies plan for and design managed lanes at the system, corridor, and project or facility levels. The following are the scan team's primary recommendations in response to this charge:

- Promote active management to optimize existing infrastructure during recurrent and nonrecurrent congestion.
- Emphasize customer orientation and focus on trip reliability.
- Integrate active management into infrastructure planning and programming processes.
- Make operations a priority in planning, programming, and funding processes.
- Develop tools to support active management investment decisions.
- Consider public-private partnerships and other innovative financing and delivery strategies.
- Provide consistent messages to roadway users.
- Consider pricing as only one component of a total management package.
- Include managed lanes as part of the overall management of congested facilities.

Implementation

The scan team firmly believes that much can be gained by implementing the various congestion management strategies discussed in this report on congested roadway networks in the United States. To that end, the team plans a number of activities and initiatives to disseminate information from the scan and move the recommendations forward within the context of congestion management in the United States. These implementation initiatives and strategies include, but are not limited to, the following:

- Organize and hold an executive strategy forum, preceded by the development of a Puget Sound feasibility study, and a concepts and issues meeting with regions that have the highest potential for and interest in implementation.
- Incorporate active management into the Strategic Highway Research Program II (SHRP II) capacity operations research.
- Develop a white paper on regional planning for congestion management.
- Propose a National Cooperative Highway Research Program (NCHRP) synthesis on the state of the practice of planning for managed lanes.
- Propose an NCHRP project on managed lanes.
- Develop a broader FHWA and Federal Transit Administration (FTA) guidance document tied to the congestion management process.
- Coordinate FHWA analysis tool research to include active traffic management.
- Develop and deliver marketing and outreach materials,

including design and user information issues.

- Promote an FHWA interdisciplinary group.
- Explore the integration of active traffic management into public-private partnerships, including the creation of a template for negotiations that includes performance measures and training and addresses the financing of active traffic management.
- Sponsor a domestic scan and case studies on managed lanes.
- Incorporate scan recommendations into the FHWA managed lane program plan.

Chapter 1

Introduction

In June 2006, a team of 11 transportation planning, design, and operations experts from the United States visited five European countries to assess and evaluate various practices related to the congestion management programs, policies, and experiences that are being planned, have been implemented, or are operating on freeway facilities. This scan also sought information on how agencies plan for and design managed lanes at the system, corridor, and project or facility levels. During this trip, the team members heard numerous presentations about congestion management policies, strategies, and practices from a variety of perspectives, including national, state, and local transportation agencies, as well as current research efforts to assist these efforts. Using the information obtained during the trip, the team identified several areas in which U.S. practices have the potential to be improved. This report describes the team's findings and recommendations.

Background

The Federal Highway Administration's (FHWA) Office of International Programs focuses on meeting the growing demands of its partners at the Federal, State, and local levels for access to information on state-of-the-art technology and the best practices used worldwide. As part of this office, the International Technology Exchange Program accesses and evaluates innovative foreign technologies and practices that could significantly benefit U.S. highway transportation systems. This approach allows for advanced technology to be adapted and put into practice efficiently without spending scarce research funds to recreate advances already developed by other countries.[1] The main avenue for accessing foreign innovations is the International Technology Scanning Program. The program is undertaken jointly with the American Association of State Highway and Transportation Officials (AASHTO) and the Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP).

Planning for the congestion management scanning study began in November 2005 with a desk scan that recommended Denmark, England, Germany, and the Netherlands as the four countries to visit. The initial team meeting occurred in December 2005 in Washington, DC, and the trip took place June 2–8, 2006. As part of the trip, the scan team participated in the First International Symposium on Freeway and Tollway Operations in Athens, Greece, June 4–7, 2006.

Purpose

The continued growth in travel along congested urban freeway corridors is exceeding the ability of transportation agencies to provide sufficient roadway capacity in major metropolitan areas with limited public funding for roadway expansion and improvement projects. High construction costs, constrained right-of-way, and environmental factors are pushing agencies to explore context-sensitive solutions, such as managed lanes, to mitigate the detrimental effects of congestion while optimizing the use of limited public funding.

The purpose of this scan was to examine the congestion management programs, policies, and experiences of other countries that are in the planning stages, have been implemented, or are operating on freeway facilities. This scan sought information on how agencies approach highway congestion, actively manage and operate freeway facilities, and plan for and design managed lanes at the system, corridor, and project or facility levels. It builds on two other scans that focused on travel demand management and traffic incident response. The travel demand management scan assessed European approaches to managing demand for automobile and truck travel through such means as traveler information, technology, improved modal options, pricing, and new institutional arrangements.[2] The traffic incident response scan studied traffic incident response practices, procedures, and technologies across Europe.[3] While demand management and incident response relate to the purpose of this scan and are components of congestion management, this scan's primary focus was on agencies' use of managed lanes to provide additional roadway capacity and flexible operating strategies to respond to changing traffic conditions. The scan also assessed European experiences to determine how agencies can integrate managed lane strategies into their congestion management program, network, and corridor planning and how managed lanes fit within the development of highway improvement projects. To help the host countries address the team's concerns, a set of amplifying questions (see Appendix C) was provided to the hosts several months before the trip.

Congestion Management and Managed Lanes in the United States

The U.S. highway system is a critical component of American life. It provides extensive and flexible personal mobility to American citizens and efficient freight movement

to support the domestic economy.[4] Both of these services are affected by investment and location decisions that governmental entities across the country make in their planning processes. However, an increase in travel, congestion, and environmental and financial constraints interfere with the system's ability to provide these services. For example, the growth in vehicle miles traveled (VMT) continues to outpace lane mile growth across the country. Between 1993 and 2000, VMT increased 2.7 percent annually while the number of U.S. lane miles grew only 0.2 percent annually.[4] This growth in travel places a strain on an already-overburdened transportation system.

Congestion in urban areas of the United States is increasing. It occurs on more roads during longer parts of the day, delaying more travelers every year.[5] "Rush hour" grows longer and costs Americans dearly in delays, increased fuel consumption, lost productivity, and related crashes. Congestion interferes with daily life, and any method to alleviate it, such as managed lane projects, can reduce its impact on productivity. Another reality of improving the transportation infrastructure today is that agencies must function within environmental constraints. Agencies must consider the environment in planning transportation projects, minimize the negative impacts of construction, and work to reduce transportation-related pollution in the process. They must demonstrate environmental stewardship and improve the environmental quality of their transportation decisionmaking.[6]

Financial constraints are another burden for transportation agencies. As public resources become scarcer, State and local governments are challenged to meet growing transportation needs with limited funding.[7] An emerging trend in transportation spending is the reality that State and local governments are devoting a larger share of their capital spending to preserving their existing transportation infrastructure, leaving less money for new roads and bridges and system enhancements.[4] As a result, agencies are seeking alternative funding mechanisms and innovative finance techniques for critical projects.

Congestion management is a primary strategy that U.S. agencies use to operate their facilities in this environment. As figure 1 illustrates, a variety of factors, both recurring and nonrecurring, cause congestion for American travelers. Thus, FHWA has designated congestion mitigation as one of its "vital few" priorities and is targeting resources to develop and sustain regional partnerships to address all aspects of congestion.[8] Various operational and management strategies and methods exist for mitigating congestion and its impact on roadway users. For example, to combat recurring congestion in the freeway environment, which accounts for about 45 percent of all congestion in the United States, agencies undertake freeway management and traffic operations through policies, strategies, and actions to enhance mobility.[8] These strategies include roadway improvements such as widening and bottleneck removal, operational improvements, ramp management and control, and managed lanes. Mitigation techniques for nonrecurring congestion include management of incidents, work zones, road weather, and planned special events.[8] All

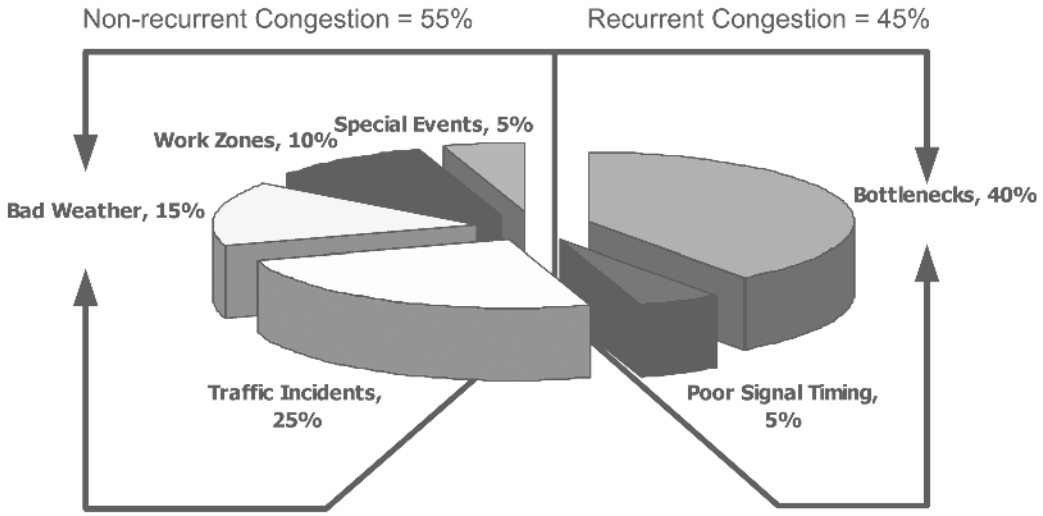

Figure 1. Causes of congestion in the United States.[8]

of these strategies center on the theme of getting more out of facilities already in place.

Managed lanes, a component of congestion management, are defined as highway facilities or a set of lanes in which operational strategies are implemented and managed (in real time) in response to changing conditions to preserve unimpeded flow. They are distinguished from traditional forms of lane management strategies in that they are proactively implemented and managed and may involve using more than one operational strategy with the goal of achieving unimpeded flow. Figure 2 is a diagram often used by FHWA and other U.S. agencies to illustrate the potential lane management strategies that fall into this broad definition of managed lanes. On the left of the diagram are the applications of a single managed lane operational strategy—pricing, vehicle eligibility, or access control. In the middle of the diagram are more complicated managed lane facilities that combine more than one strategy. The multifaceted facilities on the far right of the diagram are those that incorporate or combine multiple lane management strategies. Managed lane projects have the potential to improve mobility while reducing the increase in pollution and minimizing the impact on the environment. They also have the potential to better use existing facilities and reduce the impact of the increase in travel. They may lend themselves to alternative funding mechanisms, thereby reducing financial constraints and allowing projects to be completed sooner than under traditional funding schemes.

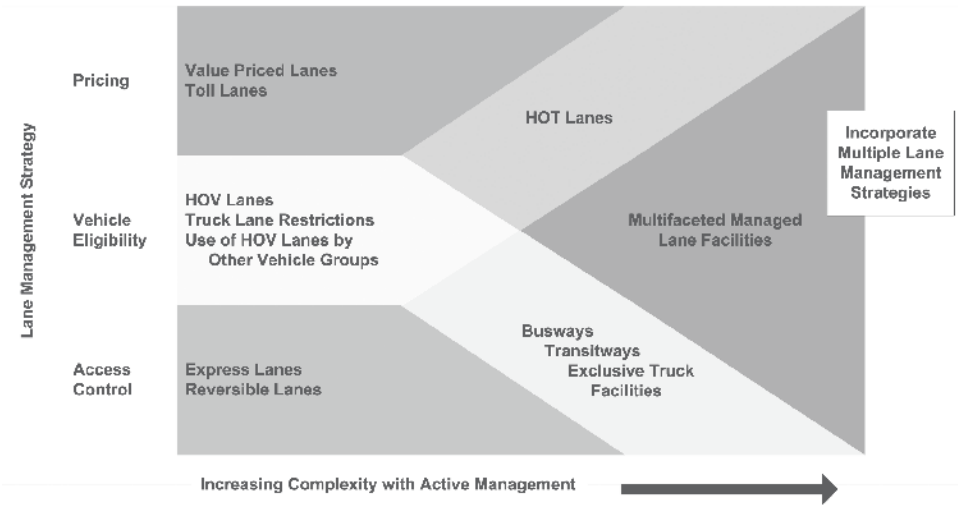

Figure 2. Typical U.S. managed lane facilities and applications.[10]

The primary purpose of managed lanes is to improve the performance of freeway facilities. Managed lane strategies can be operated and different strategies can be applied to accomplish mobility, safety, community, financial, and homeland security goals. All of these goals are ways a region can improve the overall quality of life for its citizens and ensure the long-term viability of the community. For example, typical mobility goals include providing a transportation system that can handle current and future demand, increasing mobility and accessibility by offering travel options, providing additional facility capacity, optimizing the capacity of existing managed lanes, providing congestion relief, and modifying travel demand.[9] Furthermore, managed lane strategies can be linked to specific objectives a region is trying to achieve, including increasing vehicle-, person-, and goods-carrying capacity; maintaining free-flow speed; maintaining or improving level of service; reducing travel time; and increasing trip reliability. These goals and objectives can help a region and other stakeholders clearly identify which managed lane operational strategies are best suited for the region.

Incorporating managed lanes into the planning and investment decisionmaking process requires agencies and regions to consider managed lanes as a viable congestion management strategy. Critical issues that agencies need to address when planning managed lanes include geometric design and cross section, traveler information needs, traffic control devices, enforcement, environmental justice, evaluation and monitoring, funding and financing, incident management, interoperability, interim and special use, operational flexibility, and pricing as an option.[9] While these planning considerations are general transportation factors that can apply to virtually any mode, they have particular ramifications within the managed lanes context. For example, the challenges of operational flexibility are evident when considering a change in the operation of an existing restricted-use lane, restricting the use of a lane not currently restricted, or adding additional roadway capacity to accommodate changes. Based on these challenges, agencies recognize that implementing managed lanes within a freeway corridor or region is a long-term endeavor that may evolve over time. Thus, throughout the entire planning process, an agency should consider these issues when assessing managed lane strategies as potential solutions to the region's transportation needs and when formulating the long-range regional plan and implementation program.

The initial desk scan did not indicate that managed lanes facilities, as defined in the United States, are operating in many places across Europe, nor are they in the planning phases in most European countries. Acknowledging this fact, the team decided to visit the selected countries to assess their policies, programs, and commitment to proactively manage and operate their highway facilities. Moreover, the team wanted to learn about the operational strategies these countries use and their positions on the use of managed lanes as part of their overall approach to operations and traffic management. The intent was to identify key issues for agencies to consider when developing a proactive congestion management program, including planning for, designing, and operating managed lane facilities, and how an agency can integrate managed lane operational strategies into the various decisionmaking processes related to roadway infrastructure investment.

Active Traffic Management—A Definition

The scan team arrived in Europe with the intent of examining congestion management programs, policies, and experiences, and how they plan for and implement managed lanes. What the team uncovered during the trip was that and more: a complete package of strategies that make up the broader concept of active traffic management. This approach to congestion management is a more holistic approach that can include the current U.S. application of managed lane strategies to congested freeway corridors. It is the next step in congestion management.

What is active traffic management as the scan team envisions its application in the United States? It is the ability to dynamically manage recurrent and nonrecurrent congestion based on prevailing traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility. It increases throughput and safety through the use of integrated systems with new technology, including the automation of dynamic deployment to optimize performance quickly and without the delay that occurs when operators must deploy operational strategies manually. This congestion management approach consists of a combination of operational strategies that, when implemented in concert, fully optimize the existing infrastructure and provide measurable benefits to the transportation network and the motoring public. These strategies, discussed in more detail in Chapter 2, include speed harmonization, temporary shoulder use, junction control, and dynamic signing and rerouting. Managed lanes, as applied in the United States, are an obvious addition to this collection. In addition, various institutional issues essential to the successful implementation of active traffic management include a customer orientation; the priority of operations in planning, programming, and funding processes; cost-effective investment decisions; public-private partnerships; and a desire for consistency across borders.

The scan team saw the European approach in action in each of the countries visited: Denmark, England, Germany, and the Netherlands. Through deployment of these strategies, agencies in these countries have control over entire facilities and are able to fully optimize the investment in the infrastructure to meet the needs of the customer. Depending on the location and the combination of strategies deployed, specific benefits Europe has measured as a result of this congestion management approach include the following:

- An increase in average throughput for congested periods of 3 to 7 percent
- An increase in overall capacity of 3 to 22 percent
- A decrease in primary incidents of 3 to 30 percent
- A decrease in secondary incidents of 40 to 50 percent
- An overall harmonization of speeds during congested periods
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These countries have been able to implement active traffic management and gain acceptance from the public and policymakers because they are seeing real results. For this reason, the scan team firmly believes that active traffic management is the next evolution in congestion management in the United States and we have much to learn from the experiences in Europe to make it a reality at home.

Team Members

The 11 team members—all with expertise in planning, designing, and operating transportation facilities—included individuals from four State transportation agencies, the private sector, and FHWA. On the team were Chuck Fuhs of Parsons Brinckerhoff, Charlie Howard of the Puget Sound Regional Council, Raymond Krammes of FHWA, Beverly Kuhn of the Texas Transportation Institute, Robin Mayhew of FHWA, Mohammad Mirshahi of the Virginia Department of Transportation (DOT) (co-chair), Margaret Moore of the Texas DOT, Jon Obenberger of FHWA (co-chair), Khani Sahebjam of the Minnesota DOT, Craig Stone of the Washington State DOT, and Jessie Yung of FHWA. Appendix A contains contact information and team member biographies. Figure 3 shows the scan team in front of the Federal Highway Research Institute (BASt) in Bergisch-Gladbach, Germany.

Team Meetings and Travel Itinerary

During the 2-week trip, the team participated in the First

International Symposium on Freeway and Tollway Operations and visited representatives in Denmark, England, Germany, and the Netherlands. The team members left the United States on June 2, 2006, and held their first team meeting on June 4. After participating in the symposium in Athens, Greece, the team departed for Germany and met with the German hosts on June 8–9, including meetings in Bergisch-Gladbach, Cologne, and Frankfurt. The team held a midpoint meeting on June 11. The team met next with representatives in Copenhagen, Denmark, on June 12 and with hosts in the Netherlands June 13–14 in Rotterdam and Utrecht. The team members then traveled to England, where they met with representatives of several groups in Birmingham and London June 15–16. The team held a wrap-up meeting on June 17 and a final meeting August 29–30 in Washington, DC. Table 1 summarizes the team meetings and travel schedule.

Host Delegations

During the 2-week trip, the team members met with representatives from the various national and regional transportation agencies in the host countries. A list of individuals the team met with and contact information are in Appendix D. Many organizations represented in the meetings are known by acronyms, which are based on the native-language name of the organization. The team also visited several sites in the five countries, listed in table 2 (see next page).

Figure 3. Scan team members in Bergisch-Gladbach, Germany: (left to right) Robin Mayhew, Jon Obenberger, Chuck Fuhs, Ray Krammes, Mohammad Mirshahi, Craig Stone, Meg Moore, Jessie Yung, Khani Sahebjam, Charlie Howard, and Beverly Kuhn.

Report Organization

The purpose of this report is to describe the innovative approach to congestion management and managed lanes examined in each city, summarize the findings from the scan trip, suggest strategies that might be applicable to the United States, and recommend activities that might increase awareness and knowledge of the need to and means for

Table 1. Team meetings.

Date	Location	Purpose or Host
December 13, 2005	Washington, DC	Initial team meeting to determine emphasis areas and develop amplifying questions.
June 4, 2006	Athens, Greece	Kickoff trip meeting to review travel plan and make note-keeping assignments.
June 4–7, 2006	Athens, Greece	First International Symposium on Freeway and Tollway Operations
June 8–9, 2006	Bergisch-Gladbach, Cologne, and Frankfurt, Germany	Meet with German hosts.
June 11, 2006	Lund, Sweden	Midtrip meeting to review findings to date and initiate draft report outline.
June 12, 2006	Copenhagen, Denmark	Meet with Danish hosts.
June 13–14, 2006	Rotterdam and Utrecht, Netherlands	Meet with Dutch hosts.
June 15–16, 2006	Birmingham and London, England	Meet with English hosts.
June 17, 2006	London, England	Final trip meeting to identify key findings, develop preliminary recommendations, and finalize report outline.
August 29–30, 2006	Washington, DC	Final team meeting to finalize report and implementation plan.

Table 2. Sites visited during the scan.

Country	Sites Visited	Location
Greece	• Attiki Odos Headquarters, Maintenance Yards, and Traffic Management Center	Athens
Germany	• Federal Highway Research Institute (BASt) • Traffic Control Center Hessen	Bergisch-Gladbach Rodekheim
Denmark	• Copenhagen Area Project • Danish Road Directorate	Copenhagen Copenhagen
The Netherlands	• AVV Transport Research Center • National Traffic Management Center (VCNL)	Rotterdam Utrecht
England	• National Traffic Control Center • West Midlands Traffic Control Center • Highways Agency Headquarters	Quinton Quinton London

planning for congestion management and managed lanes in light of this European experience.

Chapter 2 summarizes the visits to each country, both to provide a context for implementation and to reveal the full range of strategies and techniques explored. Chapter 3 presents the key findings from the scan, organized by primary challenges the European countries face, their approach to congestion management, examples of managed lanes operational in Europe, and the direction of managed lanes in the countries visited. Chapter 4 provides an overall assessment of active management and its potential role in the United States. Chapter 5 summarizes the implementation plan for the scan.

European Agency Approaches to Congestion

This chapter describes the findings from each site visit. It provides a context for each country's overall approach to congestion management and summarizes key strategies deployed in each country related to traffic management and managed lanes.

Greece

The scan team began the scanning study in Athens, Greece, to participate in the First International Symposium on Freeway and Tollway Operations. While this country was not on the list of those visited from the direct perspective of the scan purpose, the group was able to assess some of the congestion management issues in Greece as part of symposium activities. The following sections highlight the observations and findings that pertain to the scan purpose and objective.

Overall Congestion Management Approach

Greece is one of the countries in the Balkan Peninsula region of southeastern Europe. It is experiencing significant economic growth and expansion largely as a result of joining the European Union (EU). Along with this growth comes an increase in congestion on the country's roadway network. Most of the roadways across Greece are two-lane undivided roadways providing local access to users. Only recently have projects been undertaken to expand these roadways to increase mobility from both a national and regional perspective.

National Perspective

At the national level, Greece has no modern freeway facilities funded completely with public dollars. The government has designated specific corridors on the network as part of the EU Trans-European Transport Networks (TEN-T) program. The corridors are identified as those that play a crucial role in ensuring the free movement of passengers and goods throughout the European Union and achieving balanced economic growth in the member countries.[11] The primary corridors that are part of TENT-T in Greece are the Egnatia Motorway and the Pathé Motorway. As figure 4 shows, they provide critical access to adjacent countries while providing mobility throughout Greece and opening access to all regions of the country. The upgrade of these facilities to limited-access freeways is being funded in large part by private sector investment.

The Egnatia Motorway, the primary east-west route across Greece from the eastern port of Igoumenitsa to Turkey, links the major cities in northern Greece along with five ports and eight airports and intersects with eight major north-south roadways.[12] This four-lane motorway, which follows a second century route, is mostly complete, with full completion expected by 2008. The Pathé Motorway is the main north-south route through Greece that connects Patras

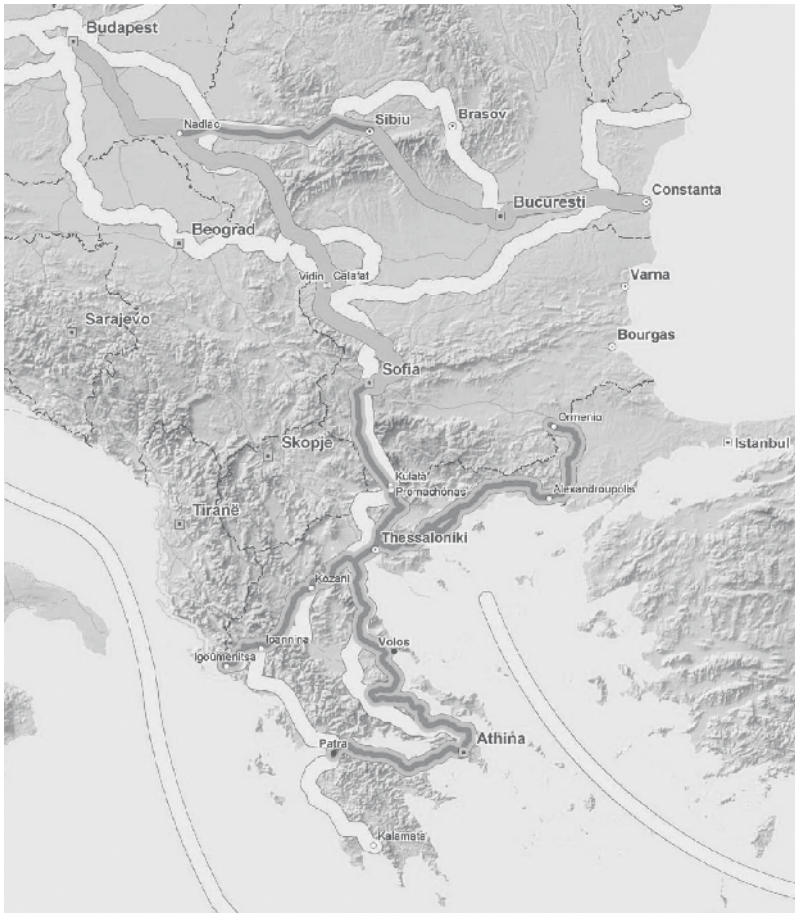

Figure 4. Greek motorways on TEN-T in Athens, Greece.[11]

in the south with Thessaloniki in the north and Bulgaria.[12] Mostly complete with four- and six-lane cross sections, the Pathé Motorway will close the missing links between Thessaloniki and Sofia by 2010 and will ensure primary access to other countries in this part of Europe. This motorway also links with the Attiki Odos Toll Motorway, a major ring road around Athens discussed in the next section. Both of these completed roadways will serve as a major national network across Greece and enhance regional and local mobility for all Greeks.

The national trend in transportation finance is the use of public-private partnerships (PPPs). The economic climate is ripe for these types of alternatively financed projects, and Greece has a successful cofinanced venture in the Attiki Odos that serves as an example for future endeavors.[13] An indication of this trend is the seven concession projects under development to extend existing motorways and meet the mobility needs of the country.[14] Critical partners in these projects will be Greek banks and construction companies, who have already proven their commitment to infrastructure expansion.

Regional Perspective

The Attiki Odos Toll Motorway, opened in 2004 before the Summer Olympics, is the first urban freeway in Greece (see figure 5).[15] The facility runs from Elefsina to Markopoulo, providing access to the region around Athens, including the Athens airport.[16] Also known as the Attica Tollway, Attiki Odos significantly aids in reducing congestion in Athens. A major link in the region's mobility, it is connected to the TEN-T motorways in the country. A total of 65 kilometers (km) long, the facility is instrumented with closed-circuit television (CCTV) cameras, dynamic message signs (DMS), lane control signals, and pavement sensors to monitor operations and measure performance. The speed limit is 100 kilometers per hour (km/h) in the sections through the center of Athens and 120 km/h on the outer ends in the

Figure 5. Attiki Odos Toll Motorway in Athens, Greece.[16]

suburbs. Electronic toll collection (ETC) is used for nearly 50 percent of all toll transactions during peak hours and 40 percent overall. Toll discounts are offered to frequent users, ranging from 15 percent for habitual commuters to 40 percent for those logging more than 80 transactions a month, such as taxis.

A public-private partnership project (PPP), the Attiki Odos is only the first of numerous motorways to be constructed in Greece. Plans are underway to construct nearly 1,000 km of additional motorways under a number of concession projects, which will enhance connectivity and mobility to critical regions around Athens and across the country.[13] The Ministry of Environment, Physical Planning, and Public Works considers these major corridors, including those designated as TEN-T routes, key to developing a critical and dense network of modern motorways to serve the people of Athens and surrounding regions and to help reduce congestion.[14]

Communication, Information, Data, and Performance Monitoring

As part of the construction and operation of Egnatia Motorway, the operating agency (Egnatia Odos A.E.) has deployed traffic count collection and processing systems on sections open to traffic.[17] This system, an integrated group of 65 data-collection stations along the motorway, uses inductive loops, microwave sensors, and telemetry software to collect traffic data and send them back to the toll authority's headquarters. These data, along with a traffic forecasting model, are used to predict demand on the transport networks for use in making decisions on motorway design, monitoring and telematic installations, feasibility studies, environmental assessments, maintenance needs, and other planning-related activities associated with the motorway and its intersecting roadways.[17] Similar data collection systems are in place on the Attiki Odos for monitoring operations and performance of the motorway around Athens.

Traffic Management Strategies

The following sections summarize specific traffic management strategies Greek agencies use to manage congestion on critical roadway networks, including tolling, variable speed limits, and active traffic management.

Tolling

The primary method used to manage congestion along the Attiki Odos Toll Motorway is tolling. The toll is a flat fee of €2.70 for passenger cars and light commercial vehicles, regardless of the distance traveled on the facility. Rates are lower for motorcycles and higher for larger vehicles. The intent of this flat toll schedule is to discourage short-distance trips.[15] The toll authority that operates the facility, Attikes Diadromes, may consider variable tolling to manage traffic flow in the future if congestion on the facility becomes detrimental to operations.

Variable Speed Limits

The facility also uses variable speed limits at the entrances to tunnels along the tollway as well as dynamic lane assignment signals (see figure 6). These signs are used to alert motorists if the advisable speed limits inside the tunnel are different from the rest of the facility. Moreover, these signals alert motorists if specific lanes in the tunnel are closed, such as for maintenance or an incident.

Congestion at toll plazas is reduced by the use of dedicated lanes for ETC. As figure 7 (see next page) shows, numerous ETC lanes are provided for customers and advance signing provides clear information to the user of impending toll payment, dedicated lanes, and automated enforcement of tolls at the plaza.

Active Traffic Management

Attikes Diadromes operates a state-of-the-art traffic management center (TMC) for the Attiki Odos (see figure 8 on next page). The center operates 24 hours a day, 7 days a week and monitors operations along the facility using the deployed technology noted previously. Operators in the center use dynamic message signs to alert tollway users to real-time travel information, basic safety rules, and special messages on extraordinary traffic conditions, such as an incident.[16]

A critical component of the active management of the tollway is a comprehensive system for handling incidents, the primary objective of which is to enable quick intervention in incidents while providing high-quality services that ensure optimum traffic conditions. Through a combination of pavement sensors, closed-circuit televisions (CCTV), emergency roadside telephones spaced every 100 meters (m), and patrol units (as shown in figure 9 on page 15) that operate around the clock, trained personnel at the TMC are alerted to incidents along the roadway. These personnel are critical to the efficient provision of assistance at incidents and the quick remedy of any problem. They maintain

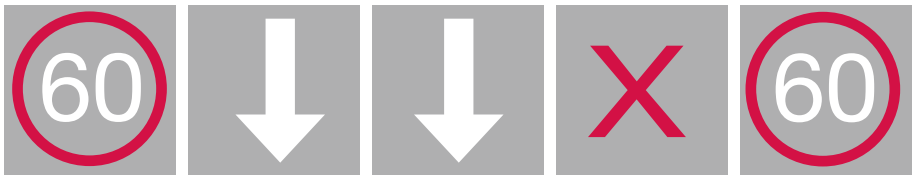

Figure 6. Attiki Odos Toll Motorway variable speed limit signing in Athens, Greece.[16]

Figure 7. Attiki Odos toll plaza (left) and related plaza sign (right) in Athens, Greece.

constant communication with personnel in the patrol units who serve as first responders and offer assistance at incidents at no charge.

TMC staff also provides information to road users via dynamic message signs and alert vehicle recovery units, the traffic police department, the ambulance service, and the fire brigade when necessary to clear an incident swiftly. Moreover, the staff coordinates road maintenance and vehicle cleaning activities to ensure that they do not negatively impact operations and that the appropriate specialized vehicles and personnel are deployed for each incident. Duties of incident management partners are clearly defined in manuals and formal agreements to ensure a clear chain of command and swift response and removal.

The Egnatia Odos facility also has a complex incident management strategy with a four-step process of detection, verification, response, and clearance. The TMC for the facility uses technologies similar to those used on the Attiki Odos and is responsible for traffic data collection, traffic management, weather information dissemination, emergency management, and provision of travel information to users.[18] Critical partners in the incident management structure include emergency crews, highway assistance, fire brigades, police, and ambulance services.

Figure 8. Attiki Odos Traffic Management Center in Athens,

Managed Lane Strategies

Managed lane-related operational strategies have been deployed primarily on Greek arterials because Greece did not have any urban freeways until 2004. To date, these freeway facilities are not congested and are not identified as needing managed lanes to help manage congestion. The following sections summarize the two types of managed lane strategies that have been implemented on arterials in Athens.

Bus-Only Lanes

One managed lane operational strategy of note in Greece is bus lanes that are operational in Athens and expanding outside the city center.[15] Bus lanes operate on about 50 km of roadways in the city. They operate as exclusive bus lanes on weekdays from 6 a.m. to 9 p.m. and on Saturday from 6 a.m. to 4 p.m., with no restrictions on Sundays.[15]

Olympic Lanes

During the 2004 Olympic Games in Athens, various managed lanes were established on the urban street network to facilitate transport to and from the various venues in the Olympic cities. Called Olympic Lanes, these lanes were for the exclusive use of Olympic athletes, VIPs, accredited media, sponsors, technical officials, public transport buses carrying spectators, and Olympic-accredited vehicles.[15] The restrictions on these lanes, which were on arterial streets, were from 6:30 a.m. to midnight during the 17-day Olympic Games.[19] Special traffic arrangements were also implemented during the companion Paralympic Games in Athens September 15 to 30, 2004. These included traffic control zones (TCZs) where access and circulation were modified to allow access to specific venues to authorized vehicles only.[20] Figure 10 shows an example of the TCZs around the Faliro Coastal Zone Olympic Complex.

With the exception of the bus lanes and Olympic lanes, no additional managed lane strategies operate in Greece and the transportation authorities have no plans to implement any in the foreseeable future. However, managed lane facilities may be needed as congestion increases on the expanding freeway network.

Figure 9. Attiki Odos incident response unit in Athens, Greece.

Germany

Overall Congestion Management Approach

The German federal motorway network is about 12,000 km across 10 states—mostly four- and six-lane facilities—carrying an average daily traffic (ADT) of about 49,000 vehicles.[21] These federal roads carry about one third of all of the traffic across the country, yet are only a small percentage of the entire German roadway network. Since the removal of the Iron Curtain and reunification of Germany, demand on the network has increased and is expected to increase an additional 16 percent for passenger transport and 58 percent for freight transport by 2015.[21] The federal government owns the federal motorways and highways and finances their construction, maintenance, and telematic infrastructure deployment, while the individual states are responsible for maintenance,

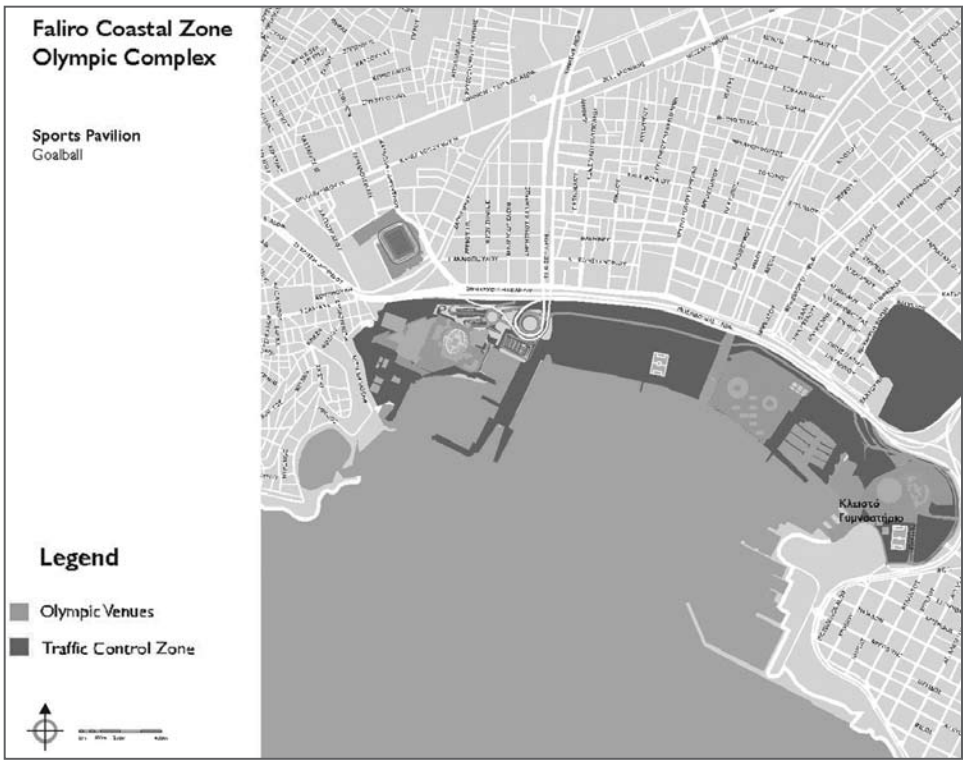

Figure 10. Faliro Coastal Zone Olympic Complex in Athens, Greece.[20]

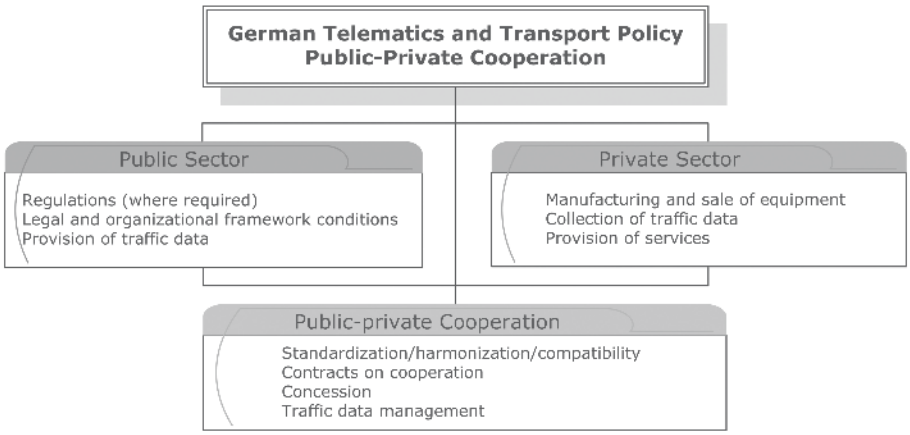

Figure 11. German public-private cooperation policy.[21]

ment of the federal motorway network. This program's objectives are to (1) increase by 1,200 km the length of motorways equipped with traffic control systems, (2) increase by 2,400 km the length of motorways with dynamic diversion possibilities, and (3) increase by 15 the number of traffic control centers across the country. Both federal initiatives illustrate a national movement to upgrade and actively manage the motorway network for efficient operations and to enhance the mobility of the country's citizens.

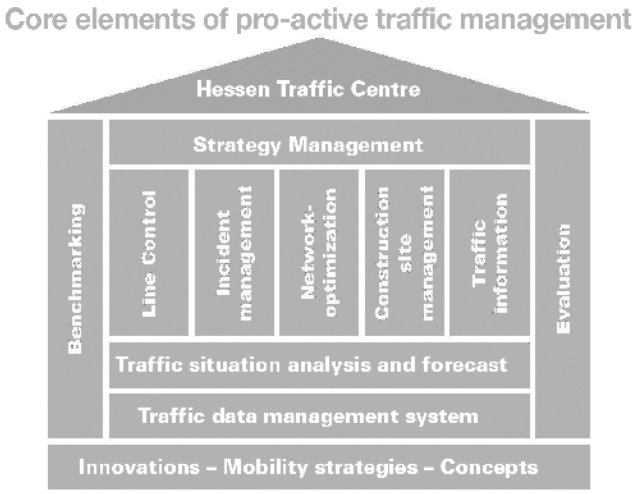

Figure 12. Elements of proactive traffic management in Hessen, Germany.[22]

operations, traffic safety, traffic regulations, and financing the planning and operational activities for the network.[22]

National Perspective

In response to this growing demand, the Federal Ministry of Transport, Building, and Urban Affairs established a Federal Transport Infrastructure Plan to upgrade the road network by 2015 through major construction projects. This plan includes constructing 1,730 km of new motorways, widening 2,162 km of existing motorways, and constructing 717 bypasses across the country.[21] In addition, the ministry has a comprehensive 5-year Programme for Traffic Control on Federal Motorways, which is geared toward overall manage-

The German federal government also has a policy on telematics and transport, with a primary emphasis on public-private cooperation. The intent is to define specific responsibilities that are best handled by the public sector, those that are best handled by the private sector, and those that can best be accomplished by public-private partnerships. This policy, shown in figure 11, recognizes the strengths of the private sector in some arenas and acknowledges that some activities can be undertaken only by governmental agencies and should remain under public control.

Regional Perspective

At the regional level, German states establish freeway operation programs for their motorway networks with two primary objectives. The first objective is to maintain or increase safety by harmonizing traffic flow, providing hazard warnings to motorists, and providing dynamic in-vehicle information on traffic conditions to users.[22] The second objective is to maintain and improve mobility, which is achieved through the optimal use of the existing network capacity and the use of various operational strategies to temporarily increase road capacity.[22]

Traffic Center Hessen has established a proactive traffic management approach, illustrated in figure 12. This approach is a comprehensive framework that encompasses benchmarking of network performance; deploys and maintains various traffic management strategies to meet the aforementioned objectives; incorporates data management, traffic analysis, and forecasting to evaluate and assess the impacts of those strategies; and facilitates the implementation of innovations to enhance mobility. The various traffic

management strategies employed to manage congestion are discussed later in this section.

This proactive traffic management program is part of a larger initiative called "Staufreies Hessen 2015" ("Congestion-Free Hessen 2015"). Other regional administrations have similar programs under development, and the intent of the Hessen program is to no longer have Hessen in the traffic-related media by the target year.[23] The primary focus of the plan is on the technical aspects of managing congestion and addressing safety needs. However, the strategic planning of roads is not included in this initiative, and the states must compete for federal funds for such programs.[23] The scan team did not identify any regional plans to address future expansion of the freeway network.

Communication, Traveler Information, Data, and Performance Monitoring

The motorways across Germany outfitted with traffic control systems gather traffic data from such technologies as inductive loop detectors, floating cars, video cameras, and other sensors deployed along the facility.[22] This data is critical to the successful and efficient management of the roadway network and the management of congestion on critical segments. Field data processed at the regional traffic management center is used to determine such performance measures as traffic flow, speed, headways, level of service, travel time estimation, and percentage of trucks in the traffic stream. This data is also used to estimate congestion levels and predict performance.[22]

The Germans have a long history of providing traveler information to motorists. Traditionally, agencies have used public broadcast methods and law enforcement to alert roadway users to incidents, congested conditions, and other events or situations that may impact operations. Traffic management centers now play a critical role in this communication strategy. A primary use of the traffic data gathered by TMCs is to provide traveler information to users and actively manage congestion on the network. Operating agencies firmly believe in the need to gain the trust of users so that they will comply with changes in speed, lane use, and route guidance information. Thus, they provide accurate and reliable information that does not adversely impact the roadway user. All of these efforts support the federal goal to have 80 percent of all trips on the motorway network adequately served by standardized real-time traffic and traveler information (RTTI) by 2010.[21]

Traffic Management Strategies

The following sections summarize specific strategies undertaken by agencies in Germany to manage congestion on critical roadway networks. The strategies include speed harmonization, queue warning, temporary shoulder use, junction control, construction site management, truck restrictions, ramp metering, heavy goods distance-based tolling, and traffic and traveler information.

Figure 13. Speed harmonization at Traffic Center Hessen in Germany.

Speed Harmonization

Speed harmonization has been used in Germany since the 1970s and is geared toward improving traffic flow based on prevailing conditions. Known locally as line control, speed harmonization is deployed on motorway sections with high traffic volumes. The speed harmonization system in the Rhine-Main area, which is monitored from Traffic Center Hessen shown in figure 13, monitors traffic volumes and weather conditions along the roadway. If sudden disturbances occur in the traffic flow, the system modifies the speed limits accordingly, providing users with the quickest possible warning that roadway conditions are changing.[24] The Germans have found success with speed harmonization on their motorways. For example, when implemented on the A5 between Bad Homburg and Frankfurt/West, speed harmonization was attributed with a 3 percent reduction in crashes with light property damage, a 27 percent reduction in crashes with heavy material damage, and a 30 percent reduction in personal injury crashes.[22]

Modeling and freeway simulation are also important to the overall management of congestion in Germany. Like other countries, Germany uses the microscope traffic simulation program VISSIM to assess the impact of operational changes to the roadway network. This behavior-based multipurpose

Figure 14. Congestion warning system in Germany.[23]

Figure 15. Right shoulder use with speed harmonization in Germany.[29]

program is extremely useful for optimizing complex technical systems in the laboratory before they are implemented in the field.[25] To support the speed harmonization strategies common to motorways in Germany, the German-based company that developed VISSIM wrote the software code so that the simulation package interfaces with the speed harmonization systems. Thus, the software incorporates the different thresholds for the deployment of speed harmonization and handles speed distributions across all lanes.[26] This tool has proven to be extremely useful in assessing the overall impacts of speed harmonization and other congestion management strategies on motorway operations.

Queue Warning

A major addition to the speed harmonization system in Germany is its queue warning system. Integrated with the active management gantries, this system involves displaying a congestion pictograph on each side of the speed harmonization gantry indicating congestion ahead, as shown in figure 14. In other installations, this congestion pictograph is displayed on an overhead DMS. This warning system is intended to help reduce the occurrence of secondary incidents caused by either recurrent or nonrecurrent congestion. Gantries are generally spaced 1 km apart, and the system typically begins reducing speeds between three and four gantries before an incident.[23]

The first installation of the queue warning system was on the Motorway A8 between Stuttgart and Ulm. Positive results from the pilot included fewer incidents, reduced incident severity, a considerable reduction in higher travel speeds combined with a strong harmonization of all driving speeds, closer headways, more uniform driver behavior, a slight increase in capacity, and overall safer driving because of motorists' awareness of oncoming risks and their tendency to approach the back of a queue with care.[21] The result of this successful pilot has been broader implementation of the queue warning system across the country and the inclusion of this strategy in the overall approach to managing congestion.

Temporary Shoulder Use and Speed Harmonization

Temporary shoulder use is a congestion management strategy typically deployed in conjunction with speed harmonization to address capacity bottlenecks on the freeway network. The strategy, known in Germany as temporary hard shoulder use, provides additional capacity during times of congestion and reduced travel speeds. Germany has used the right shoulder as a driving lane during peak travel periods since the 1990s, with the first deployment on the A4 near Cologne in December 1996.[27] Today, nearly 200 km of temporary shoulder are in operation around the country. This temporary shoulder use is one of several traffic control systems developed by the Federal Ministry of Transport and used in various locations in the country.[28] When travel speeds are reduced, signs indicate that travel on the shoulder is permitted, as figure 15 shows. This installation is located on the Autobahndirektion Südbayern (South Bavaria) and has had the official signs added digitally for illustrative purposes. Figure 16 shows

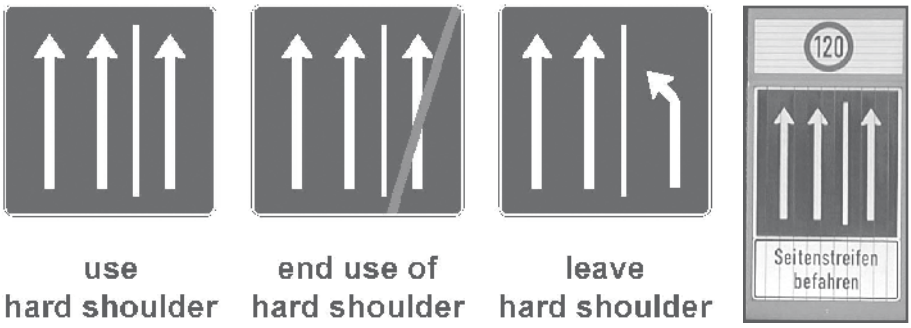

Figure 16. Temporary shoulder use regulatory signs in Germany.[29]

the complete series of signs indicating operations related to temporary shoulder use, including one with a supplemental speed limit indication (used when overhead gantries are not present). These signs and the overhead lane messages are blank when travel on the shoulder is not permitted. Temporary shoulder use is permitted only when speed harmonization is active and speed limits are reduced. Other components typically installed with the required regulatory signs include overhead gantries with speed limit displays, dynamic direction signing, video cameras, and connection to the traffic management center for deployment and monitoring.

As to be expected, traffic management centers play an integral part in implementing temporary shoulder use. CCTVs are used to ensure that disabled vehicles are not blocking shoulders. Their deployment is closely tied to the speed harmonization system and the relevant data are gathered to implement that strategy. Generally, implementation of temporary shoulder use is at the discretion of the TMC operator, although traffic volumes help determine the need for the strategy.[23] Overall, temporary shoulder use affords congested motorways with higher throughput, as shown in figure 17. The addition of the third lane in the form of temporary shoulder use, while slightly decreasing speed and initially reducing volumes on the motorway, actually delays the onset of congestion and breakdown and increases the overall throughput on the facility.

This strategy is not without drawbacks, including installation, maintenance, traffic safety, and incident costs. Thus, the Federal Highway Research Institute (BASt) in Germany developed a software tool to conduct an economic assessment of the implementation of hard shoulder use (either temporary or permanent) on congested motorways.[29] This software tool has a general framework that measures the various costs and benefits of temporary right-shoulder use to determine project viability and economic effectiveness. These costs include capital investment, maintenance, traffic safety and incidents, speeds and travel time, and emissions.[29] The software can assess numerous temporary shoulder-use applications at once to help the user identify the most effective locations for implementation. Once the user inputs the various data the software requires, the tool weighs costs against positive impacts to arrive at a benefit-cost ratio for each potential application. In each run, the program calculates the benefit-cost ratio for one location and different implementation strategies (i.e., permanent, temporary, and with speed harmonization). The implementing agency can then select for implementation the locations

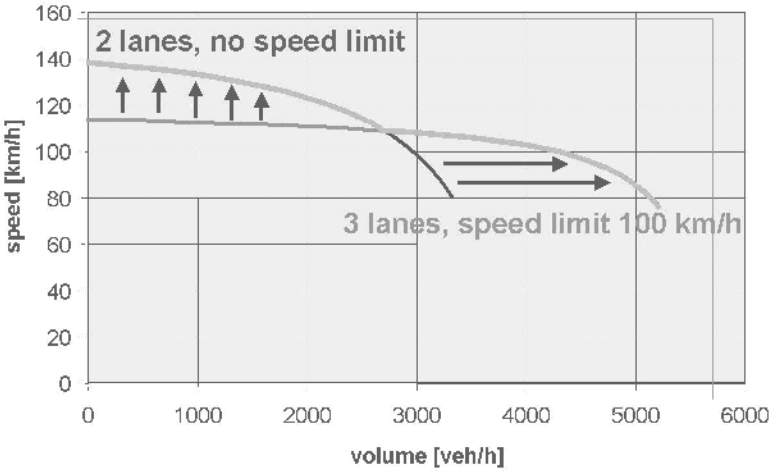

Figure 17. Speed-volume relationship of temporary shoulder use in Germany.[29]

that have the best benefit-cost ratio and represent the best investment of limited resources.

Junction Control

A variation of the temporary shoulder use in Germany is junction control, a combination of ramp metering and lane control at on-ramps.[30] Typically, the concept is applied at entrance ramps or merge points where the number of downstream lanes is fewer than upstream lanes. The typical U.S. application to this geometric condition would be a lane drop for one of the outside lanes or a merge of two inside lanes, both of which are static treatments.[28] The German dynamic solution is to install lane control signals over both upstream approaches before the merge (shown in figure 18 on next page), and provide priority to the facility with the higher volume and give a lane drop to the lesser volume roadway or approach.[28]

Construction Site Management

Transportation agencies and maintenance centers across Germany have at their disposal a construction site management tool for motorways. The intent of this computer software is to assess the impacts of short-term construction projects on congestion and allow for the optimization of timing for such efforts.[23] As depicted in figure 19 (see next page), the tool identifies the level and duration of major congestion impacts resulting from short-term work zone projects based on traffic volumes from a typical day. It easily allows the user to compare start times for a project and minimize congestion impacts by moving construction to a less critical time of the day. Although most construction is not performed at night because of safety issues, some projects are scheduled for nighttime hours if their daytime

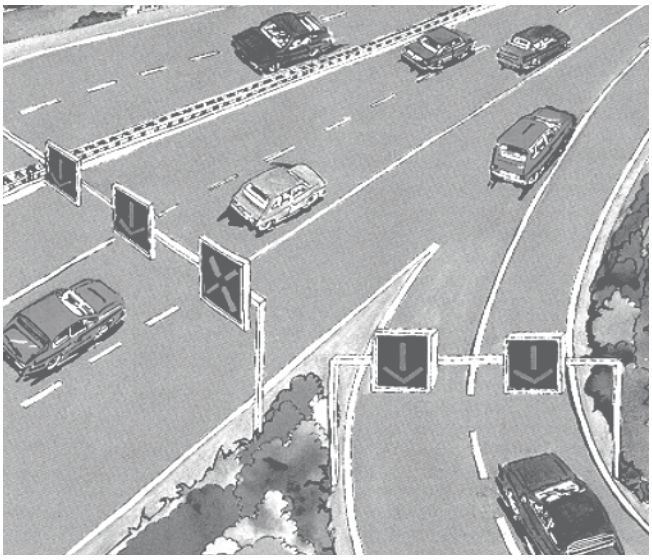

Figure 18. Junction control schematic in Germany.[21]

impacts on congestion and operations are too severe. While most of these maintenance-related projects are undertaken by outside contractors, some maintenance is done by internal personnel. Despite the obvious benefits of using the construction site management tool, maintenance centers are not required to use it, so there is not much motivation for them to alter their typical schedules for projects.

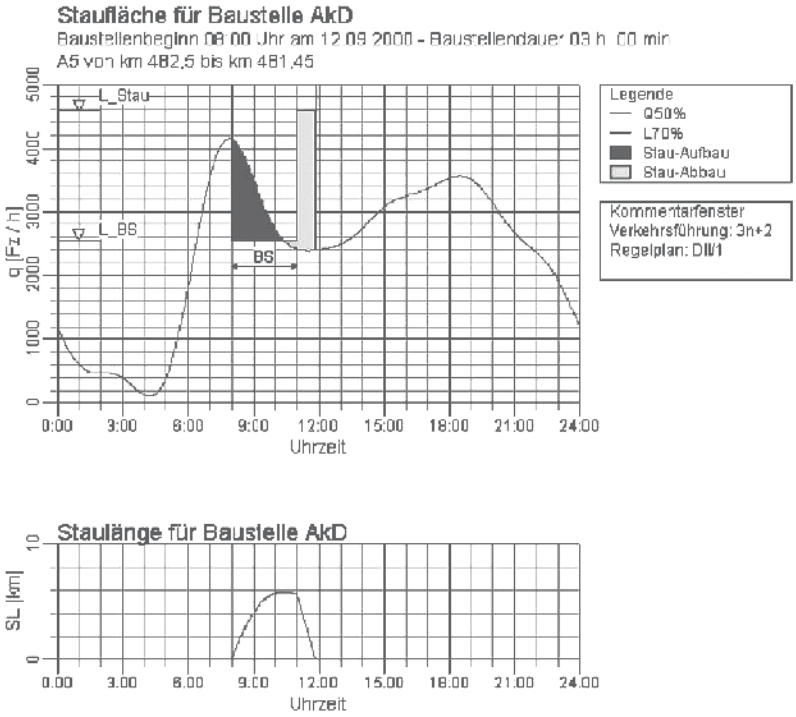

Figure 19. Road works management tool.[22]

Truck Restrictions

In Germany, most heavy vehicles have considerably lower speed limits than automobiles, such as those shown in figure 20 for the Autobahn roadways. In addition, trucks are often restricted to the rightmost lane across Germany (as well as many other European countries), which is mostly a practical matter when combined with lower speed limits and typical four-lane expressway cross sections.[31]

Specific operating behavior is also required of trucks on motorways under the control of speed harmonization. For example, when speed harmonization is not in effect, heavy vehicles may use any lane of a motorway. However, under speed harmonization, they must use only the right lane and are not allowed to pass slower heavy vehicles using the same lane.[23] When drivers see speed harmonization signs on gantries, they automatically know that these restrictions are in effect and act accordingly. The average truck traffic on most motorways is between 10 and 12 percent.[23]

Ramp Metering

Ramp metering is fairly new in Germany. Because geometric constraints on both freeways and surface streets provide limited storage, applications are limited as a whole. The concept was first tested in 1999 in five pilot projects on the A40, yielding positive results. In the pilot project, congestion decreased more than 50 percent during peak periods and traffic incidents at the ramps decreased 40 percent.[33] Also, average speeds on the A40 increased by more than 10 km/h during peak travel periods. As a result of these successful tests, more ramp metering systems are being installed across the country.

The typical operation, shown in figure 21, is initiated when ramp demand exceeds 1,000 vehicles per hour. The systems run constantly during peak periods and allow no more than two vehicles per cycle to ensure the dispersion of platoons in the entering traffic.[33] Originally, static signs were placed at the signal to indicate how many vehicles were to enter on one cycle. However, the dynamic signs shown in figure 21 were installed to eliminate user confusion and to allow changes in the number of vehicles per cycle based on current traffic conditions.[33] Some systems in place, however, have had nearly no effect on operations, while some that allow only one vehicle per cycle still experience congestion.

Dynamic Rerouting and Traveler Information

As discussed previously, Germany has a national goal to adequately serve 80 percent of all trips on the mo-

torway network by standardized real-time traffic and traveler information (RTTI) by 2010.[21] A critical component of this goal is the use of advanced technologies to provide dynamic rerouting information to users. As figure 22 shows, Germany installs rotational prism guide signs that change with traffic conditions. If an incident occurs along a facility, operators at the TMC deploy alternate guide sign information combinations that provide alternate route information to roadway users. Similar information is also provided on full-matrix DMS installed on other roadways, as shown in figure 23 (see next page). On facilities that employ speed harmonization combined with temporary shoulder use, the signs change so that the information displayed for the operational lanes is appropriate.

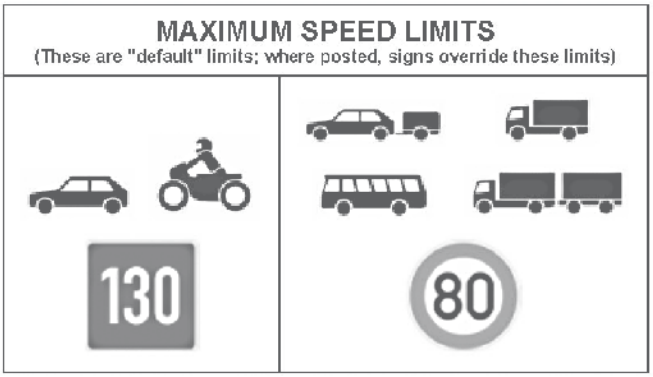

Figure 20. Autobahn speed limits.[32]

Germany also has initiated a concerted effort to standardize messages on dynamic message signs to reduce the likelihood of motorist confusion. As international traffic grows on the German motorway network, officials believe that some foreign users may not perceive the information displayed on DMS appropriately.[21] Used only for traffic-related purposes, German DMS display messages follow a set of basic principles to ensure comprehension by the most users:

- Internationally understandable legends
- As little text as possible
- As much text as unavoidable
- Symbols and signs of the Vienna Convention preferred[21]

Figure 21. Ramp metering in Germany.[26]

Graphics and pictograms are used to replace text whenever possible, and any text that does appear is to be as unambiguous as possible to minimize confusion.

Another component of the RTTI system is the traffic message channel. This information channel provides traffic-related messages to motorists via onboard Global Positioning System (GPS) units that can decode them into preferred languages. Most messages are generated from detection systems in the field and are repeated every 2 to 3 minutes to ensure their quick receipt on the roadway.[21] A variety of providers make the factory-installed or aftermarket onboard units available and are working toward significant penetration in the vehicle fleet across the country.[21] Providers include broadcasters, the automobile and radio industries, law enforcement and other authorities, and private information suppliers such as auto clubs. Nearly 5 million units are already in use and their cost is decreasing.

Figure 22. Dynamic rerouting in Germany.

RTTI transmitted via public radio is considered a major tool for traffic managers. Since traffic broadcasts began in the early 1960s, the number of traffic messages has increased considerably as a consequence of increased traffic loads and congestion. While in the beginning traffic messages were in the form of spoken messages, which meant a lot of interruptions of the running radio program, a new way to convey information to drivers is to transmit digitally encoded messages on FM frequencies in a side-band, the so-called Radio Data System (RDS). The Traffic Message Channel of the

Figure 23. Rerouting information on a dynamic message sign in Germany.[26]

Radio Data System (RDS-TMC) has been operational since 1997. Main components of digitally encoded traffic messages are location codes and event codes, based on European Committee for Standardization (CEN) and International Organization for Standardization (ISO) standards. In Germany today, RDS-TMC messages are transmitted without program interruptions on roughly 50 radio program chains.

These digitally encoded traffic messages are used in in-vehicle navigation systems, which decode the messages to improve route calculations. This enables road operators to include routes not equipped with variable direction signs or variable message signs in their management schemes. The introduction of RDS-TMC has encouraged electronic and car manufacturers to design and market new navigation devices.

It is a traffic policy objective to enable free access to safety-related traffic messages. Therefore, no subscription fees are charged for RDS-TMC information. Besides these free services offered mainly by public radio stations, commercial service providers offer encrypted TMC information by subscription.

The operation of a digitally encoded information channel has enabled traffic managers to automatically include information from roadside traffic detectors in the information chain. Typically, 2 to 5 minutes are needed to provide information about congestion.

The success of RDS-TMC in Europe and especially in Germany has contributed to its worldwide application, including in the United States, Australia, and Singapore. Efforts are underway to use digital transmission channels such as digital multimedia broadcasting (DMB) in the future to provide a higher transmission capacity so that local and urban information can also be included.

Truck Distance-Based Tolling

Since the formation of the European Union, truck traffic has increased significantly on Germany's motorway network, much of it passthrough traffic headed to other EU countries. The increased use of the network increases maintenance costs. Thus, Germany implemented heavy goods vehicle tolling on its motorways in 2006 to accomplish several objectives, one of which was to guarantee the financing of new roads and maintenance of the entire network.[34] Other motivations for this electronic toll system, shown in figure 24, are to create a pricing scheme borne by the originators of road demand, create an incentive to change the modal split for freight, enhance the efficient use of trucks, and promote implementation of innovative technology.[34]

Managed Lane Strategies

Operational strategies that would be classified as managed lanes according to the U.S. definition include speed harmonization combined with temporary shoulder use and truck restrictions. This actively managed approach works to increase throughput under congested conditions and optimizes the use of the existing infrastructure based on current conditions.

Denmark

Overall Congestion Management Approach

Traffic and congestion are increasing in Denmark as they are elsewhere in Europe. Figure 25 shows that traffic volumes grew significantly on motorways and other roads across the country in the 1990s, and traffic is expected to grow at an average annual rate of 1.7 percent through 2010, putting ever-growing demand on the roadway network.[35] As in other countries in Europe, a growing percentage of this mileage increase is on major trunk roads and motorways, and the potential of expanding the network with additional major roads is not realistic. Thus, the current network must be used effectively and efficiently to ensure future mobility.

National Perspective

The national vision for transportation in Denmark is to work collaboratively with all other players to provide a network that benefits all.[37] Potential partners include regional and local authorities, traffic companies, organizations, and industries across the country. This collaborative approach is especially critical with the Danish government's decision in 2002 to merge the existing 13 counties and 172 municipalities into some 100 larger municipalities.[38] Removing a level of government works to eliminate complexities in the roles and responsibilities of agencies, but emphasizes the need

for support and cooperation from all parties to ensure successful management of transportation.

Overall, the Danish Road Directorate acknowledges that planning for the future requires adequate and detailed information about the status of transportation and traffic on the existing network. From the perspective of traffic planning and congestion management, the Road Directorate has three main thrusts to ensure mobility for all citizens, all of which are supported by the information it gathers on the existing network. First, sustainability of the transportation network is critical for future mobility. The Road Directorate makes data and analysis results available to researchers and the public to help ensure that tools developed to improve transportation do so in a sustainable manner.[37] Accessibility is a primary factor in mobility. As such, the Road Directorate is developing and deploying congestion management strategies to optimize the use of the existing road network.[37] Finally, the Road Directorate uses large-scale decisionmaking tools and econometric models to assess the impact of transportation measures on society for such factors as travel time, energy consumption, cost, and safety.[37] These tools are available to all collaborative partners and stakeholders in the transportation arena so that all can benefit from their power and knowledge.

Another national initiative that supports transportation network management is the Road Sector Information System (VIS). This national database contains data for all national and regional roads on such items as roads, bridges, pavements, traffic, and incidents.[37] Incident data for local roads are also included, and both the Road Directorate and the regional authorities own the database. The database is linked to other systems to generate traffic analyses, analyze incidents, and illustrate congestion growth on the network. This tool has been useful in identifying bottlenecks and high-incident locations on the network to target improvements. As a result of VIS, incidents have dropped 50 percent during a period when traffic volumes have doubled.[37]

Regional Perspective

The national approach to traffic management is mirrored at the regional level. By the end of 2006, the Road Directorate was scheduled to open an additional six regional road centers to monitor and support the future motorway network in the country.[38] The six centers will take over the responsibilities that the counties used to perform and will continue to support the cooperative and collaborative approach to transportation management for the country.

Figure 24. Distance-based heavy goods vehicle tolling in Germany.[34]

The Road Directorate has also deployed intelligent transportation systems (ITS) in major regions to monitor the presence and development of congestion and to inform road users of traffic conditions. The data is part of that gathered by the Traffic Information Center (TIC). In addition, the Road Directorate has developed the TRIM system, which gathers traffic data and provides information to users on traffic conditions on 100 km of roads in the Copenhagen area.[36] One unique aspect of TRIM is that the Road Directorate continuously records the traffic data. These recordings are available on the Internet *(www.traffiken.dk)* in the form of the TRIM Player, where users can play back recordings and get a feel for the growth of congestion on a particular roadway.[36]

Within a corridor, the Road Directorate has as a policy to minimize the impact construction will have on the local roadway network. The agency's policy is to keep as much traffic as possible on the motorways through a work zone and not divert to the local road system.[39] Essentially, adding vehicles to the local road system and having a diverse

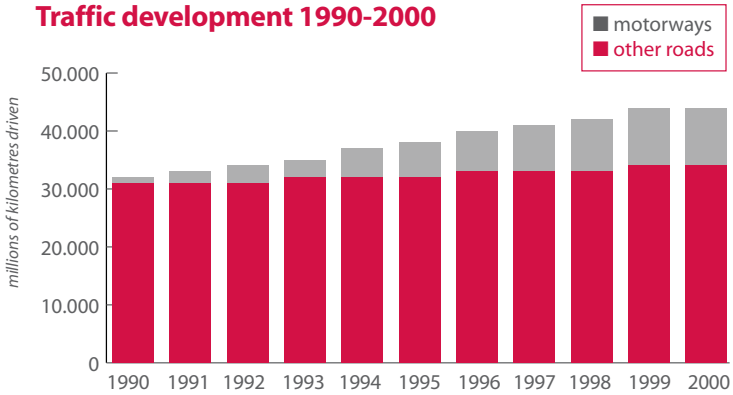

Figure 25. Traffic growth in 1990s in Denmark.[36]

Figure 26. Speed harmonization in Copenhagen, Denmark.

Figure 27. Traffic Information Center in Copenhagen, Denmark.

vehicle mix on these smaller roads is undesirable and unpopular with local residents. Efforts such as maintaining the same number of through lanes, minimizing complete road closures, and working to share information with local stakeholders work to minimize this route diversion.[39]

Communication, Traveler Information, Data, and Performance Monitoring

The Danish Road Directorate places a high priority on communicating with the road user about traffic conditions. The TIC and open cooperation with all partners help ensure that users have current information about routes so they can make informed choices about their trips. Furthermore, on major reconstruction projects communication is seen as critical to project success and customer satisfaction. For example, the M3 reconstruction project through Copenhagen has several full-time staff members whose only responsibility is public relations with employers and residents in areas served and impacted by the motorway.[39] Also, as discussed in the previous sections, the Road Directorate uses traffic data from VIS in modeling to identify bottlenecks and predict traffic conditions for use in planning efforts and potential system improvements.[40]

Traffic Management Strategies

The following sections summarize specific traffic management strategies undertaken by agencies in Denmark to manage congestion on critical roadway networks. Those strategies include speed harmonization, truck restrictions, and traveler information.

Speed Harmonization

The M3 Motorway around Copenhagen serves as an excellent example of the use of speed harmonization, also known as variable speed limits, to manage congestion during a construction project. The Road Directorate of the Danish Ministry of Transport and Energy decided to deploy speed harmonization as part of work zone traffic management strategies for the multiyear widening of the M3. Using traffic detection systems, CCTV cameras, and DMS, control center staff in the region monitor traffic and reduce speeds when congestion begins to build.

This active management strategy has been deemed a success by Road Directorate and project staff. As a result of the speed harmonization shown in figure 26, incidents on the motorway have not increased during the reconstruction project, while the existing two lanes have been maintained at a narrower-than-normal width and no entrance ramps, exit ramps, or bridges have been closed.[39] Furthermore, the equipment used to implement speed harmonization will be a permanent installation on the completed facility, which is being constructed with the expectation that the right shoulder will be used as a temporary lane when congestion warrants it in the future.

Truck Restrictions

Since 2005, heavy trucks, buses, and vehicles towing trailers have been prohibited from passing on certain stretches of the Danish motorways.[41] These restrictions were originally implemented on a trial basis to improve traffic flow along with reduced travel speeds for the same vehicles. Reduced speed limits for these vehicles are 50 km/h in urban areas, 70 km/h in rural areas, and 80 km/h on motorways across the country, compared with 50 km/h, 80 km/h, and 130 km/h for passenger vehicles and motorcycles in the same areas.[41]

Traveler Information

In response to the growing traffic demands on the country's road network, the Road Directorate established the Traffic Information Center (TIC), shown in figure 27. The center's mission is to improve the use of the country's roadway capacity by creating an intelligent road where users can get relevant information about the roadway network at any time.[35] The center is responsible for providing traffic information about Denmark and supporting emergency preparedness for the national roadway network.

Initially established in 1982 as a cooperative effort with private company Falck A/S to provide traffic reports on morning radio news programs, the TIC operates 24 hours a day, 7 days a week and gathers reliable traffic-related data (e.g., volumes, speed, wind, air, road-surface temperature) from such providers as law enforcement, counties, municipalities, private citizens, private companies, transportation agencies, traffic reporters, road sensors, monitoring cameras, weather stations, and Road Directorate offices.[35] Because of the size of Denmark, the TIC serves as the traffic management center for the entire country as well as the focal point for incident management.[42] The TIC disseminates information to various outlets to ensure the broadest reach to potential users. While these data are useful for many purposes, the primary objective is to improve safety on Danish roads.[35]

Managed Lane Strategies

To date, no managed lane strategies as categorized by the United States are in operation in Denmark. However, the current expansion project on the M3 includes fully paved shoulders that can accommodate temporary shoulder use when warranted by future congestion. The presence of speed harmonization and connection with the TIC in this corridor will enable this operational strategy to be used with little to no modification when the Road Directorate decides to implement it.

The Netherlands

Overall Congestion Management Approach

The Netherlands is a country with 16.2 million inhabitants, 6.9 million cars, and more than 250 million vehicle-kilometers each day across its entire roadway network.[43] The Ministry of Transport, Public Works, and Water Management (Rijkswaterstaat) manages 3,250 km of main roads, 1,000 km of which are motorways, and operates one National Traffic Control Center (NTCC) and five regional traffic control centers.[44] As in the rest of Europe, the transportation network in the Netherlands is experiencing increasing congestion and delay. Figure 28 illustrates this growth over the past 50 years, with a continuing a trend of about 3 percent a year, and shows the critical need for congestion management.

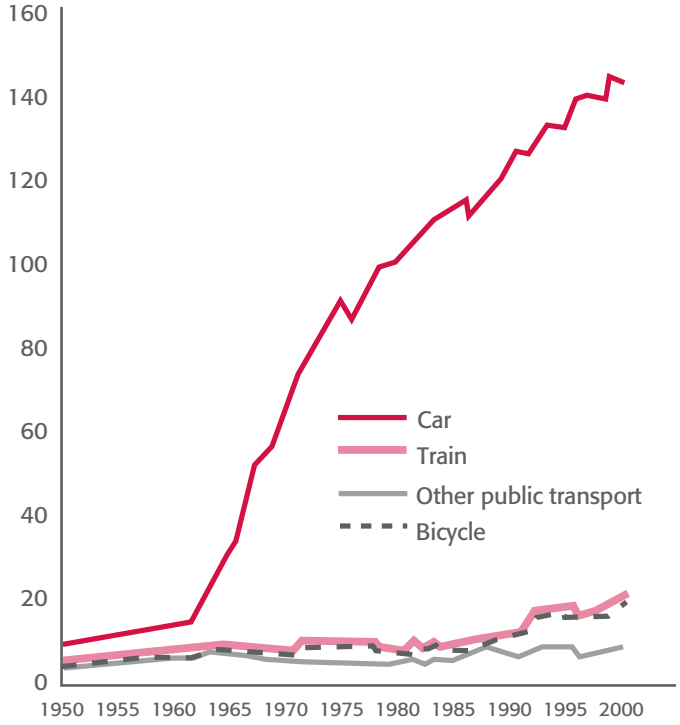

Figure 28. Fifty years of traffic growth by mode in the Netherlands.[44]

National Perspective

The federal government in the Netherlands recognizes the connection between transportation mobility and economic strength. Rijkswaterstaat has two traffic-related core tasks: ensure safe and unimpeded movement of traffic and construct, manage, and maintain the main roads and waterways.[44] It has developed a mobility policy that governs all transportation-related activities to focus on customer service and trip reliability. This approach to mobility involves five primary activities:

- Maintain roadways.
- Eliminate bottlenecks.
- Manage traffic to improve flow.
- Improve communication with users and ensure comfortable trips.
- Sustain safety.[44]

The specific customer service and reliable trip benchmarks used to measure traffic management strategies are to have (1) 95 percent of all trips arrive on time, (2) trips in urban areas take no longer than twice the time it takes during uncongested conditions, and (3) trips on other roads take no longer than 1.5 times that during uncongested

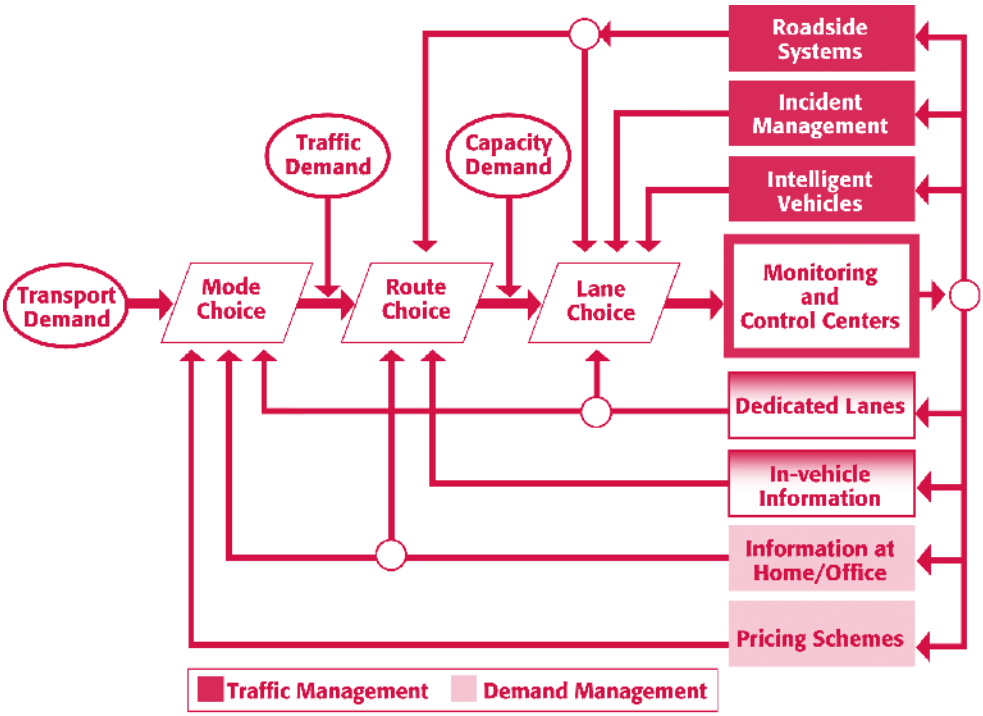

Figure 29. Traffic management as a control scheme in the Netherlands.[44]

conditions.[44] Essentially, all of the efforts undertaken to improve use of the existing roadway through traffic management work to meet these trip reliability goals. All efforts for traffic management comprise a major control scheme, shown in figure 29, that addresses traffic management and demand management. The specific traffic management strategies are discussed later in this section.

At the national level, modeling for planning purposes is used to evaluate policy options to identify the most cost-effective use of limited resources. The National Model System for Traffic and Transport (LMS) is a strategic model designed to make forecasts of mobility on the main roadway network across the country.[46] This four-step model has been used for the past 20 years to prepare all transportation policy documents. It assesses the impacts of a comprehensive

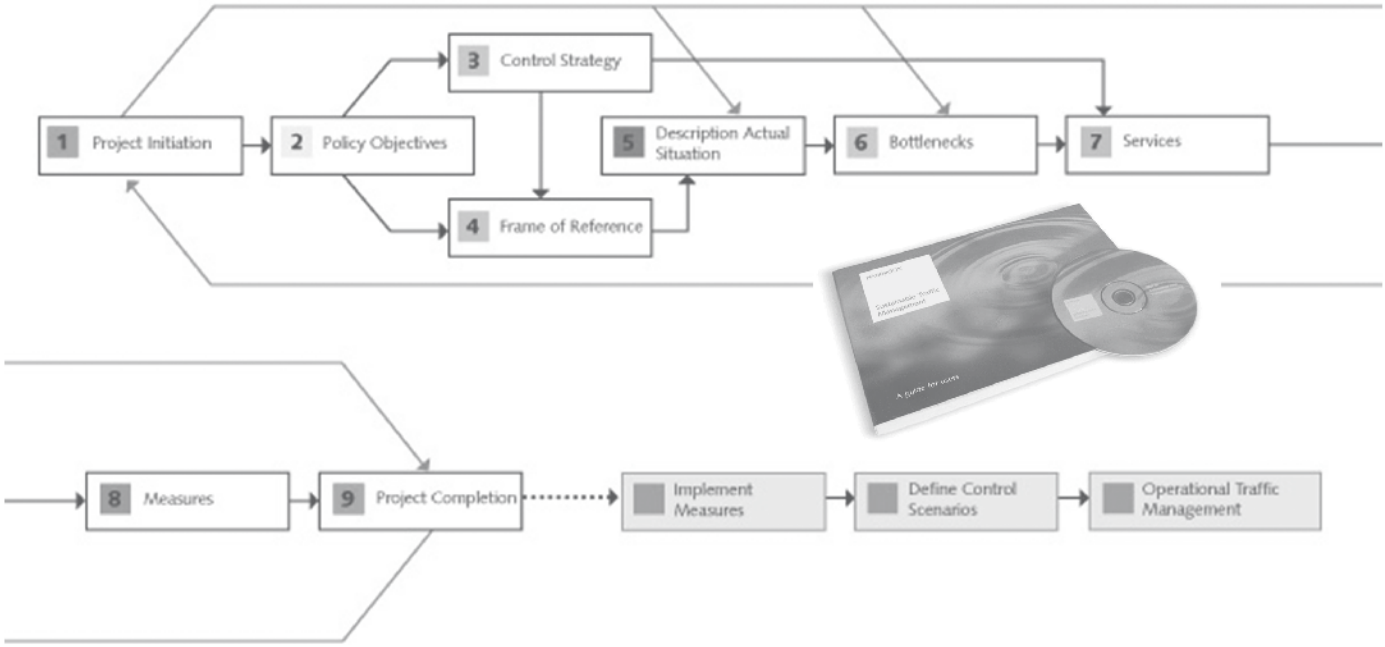

Figure 30. *Sustainable Traffic Management Handbook* used in the Netherlands.[43]

infrastructure building program, but does not give results specific to roadway sections.[46] Also, it takes goods transport into account, but does not calculate freight volumes.

Regional Perspective

The New Regional Model (NRM) is used to generate traffic forecasts to provide a better understanding of the information needed to develop regional transport policy. Based on the same philosophy as LMS, NRM provides regional mobility information and is used for planning purposes for policy decisions and the impact of projects at the regional level.[46] Unlike LMS, it can forecast traffic on national trunk roads and major connections, but the results for inner urban roads are not as reliable.

The ministry has also developed two powerful tools that regions use to assess traffic management efforts in their jurisdictions. Shown in figure 30, the *Sustainable Traffic Management Handbook* is a guide for regional and local road authorities to determine how best to address accessibility problems.[47] The handbook takes the planner through nine steps—from project initiation to completion—to address specific mobility and accessibility needs in a region. The process helps the user develop a network vision based on the policy objectives for the ministry and the region.[47]

The second tool regional authorities use is the Regional Traffic Management Explorer (see figure 31), a sketch planning and modeling tool that facilitates sustainable traffic management by quantifying benefits of traffic management strategies.[43] It allows the user to compare different scenarios to identify the most effective strategies based on the policy objectives built into the tool on accessibility, safety, and livability. It provides the impacts of operational strategies and system improvements based on such factors as travel time and delay, speed, and traffic volumes on origin-destination pairs, routes, and road sections.[43] Development of the tool was begun in 2003 and the first version was available for general use by late 2004.

Communication, Traveler Information, Data, and Performance Monitoring

In the Netherlands' national approach to congestion management, information is a primary resource in the overall traffic management architecture. As figure 29 illustrates, information is the backbone behind all traffic and demand management strategies in the control scheme. The National Traffic Control Center (NTCC), shown in figure 32, coordinates the activities of and gathers traffic-related data from the five regional traffic control centers that center on major cities and operate 24 hours a day, 7 days a week. The NTCC, which also operates 24-7, is the focal point for national

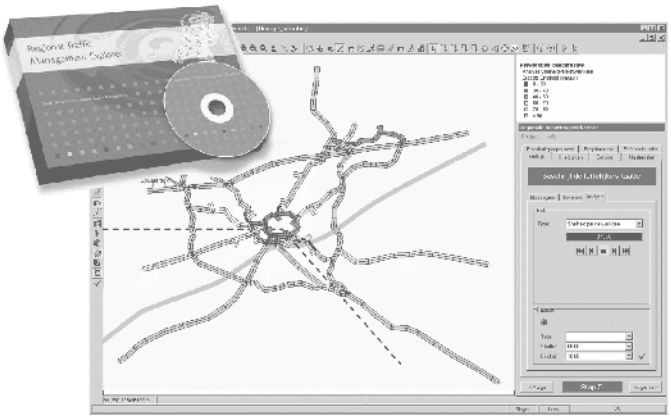

Figure 31. Regional Traffic Management Explorer used in the Netherlands.[43]

Figure 32. National Traffic Control Center in Utrecht, Netherlands.

traffic operations. It establishes national guidelines and procedures on traffic management, coordinates emergencies, communicates with other European national centers, and collects management information from around the country.[48] Traveler information is disseminated to roadway users via radio, television, electronic messaging, on the roadside, inside the vehicle, and via the Internet. The NTCC fosters cooperation between the national and regional governments to direct road users for optimal roadway performance.[48]

The power of the NTCC is also in its gathering of data from the regional centers. The data it collects from various sources are used to support the planning and management activities of the ministry. This assessment of system performance is critical to identifying the benefits of various congestion management strategies and their potential for implementation in problem locations.

Figure 33. Congestion warning system in the Netherlands.[45]

Figure 34. Speed harmonization in the Netherlands.

Figure 35. Temporary right shoulder use in the Netherlands.[49]

Traffic Management Strategies

The following sections summarize specific strategies undertaken by agencies in the Netherlands to manage congestion on critical roadway networks. The strategies include speed harmonization, queue warning, temporary shoulder use, dynamic lane marking, truck restrictions, ramp metering, dynamic rerouting, tidal flow lanes, truck lanes, and automated speed enforcement.

Queue Warning

In the Netherlands, travelers are alerted to congestion and queues by flashing lights and speed signs activated on variable speed limit signs, as seen in figure 33. This warning system, with lane control and speed limit signs generally every 500 m, was first deployed in 1981 and is also referred to as a motorway control and signaling system (MCSS). It is intended to help reduce the occurrence of secondary incidents caused by either recurrent or nonrecurrent congestion. It is deployed to indicate lane closures near incidents and work zones, and to provide queue tail warning and protection in known bottleneck locations.[45] To date, nearly 1,000 km of queue warning systems have been installed, with another 61 km planned for additional motorways across the country.

The standard speed limit is 120 km/h on the motorways, but posted speeds can drop to 90 km/h, 70 km/h, or as low as 50 km/h if a shock wave or speed drop is detected. These conditions are normally due to high volumes or incidents and incidents occurring on the facility.

The primary functions of the signaling systems are to provide a service to road users and to close lanes for incidents or construction as needed. The Dutch have seen definite benefits from their congestion warning system. As a result of implementation, throughput on facilities in the system increased between 4 and 5 percent, and safety assessments in 1983 and 1996 revealed an increase in traffic stream stability, a 15 to 25 percent decrease in primary incidents, and a 40 to 50 percent decrease in secondary incidents as a result of implementation.[45]

Speed Harmonization

The Netherlands has used speed harmonization for many years. Some deployments have been implemented to promote safer driving during adverse weather conditions (such as fog), while others have been used to create more uniform speeds. Most recently, the Netherlands' MCSS, shown in the two right lanes of figure 34, has been used to reduce speed in a densely populated and environmentally sensitive area to reduce polluting elements. The posted speed limit of 80 km/h is further effectuated by an

automated speed enforcement system, which measures average speed over a section of the highway, normally 2 to 3 km long. The system has reduced collisions by about 16 percent, increased throughput 3 to 5 percent, and reduced the cost of work zone traffic control.[45]

Temporary Shoulder Use

The Netherlands implemented temporary right shoulder use—also known as hard shoulder running or the rush hour lane—in 2003 as part of a larger program to improve use of the existing infrastructure. As figure 35 shows, a gantry with lane control signals indicates when the shoulder is available for use. Where a rush hour lane passes through a junction and at the end of a hard shoulder running section, guidance information changes according to lane use.[49] Assessment of this strategy reveals that implementing temporary shoulder use has increased overall capacity 7 to 22 percent (depending on usage levels) by decreasing travel times from 1 to 3 minutes and increasing traffic volumes up to 7 percent during congested periods.[43]

In addition to allowing temporary use of the right shoulder, the Dutch also deploy the use of traveling on a dynamic lane on the median side of the roadway. As figure 36 shows, the left lane—also known as the plus lane, or a narrowed extra lane provided by reconstructing the existing roadway while keeping the hard shoulder—is opened for travel use when traffic volumes reach levels that indicate congestion is growing.

The Dutch have seen a reduction in incidents on facilities with a plus lane, as shown in figure 37. Additional safety benefits may include fewer queues and shock waves, lower travel speeds with harmonization, better monitoring, and swifter incident response.[45] As in Germany, temporary shoulder use is allowed only when speed harmonization is in effect. Also, additional facilities are always implemented along with temporary shoulder use to help mitigate any adverse safety consequences the operational strategy may create, including the following:

- Overhead lane signs
- Emergency refuge areas with automatic vehicle detection
- Speed reduction during times of temporary shoulder use
- Variable route signs at junctions
- Advanced incident detection
- CCTV surveillance
- Incident management
- Public lighting[49]

Figure 36. Plus lane in the Netherlands.[45]

Dynamic Lane Marking

A new congestion management strategy in pilot testing on the A44, A12, and A50 is dynamic lane marking. Technical performance has proved satisfying on the A44 test track, and human factors testing on the A12 and A50 will be highlighted in 2007. The advantage of using dynamic lane marking is to change the lane configuration on the roadway according to specific traffic demand and lane destination. In theory, a fully dynamic roadway—a so-called flex road concept—could be realized (see figure 38 on next page). However, such a high-tech concept of a fully dynamic roadway will not be achieved for a number of years. Meanwhile, the Dutch have planned pilots with uncomplicated traffic solutions of dynamic lane configurations such as off-ramps in sections with hard shoulder running (see figure 38). The lane markings on figure 38 are digitally superimposed for illustrative purposes.

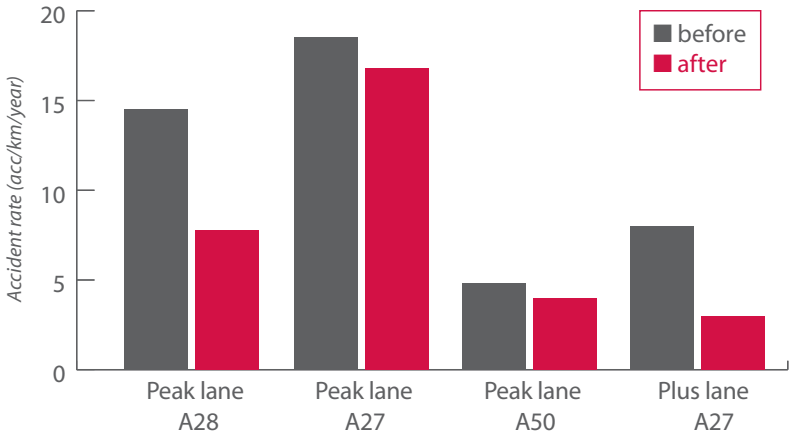

Figure 37. Incident reductions for Dutch temporary shoulder use.[49]

Figure 38. Dynamic lane marking in the Netherlands.[45,49]

Figure 39. Dynamic truck restriction testing in the Netherlands.[50]

Figure 40. Ramp metering in the Netherlands.

Truck Restrictions

Truck restrictions were first implemented in the Netherlands in 1997 on a 185-km, two-lane motorway during the morning and evening peak travel periods.[50] The restriction prohibits heavy vehicles from passing on the left on these facilities. Since that time, the measure has been extended three times by adding motorways and increasing the duration of the restriction. Currently, the restrictions are on 1,100 km of two-lane motorways. Restricted times are 6 to 10 a.m. and 3 to 7 p.m. on 700 km of motorway and 6 a.m. to 7 p.m. on the remaining 400 km.[50] Also, the restriction is in place when temporary shoulder use is in effect on those motorways. To date, the Dutch have experienced positive results with these restrictions. In addition to a slightly higher capacity (3 percent) on motorways with restrictions, there has been an increase in left-lane travel speed and more stable and homogeneous traffic flow.[50]

Testing of dynamic truck restrictions is underway on select motorways in the Netherlands to assess the potential for more effective implementation. As figure 39 shows, sign gantries display a pictograph when the restrictions are in effect. The system responds to changing roadway conditions and operates fewer hours than the typical static restrictions elsewhere. Preliminary evaluation results are favorable for two-lane facilities with positive opinions from both passenger car and truck drivers.

Ramp Metering

Ramp metering was first implemented in the Netherlands in 1989 to relieve motorway congestion, improve merging behavior, and discourage drivers from exiting the facility for a short distance to avoid congestion on the motorway (locally known as "rat runners").[45] Figure 40 shows a typical installation for a two-lane ramp, which includes two signal heads on an overhead gantry and ground-mounted signal heads on each side of the ramp that face the driver at the stop bar. Each installation provides a bypass lane for

emergency vehicles and buses, and the typical length of a slip-ramp with metering is 300 m. Many ramps use photo enforcement cameras to record violations.

To date, 44 ramps have installations with another 16 planned, a testament to the success of this congestion management strategy. Benefits of these meters include an increase in motorway speeds, a major reduction in shock waves on the motorways, a reduction in short trips, fewer incidents, and a capacity increase on the general purpose lanes of up to 5 percent.[45,43]

Dynamic Route Information Panels

Dynamic route information was first used in the Netherlands in 1990. Today, more than 100 gantries displaying these panels are used across the country on major motorways with another 22 planned.[45] Shown in figure 41, these panels (which can be either DMS or rotational prism signs) are intended to provide en route information on queues, major incidents, and appropriate routes.

The systems provide users with a more satisfactory and less stressful trip because they are more informed about roadway conditions.[45] Several assessment studies indicate that under normal conditions, between 8 and 10 percent of motorists adhere to the revised route information and that overall network performance may increase up to 5 percent. While the information panels are an effective congestion management strategy today, the Dutch believe that the long-term usefulness of this strategy may be limited because they anticipate that all critical road and traffic information will eventually be provided to the user in the vehicle.[45] Furthermore, Dutch law does not require the government to provide traveler information directly to users. Instead, information is sold or provided to independent information service providers who repackage that information and disseminate it through various sources.

Tidal Flow

The only tidal flow (reversible flow) lane in the Netherlands, shown in figure 42, was originally opened as a carpool lane in 1992. This reversible-flow lane operates in the morning peak inbound direction toward Amsterdam and outbound in the evening.[45] The facility operated as a carpool lane only for about 4 months, and is now available to all users. Political pressure, a lack of communication with the public, and underutilization were several reasons behind the operational change.

Automated Enforcement

Automated speed enforcement is in the testing phase in the Netherlands. Figure 43 illustrates an installation of the system.

Figure 41. Dynamic route information panels in the Netherlands.[45]

Figure 42. Tidal flow lane in the Netherlands.[45]

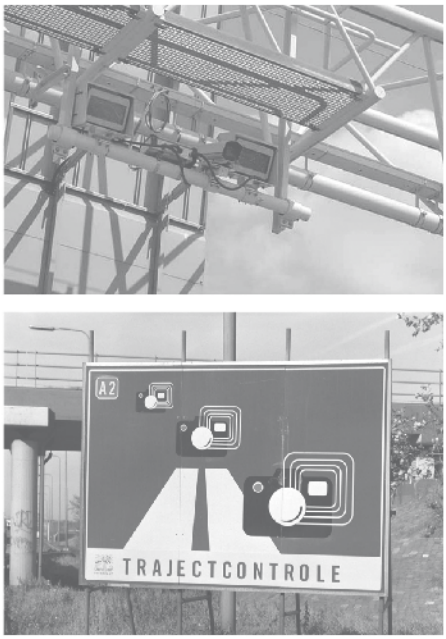

Figure 43. Automated speed enforcement testing in the Netherlands.[45]

Figure 44. National Traffic Control Center in Birmingham, England.

Figure 45. West Midlands Traffic Control Center in Birmingham, England.

The impetus behind automated enforcement is better air quality and air pollution reduction.[45]

Managed Lane Strategies

Operational strategies classified as managed lanes according to the U.S. definition include speed harmonization combined with temporary shoulder use and queue warning, truck restrictions, dynamic lane markings, and the tidal flow facility. These strategies involve the active management of the facility and the combination of eligibility requirements to optimize throughput on the roadway network.

England

Overall Congestion Management Approach

Like other countries across Europe, the United Kingdom faces a number of new transportation and mobility challenges. Traffic growth trends indicated that volumes will increase 29 percent by the year 2010, and with increased volume comes increased congestion on the transportation network.[51] Estimates are that nonrecurrent congestion in the form of incidents (25 percent) and construction (10 percent) account for 35 percent of this congestion. Thus, in 2004 the Department for Transport established a long-term strategy for a modern, efficient, and sustainable transport system supported by a high level of investment. Acknowledging that transportation is vital to the economy and quality of life, the strategy focuses on providing a transportation network for 2030 that can meet the challenges of a growing economy and increasing travel demand while achieving environmental objectives.[52] Three themes support this strategy: (1) a sustained investment in the transportation network over the long term, (2) continued improvements in transportation management to maximize the benefits of public spending, and (3) planning for the future and considering new and innovative approaches to improving transportation. Underlining these themes is the objective to balance the need to travel with the need to improve quality of life.[52]

A primary goal for improving transportation across the United Kingdom is related to safety. The national goal, in place since 2000, is to maintain the network in a safe and serviceable condition.[53] A key activity is a continuous review of measures to improve roadway safety and that of work zone personnel through engineering and design improvements. Specific numbers the Highways Agency is working to meet include a 33 percent reduction in the number of deaths or severe injuries in motor vehicle-related incidents and a 10 percent reduction in minor injuries—both of which will contribute to a 50 percent reduction in child casualties.[53]

National Perspective

From the perspective of congestion management, the Department for Transport and the Highways Agency have committed to establishing a national focal point in the form of the National Traffic Control Center (NTCC). Construction began in 2001 and operations commenced in 2003 by a private concessionaire under contract with the Highways Agency. The information hub of the Highways Agency, the NTCC has a staff that monitors a network of more 1,730 CCTV cameras and 4,450 traffic sensors 24 hours a day, 365 days a year.[54] As figure 44 shows, staff members review the network and deliver vital information to the news media and other operational partners, including the police and the Highways Agency Traffic Officer Service. They also display real-time messages on the 350 DMS placed at strategic points on the motorway network.

An inherent value of the NTCC is that it monitors traffic conditions across the entire country. This public-private partnership works hand-in-hand to provide real-time information to the user by building a picture of anticipated roadway conditions. It coordinates planned events across the various regions as well as actions related to unplanned events to ensure that regional decisions on traffic control and traveler information have minimal impact on the local road network. The "Traffic England" Web site, the online disseminator of information from the NTCC, also serves as a central location to access regional traffic information from the regional control centers.

Regional Perspective

The NTCC coordinates and is interconnected with seven regional control centers across the country. These centers, one of which is shown in figure 45, monitor and maintain the roadway network within their jurisdictions and are the first line of control on congestion management. If minor incidents occur, the regional centers initiate appropriate responses related to incident and congestion management and report information on the incident to the NTCC. For major incidents, actions are coordinated with the NTCC to optimize the remaining capacity and minimize the duration and impact of the incident on the entire motorway network and the adjacent local road system.

To support the regional traffic control centers in their duties to manage congestion, the Highways Agency also has a program to address incident management that began as a pilot in 2004 with full deployment expected by the end of 2006. The Traffic Officer Service consists of trained personnel who help tackle congestion by patrolling the motorways 24 hours a day, 7 days a week to assist motorists involved in incidents. In particular, they do the following:

- Respond to motor vehicle incidents.
- Remove damaged and abandoned vehicles.
- Clear debris on carriageways.
- Undertake high-visibility patrols.
- Provide mobile/temporary road closures.
- Support police in their duties.[55]

As shown in figure 46, traffic officers wear special high-visibility clothing and drive in conspicuous Highways Agency vehicles. A unique aspect of the Traffic Officer program is that the officers have powers under the Traffic Management Act 2004 to stop and direct traffic or temporarily close lanes or roads.[55] Thus, police officers are able to concentrate on investigating the incident, which can help reduce its overall duration. The Highways Agency estimates that 25 percent of all congestion on England's motorways is caused by incidents, and the Traffic Officer Service aims to cut incident-related congestion by focusing on getting traffic moving around incidents as quickly as possible.[55]

Figure 46. Traffic officer and vehicle in Birmingham, England.

Communication, Traveler Information, Data, and Performance Monitoring

Communications and data collection are critical to ensure constant coordination between the NTCC and regional centers. Hence, the Highways Agency manages and maintains a communications network within the motorway right-of-way that is a mixture of fiber and copper cables that transmit voice and data signals from thousands of roadside devices.[54] In its commitment to developing a communications network that optimizes the existing roadway infrastructure, the Highways Agency established the National Roads Telecommunications Services (NRTS) project. This project, constructed between 2003 and 2005 and operated through a public-private partnership, serves as a single national approach to the future of the communications network on England's motorway and trunk network.[54] The project involved upgrading and expanding the existing communications infrastructure to provide reliable service and monitoring of telecommunications from roadside devices to the regional traffic control centers and the NTCC.

Once the control centers receive critical data from the field, they rapidly disseminate relevant information to more than 40 partners to ensure consistency of messages delivered to the motoring public. Some of the methods by which roadway users receive information include the Highway Agency Information Line (HAIL), dynamic message signs, live Internet updates, messages to mobile phones, interactive kiosks at motorist service areas, displays at shopping centers, ports, and airports, and Highways Agency radio. In addition,

Figure 47. M42 ATM project limits.[59]

Figure 48. M42 ATM under normal motorway conditions.[58]

Figure 49. M42 ATM with hard shoulder running.[58]

Figure 50. M42 ATM without hard shoulder running and incident.[58]

the motorway online assistant (MOLA) is a real-time network model that uses field data to predict traffic conditions up to an hour in the future[56] Another unique forecasting tool is provided on the Highways Agency "Traffic England" Web site, where users can select a region and request a traffic prediction for a specific time up to 24 hours in the future.[57] The site also plays an animation for the selected time, providing travelers with expected traffic conditions for travel planning purposes.

Performance monitoring in the United Kingdom provides the foundation to assess how well the Highways Agency meets a primary objective of travel time reliability. The method to be used to meet this objective is to focus on improving the average delay on the slowest 10 percent of journeys on the motorway network.[53] Performance measures calculated from field data include average delay, total delay, and the vehicle miles traveled along a route. Efforts to improve reliability, discussed elsewhere in this section, include incident management strategies, better coordination of the network, an emphasis on customer satisfaction, and an investment in technology to support all activities of the agency.[53]

Traffic Management Strategies

The following sections summarize specific strategies undertaken by agencies in the United Kingdom to manage congestion on critical roadway networks. Strategies include speed harmonization, temporary shoulder use, truck restrictions, ramp metering, automated speed enforcement, and pricing.

Speed Harmonization

Introduced in 2001 by the Minister of Transport, the Active Traffic Management (ATM) pilot is a new operational strategy intended to provide reliable journeys, reduced recurring and nonrecurring congestion, and enhanced information to drivers.[58] It is a direct response to road users' demands for better service within the realistic limitations of widening and expanding the roadway network. Building on advancements in technology and experience from across the globe, this pilot project will

work to make the best use of the existing capacity on a segment of the M42, the limits of which are shown in figure 47. The ATM pilot will also provide additional capacity during periods of congestion or incidents. Construction began in 2003 and the completed system includes installation of the following:

- Lightweight gantries
- Lane control signals
- Dynamic speed limit signals
- Dynamic message signs
- Digital enforcement technology
- Closed-circuit television cameras
- Enhanced lighting
- Roadway sensors
- Emergency roadside telephones
- Hard shoulder running
- Emergency refuge areas[58]

As illustrated in figure 48, the roadway will provide traditional roadway information to travelers seen on other motorways across the region. Under such conditions, all normal motorway rules apply. However, information provided to travelers will change during incidents (see figure 49) or periods of recurring congestion (see figure 50), depending on whether the hard shoulder is open for travel. In both cases, lane control signals indicate reduced speed limits and the availability of the hard shoulder for travel use rather than for emergency refuge only. The M42 system is similar to the successful system installed on the M25 in 1995. Benefits from the M25 installation, also expected from the M42, include enhanced journey reliability, improved driver behavior, and reductions in driver stress, the number and severity of crashes, traffic noise, emissions, and fuel consumption.[60]

Also, dynamic message signs provide additional information to travelers on ATM operations. Design modifications being planned to aid facility use include a change in the rumble strip between the general purpose lane and the shoulder. In the ATM section, the noise and vibration generated by the rumble strip will be reduced to a humming sound to alert motorists when they cross the line since more frequent access to the hard shoulder will be provided to motorists.[58] Operation of the system will be handled by the regional control center, with operators on hand to monitor the system, initiate the modified operations as necessary, and use a computerized system to calculate appropriate travel speeds during congestion or incidents.[58]

The origins of the ATM system are in the Motorway Incident Detection and Automatic Signaling (MIDAS) system in which speed, flow, and occupancy are detected along an instrumented motorway. Based on field data, MIDAS sets suitable speed limits when traffic flow drops below a set level in an effort to preserve capacity on the facility.[51] The system deactivates when traffic flow returns to normal. Benefits of MIDAS include an 18 percent reduction in incidents, resulting in millions saved each year on incidents and congestion.[56]

Figure 51. Shoulder use in England.

Figure 52. Emergency refuge area and call boxes in England.

Temporary Shoulder Use

A major component of the ATM system on the M42 is the availability of the shoulder for travel use rather than for emergency refuge only. To ensure safe operation of the temporary shoulder use, emergency refuge areas are spaced at 500-m intervals along the shoulder (see figure 51) and emergency call boxes are provided at each refuge area (see figure 52). Operation of the system is handled by the regional control center, with operators on hand to monitor

Figure 53. Automated speed enforcement sign in England.[51]

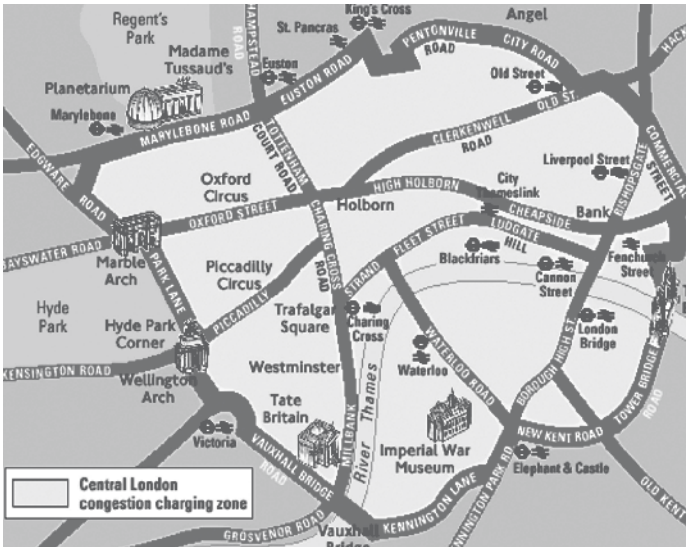

Figure 54. Congestion charging zone in London.[63]

the system and initiate the modified operations as necessary.[58] Specifically, operators use CCTVs mounted on light sign gantries or separately to check for incidents and stalled vehicles in the shoulder before activating the system.

Temporary use of the shoulder as a running lane is implemented only under controlled conditions. Dynamically used to relieve congestion and manage incidents, the strategy is deployed with mandatory speed limits, the maximum of which is 80.5 km/h (50 miles per hour).[51] Furthermore, the strategy is provided only between junctions, requiring users to exit at each junction and reenter the motorway beyond.

Truck restrictions

The first truck restrictions in England have been implemented on a pilot basis on northbound M42 near Warwickshire between 7 a.m. and 7 p.m. The 4.8-km (3-mile) stretch between Junction 10 (Tamworth) and Junction 11 (Appleby Magna) is only two lanes in each direction and heavy vehicles, which make up 17 percent of the traffic, must travel slowly up the steep grade.[61] The ban, in effect for an 18-month trial period, prevents heavy trucks from overtaking each other and restricts them to the inside lane, leaving the outside lane for faster moving vehicles. The intent is to enhance operations and safety and reduce congestion along this part of the roadway. Results of the pilot, including safety impacts and travel time savings, are still unknown.

Ramp Metering

The first pilot ramp metering project in the United Kingdom was installed on the M6 near Birmingham in 1986. Its purpose was to reduce congestion at the ramp by limiting traffic entering the motorway from the ramp and to enhance traffic flow downstream of the junction.[62] A detailed assessment of operations through data monitoring yielded promising results. On average, vehicle flow increased 5 percent at the implementation location and motorway speeds increased 14 to 18 percent at some locations.[62] Also, no negative impacts were experienced from ramp meter queues spilling into the adjacent intersections and driver compliance was high. As a result of the pilot's success, the system was updated and expanded to five additional locations on the M6, and another 30 are expected to be implemented on the M27 in 2007.[56]

Automated Speed Enforcement

Automated enforcement cameras will be used to enforce the ATM on the M42. Once speed limits are mandatory within the roadway segment, digital cameras will be used to record license plates of violators. The intent is to ensure compliance with the speed harmonization indicators for the safe and effective operation of the scheme in reducing congestion and the impact of incidents.[54] Gantries over the roadway will have static signs indicating the use of automated enforcement, as shown in figure 53.

Pricing

To date, the success of congestion charging in central London has illustrated that pricing has potential for reducing roadway congestion. As displayed in figure 54, the zone in which travelers are charged is central London, a region that was the most congested with average speeds of 14.5 km/h (9 mi/h) despite 85 percent public transport usage.[63] Since its inception in 2004, the strategy has had positive results. Essentially, congestion is down 30 percent with a decrease in all traffic entering the zone of 18 percent (33 percent for automobiles).[63] The number of trips into the central part of London has not changed; travelers switch modes, divert around the zone, or make other changes to their travel behavior. Emissions in the charging zone have also decreased, including a 12 to 16 percent reduction in

nitrogen oxides (NOx), a 12 to 16 percent reduction in particulate matter (PM10), and a 19 percent reduction in carbon dioxide (CO_2).[63] The zone will be expanded to encompass a larger area that still sees high congestion levels.

Pricing is also on the horizon as a smarter and more credible long-term option for maintaining the infrastructure in the United Kingdom. It will help ensure that users pay their appropriate share based on roadway use.[64] With vehicle ownership and demand on the infrastructure increasing, the limited resources for operations and maintenance are stretched and new roads are not favorable. Thus, the Department for Transport is assessing the feasibility of implementing pilot road pricing schemes in strategic locations across the country as early as 2010.[64] The intent is to build on commercially available systems that record usage and reduce the need to install equipment gantries all over the network to register usage. Only time will show how this approach emerges to handle both infrastructure funding and congestion management.

Managed Lane Strategies

The active traffic management project along the M42 represents the best example of managed lanes in the United Kingdom as they relate to the U.S. definition. The combination of speed harmonization and temporary shoulder use works to optimize the use of the existing infrastructure at a fraction of the cost of expanding the facility. Also, the United Kingdom is on the verge of implementing two high-occupancy vehicle (HOV) facilities to manage congestion, indicating the direction of managed lanes in the country.

HOV Lanes

One HOV project in the United Kingdom is the M606–M62 HOV gate. This junction is a major strategy route between Leeds and Manchester with an ADT of 140,000 and 24 percent truck traffic on a typical day.[65] Since widening of this junction is not a near-term solution, transportation officials determined that a short-term solution to congestion at this bottleneck is to remove the hard shoulder and designate it as an HOV lane, as shown in figure 55. This quick and relatively inexpensive conversion will provide travel time savings to the HOVs in the corridor (approximately 16 percent) without negatively impacting the non-HOV users.[65] The Highways Agency is assessing another 10 locations on the motorway network to determine the feasibility of a similar solution to other critical bottlenecks.

The Highways Agency is also developing an HOV lane along

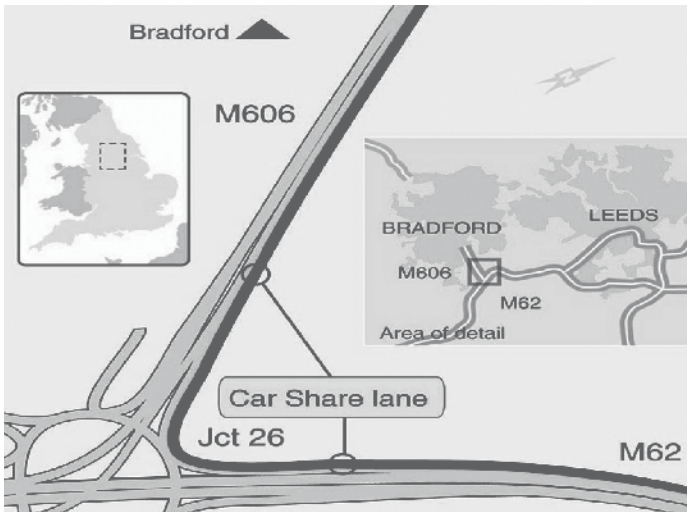

Figure 55. M606–M62 HOV gate design.[65]

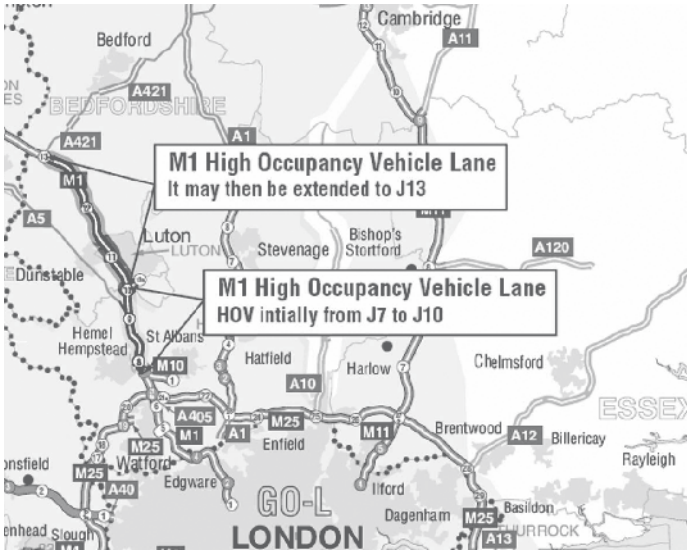

Figure 56. M1 HOV lane project.[66]

the M1 northwest of London. As illustrated in figure 56, the HOV lane would operate initially between junctions 7 and 10 with a possibility of extending the lane to junction 13.[66] The HOV lane is a late addition to a widening project on the M1 and will operate in the inside lane as a nonbarrier-separated, continuous-access facility with no buffer. The lane will operate 24 hours a day, 7 days a week, and eligible users will include vehicles with two or more occupants, motorcycles, and possibly buses. Trucks, single-occupant taxis, and vehicles towing a trailer will be prohibited from using the lane.[66] Transportation officials are also assessing how to best actively operate the facility, particularly with the possible deployment of speed harmonization in the corridor.

Key Findings and Other Observations

Primary Challenges and Issues Facing Europe

Through presentations and discussions with the European host countries, the scan team discovered several common, overarching challenges and issues facing the countries. These challenges include an increase in travel demand, a growth in congestion, a commitment to safety, and a shift in agency culture toward active management and system operation that focus on the customer, the willingness to use innovative strategies to address congestion, and the reality of limited resources to address all of these challenges. These issues resonated with the scan delegation as they represent a state of transportation that mirrors that in the United States.

Increase in Travel Demand

All across Europe, demand for transportation infrastructure is growing. In Germany alone, ADT has grown significantly between 1975 and 2000 on the entire 12,000-km federal motorway network.[21] Furthermore, forecasts predict that the demand for road transport will increase 16 percent for individual passenger vehicles between 1997 and 2015 and 58 percent for freight transport over the same period.[21] Similar trends are seen in the Netherlands. Demand in that country is expected to grow at an average rate of 2 percent a year for the next 20 years.[67] As demand increases on critical links on the European road network, agencies work to identify ways to best meet that demand in an efficient and cost-effective manner.

Congestion Growth

Often, Americans do not consider U.S. and European transportation networks on equal footing. They assume European cities have extensive public transport facilities that, when combined with higher fuel prices and denser urban development, help keep automobile ownership and related congestion at a more modest level than in the United States. However, the scan revealed that Europe and the United States face the same challenges. Despite higher fuel prices, public transit services that are fairly widespread, and significant use of alternate modes, automobile ownership is rising and congestion and air pollution are increasing in Europe.

The Netherlands is typical among European countries in its experience with increasing congestion. Figure 57 illustrates the impact of congestion growth on the Dutch roadway network over the past three decades. Bottlenecks on the system have increased since the 1970s, and they now pose a considerable threat to overall mobility for the motoring public. Because of these network failures, the Ministry of Transport, Public Works, and Water Management established an organizational policy in 1994 focusing on maintenance, more efficient use of the roadway network, and road widening. This policy has directed organizational funding and activities ever since.

Agency Culture Shift

A major attitude shift in the way European countries approach congestion management is the importance they place on the roadway user as a customer. Every country visited places significant emphasis on improving travel time reliability and keeping the roadway user informed of roadway conditions. In Germany, for example, the government has a goal to ensure that 80 percent of all journeys are served with adequate, standardized real-time traffic and traveler information services by 2010. This goal is part of a mobility management strategy that focuses on service to society and users.[21] In the Netherlands, the government's goal is to ensure predictable and acceptable travel times for users, focusing on having a maximum travel time under

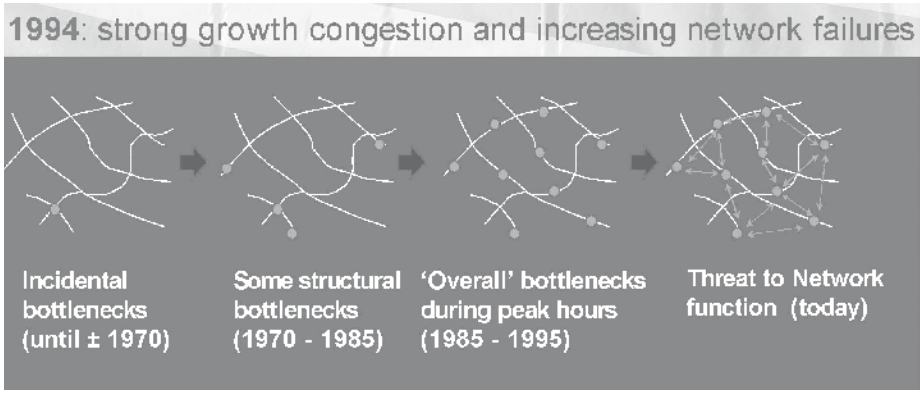

Figure 57. Congestion growth in Rotterdam, Netherlands.[49]

congested conditions of no more than twice that under uncongested conditions in urban areas and having 95 percent of all trips occur on time.[44] These countries understand the importance of public buy-in to traffic management. They acknowledge that users want to know why their speeds are being reduced or why they should divert to alternate roadways. Furthermore, they work to develop the trust of users through legitimate and reasonable speed limits to gain their cooperation in the overall management of roadway congestion.

In Denmark, the Road Directorate believed so strongly in the importance of engaging those impacted by the M3 expansion that they hired a journalist and two additional staff members to handle the public relations work that involved residents and employers in the corridor. The agency's residential and employer-based communications were geared toward communicating with customers located in the construction zone itself. It has kept landowners informed of the project's progress, including any delays and changes that may affect them. The open dialogue with and involvement of both landowners and users have helped keep complaints to a minimum. In the United Kingdom, the Highways Agency puts customers first in its business plan and has a customer-focused frontline operation of the strategic road network.[68] The Highways Agency sees the roadway user as an integral part of the system. The organization's three-pronged theme reflects this acknowledgment: "Safe roads, reliable journeys, informed travelers." Thus, the agency places the importance of communicating with the public on equal footing with saving lives and providing reliable trips on its network. In all of the countries visited, active management is a component of the customer approach to operating the roadway network.

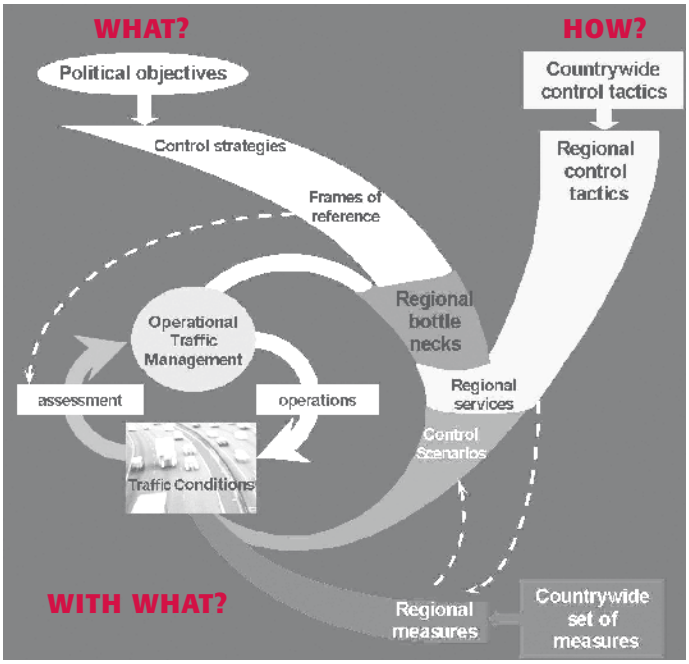

Figure 58. Traffic management architecture for the Netherlands.[45]

Innovation

Operating under the conditions mentioned previously, European transportation agencies are seeking new and innovative ways to optimize performance of the existing system and harnessing the power of advanced technologies to help accomplish their goals. Using such active management operational strategies as speed harmonization, temporary shoulder use, ramp metering, and dynamic route information—either alone or in combination—the countries are using advanced technologies to instrument congestion networks to improve throughput and increase safety. Most of these countries are no stranger to innovation. The Netherlands implemented its first speed harmonization system in 1981.[45] This operational strategy is now one component of a comprehensive traffic management architecture, shown in figure 58, that centers on implementing various control, operational, and construction components to ensure performance measures are met on a regional basis across the country.

In the 1970s, Germany implemented the operational strategy of speed harmonization to stabilize traffic flow under congested conditions.[69] Furthermore, Denmark has taken the innovative approach of using this operational strategy during a major construction project and will later make it a permanent installation along the corridor. Public-private partnerships are also becoming a well-accepted strategy for transportation finance, allowing agencies to outsource operations through stringent contracts that include performance-based incentives, thus ensuring that roadway users' needs are met effectively. These strategies and others, discussed later in this document, illustrate the fact that these countries are continually searching for innovative ways to improve safety and travel reliability and make the most of their existing infrastructure.

Commitment to Safety

Safety and the reduction of incidents and incident severity are of utmost importance in the countries the scan team visited. For example, Germany implemented its first motorway queue warning system in an effort to reduce incidents. The result has been safer driving by motorists because they are aware of oncoming conditions and approach the end of a queue with caution.[21] In addition, "safe roads" is the first part of the Highways Agency mission, a testament

to its commitment to reducing roadway fatalities and major injuries by a third over the next 2 years while balancing safety and the environment with the need to travel.[68] Also, national and regional traffic management centers are operational in all of the countries visited, each focused on traffic safety and disseminating traveler information to motorway users. It was clear to the scan team throughout its visit that the safety of network users was the highest priority and that all of the operational strategies deployed were structured to accomplish their intended optimization objective in the safest manner possible.

Limited Resources to Address Congestion

All across Europe, countries have limited resources to address the growing travel demand and congestion problems they face. Hence, cost-effective use of limited funds is paramount and typically illustrated in governmental policy. In the Netherlands, for example, the governmental mobility policy has a three-pronged approach of improving the infrastructure, improving road use, and improving and streamlining internal procedures.[44] Improving road use centers on the national management of work zones, effective incident management, and improved traffic information. These policy objectives point to the need to make the best use of the existing infrastructure, reduce waste, and concentrate infrastructure improvements on new connections, widening, and extra or designated lanes.[44] In England, the M42 Active Traffic Management Pilot Program is a proactive management strategy that is less expensive than widening, thereby making the most of the available road space and using fewer resources.[51]

European Approach to Congestion Management

Given the overwhelming similarities between congestion growth in Europe and the United States, the scan team identified seven key approaches to congestion management that have the potential to help ease congestion in the United States. While some strategies have been already implemented in some form in the United States, adopting unique aspects of their European implementation can enhance their impact, maximize the efficient use of existing facilities, and ensure that future planning efforts optimize the use of limited resources to address congestion. Furthermore, a critical component of the strategies is the presence of regional traffic management centers that are operationally integrated and interoperable with a national traffic management center that manages the roadway networks from a network-wide perspective. This coordination helps ensure that management strategies deployed in one region do not negatively impact other regions and that they foster a holistic approach to congestion management within the country and beyond its borders.

Active Management

A major weapon that most European countries use in the battle against congestion is active traffic management. This operational strategy works to provide reliable trips, reduce recurring and nonrecurring congestion, and provide enhanced information to drivers.[58] Building on advancements in technology and traffic management experience, this strategy works to make the best use of the existing capacity and provides additional capacity during periods of congestion or incidents. Active management falls into the two categories of that for recurrent and that for nonrecurrent congestion. The following sections highlight the specific applications of active management the scan team identified as having the most potential for successful application in the United States.

Active Management for Recurrent Congestion

The primary strategies for actively managing recurrent congestion are speed harmonization and temporary shoulder use. The application of these strategies is mostly consistent across the countries the team visited, with some differences in the specific signs deployed to convey the active management strategy to road users. The following sections summarize the application of these strategies in various countries and address the unique differences in their application.

Speed Harmonization

As noted earlier, the European countries the scan team visited recognize that reducing speeds under congested conditions not only improves overall performance but reduces the likelihood of primary incidents. Through speed harmonization, agencies make the most of existing capacity by delaying the point at which flow breaks down and stop-and-go conditions occur. Under speed harmonization, an expert traffic management system monitors travel data from an instrumented roadway. Once travel speeds and traffic volumes reach a certain threshold set by the system's algorithms, the system automatically begins to reduce speeds incrementally across all lanes along the motorway upstream of where the congestion is heaviest.

The intent of speed harmonization is to extend the time that efficient travel is available to users. Sign gantries spanning the facility provide speed limit information and varying additional information, depending on the specific country's implementation. The speed harmonization systems are configured primarily to automate the deployment. The expert system in place in the traffic management center monitors data coming from sensors in the field and automatically triggers the deployment of the speed harmonization system when congestion thresholds are exceeded and

congestion and queue formation are impending—all without requiring operator intervention. This is considerably different from the U.S. approach, in which agencies rely heavily on operators to manage the system and deploy management strategies manually.

In Denmark, the Road Directorate of the Danish Ministry of Transport and Energy deployed speed harmonization as part of work zone traffic management strategies for the multiyear widening of the M3. Using traffic detection systems, CCTV cameras, and DMS operated by control center staff in the region, traffic is monitored and speeds are reduced when congestion begins to build. This active management strategy has been deemed a success by Road Directorate and project staff. As a result of speed harmonization, incidents on the motorway have not increased during the reconstruction project, while the existing two lanes have been maintained at a narrower-than-normal width and no entrance ramps, exit ramps, or bridges have been closed.[39]

The Netherlands has used speed harmonization for many years. Some deployments have been implemented to promote safer driving during adverse weather conditions (such as fog), while others have been used to create more uniform speeds. The Netherlands' Motorway Control System provides lane control and speed limit signs generally every 500 m and is used to slow traffic in advance of a slowdown, shock wave, or work zone. The system has reduced collisions by about 16 percent, increased throughput 3 to 5 percent, and reduced the cost of work zone traffic control. The standard speed limit is 120 km/h on the motorways, but variable posted speeds can drop to as low as 50 km/h if an incident occurs. Speed harmonization in Germany, known locally as line control, has been in use since the 1970s. It is geared toward improving traffic flow based on the prevailing conditions and is deployed on motorway sections with high traffic volumes.

Temporary Shoulder Use

Temporary shoulder use is a congestion management strategy typically deployed in conjunction with speed harmonization. The strategy provides additional capacity during times of congestion and reduced travel speeds. In Germany, the right shoulder has been used during peak travel periods since the 1990s.[27] This use of shoulders is part of several traffic control systems developed by the Federal Ministry of Transport and applied in various locations in the country.[28] In England, the first deployment of temporary shoulder use is part of a comprehensive traffic management system that also involves speed harmonization. A critical component of the M42 system is the installation of emergency refuge areas at 500-m intervals along the shoulder, each equipped with an emergency call box.

The Netherlands, in addition to allowing temporary use of the right shoulder, also deploys temporary use of the left shoulder under congested conditions. The left lane, or plus lane, is opened for travel use when traffic volumes reach levels that indicate congestion is growing. As in Germany, temporary use of the left lane is allowed only when speed harmonization is in effect. Additional facilities implemented to mitigate any adverse safety consequences of temporary shoulder use include overhead lane signs, emergency refuge areas with automatic vehicle detection, speed reduction, variable route signs at junctions, advanced incident detection, CCTV surveillance, incident management, and public lighting.[49]

A variation of temporary shoulder use deployed in Germany is junction control, a combination of ramp metering and lane control at on-ramps.[30] Typically, the concept is applied at entrance ramps or merge points where the number of downstream lanes is fewer than upstream lanes. These strategies for managing recurrent congestion work to make traffic flow more uniform. They maximize use of the existing capacity, while temporarily adding to that capacity in a manner that does not increase roadway safety hazards.

Active Management for Nonrecurrent Congestion

While speed harmonization and temporary shoulder use are congestion management strategies for recurrent congestion, European countries also implement them for nonrecurrent congestion. They are powerful tools for providing better operations during incidents along the motorway. In addition, the Europeans use active rerouting to provide alternate travel information for roadway users during incidents. Germany uses dynamic message signs and rotational prism guide signs to provide alternate route information during incidents, both of which adapt to appropriate lane designations when temporary shoulder use is in effect. Dynamic rerouting, a traffic message channel, and standardized messages for DMS are part of a comprehensive German approach to serve 80 percent of all trips with real-time traveler and traffic information by the year 2010.

Providing alternate route information is also a critical component of the regional traffic management centers in England. When major incidents create significant delays on the motorways, center personnel coordinate with the National Traffic Control Center and local authorities to ensure that diverted traffic will not negatively impact the local road networks. This coordinated provision of detailed alternate route information helps reduce nonrecurrent congestion and provides better travel experiences for motorway users.

One particular fact the scan team noted is related to

deployment of detection technology for active management purposes. In most of the countries the team visited, loop detectors were installed on instrumented freeway corridors at shorter intervals than in the United States. Depending on the country, detectors are installed every 500 to 1,000 m, and reliability of these detectors is very high because of dedicated resources to maintain them and routinely replace faulty ones. The high density of detection provides operators with a detailed, comprehensive assessment of facility conditions and helps serve as the data backbone for automated systems. In addition, CCTV equipment is installed at closely spaced intervals to quickly and reliably check shoulders for clearance before implementing temporary shoulder use without having to conduct a physical inspection on the ground. Finally, these technology deployments support incident management operations, discussed in the next section.

Customer Orientation

A key component of the customer approach to congestion management in Europe centers on the need to ensure travel time reliability. Related to that reliability is the impact nonrecurring congestion has on travel time. European countries recognize the major role nonrecurrent congestion plays in overall urban delay. As in the United States, nonrecurrent congestion makes up anywhere from 40 to 60 percent of all congestion on urban motorways, a significant portion of which is a result of incidents. As figure 59 shows, statistics in Germany indicate that nonrecurrent congestion in the form of work zones and incidents accounts for 61 percent of travel time losses on German motorways. Thus, European countries acknowledge that swift response to incidents is critical to managing congestion, reducing the occurrence of secondary incidents, and focusing on the needs of roadway network users. Moreover, they recognize that reducing speeds under congested conditions not only improves overall performance but reduces the likelihood of primary incidents.

In Greece, Attica Tollway operators employ a comprehensive system for handling incidents, the primary objective of which is to enable quick intervention in incidents while providing high-quality services that ensure optimum traffic conditions. The 24-7 operations are undertaken by personnel critical to the efficient provision of assistance to incidents and the quick remedy of any problem. They maintain constant communication with personnel in patrol units who are the first responders to tollway incidents. Their commitment to efficient incident management is a testament to their commitment to provide high-quality service to customers and enhance mobility around Athens. The Highways Agency in England has a similar program that began as a pilot in 2004 with full deployment expected by the end of 2006. The Traffic Officer Service consists of trained personnel who tackle congestion by patrolling motorways 24 hours a day, 7 days a week to assist motorists involved in incidents. A unique aspect of the program is that the officers have powers under the Traffic Management Act 2004 to stop and direct traffic or temporarily close lanes or roads.[55] Thus, police officers can concentrate on investigating the incident, which can help reduce its overall duration. The Highways Agency estimates that 25 percent of all congestion on England's motorways is caused by incidents, and the Traffic Officer Service aims to cut incident-related congestion by focusing on moving traffic around incidents as quickly as possible.[55]

Several countries visited also have a congestion or queue warning system integrated with their active management systems. In Germany, this system involves the display of a pictograph on the DMS that indicates congestion ahead. It is also displayed in conjunction with speed harmonization and alerts motorists to reduce their travel speed as directed by the overhead gantries. In the Netherlands, travelers are alerted to congestion by flashing lights on the variable speed limit sign. Like the strategies mentioned above, the warning systems are intended to reduce the occurrence of secondary incidents caused by recurrent or nonrecurrent congestion. While these incident management strategies are not significantly different from those used in the United States, they do represent a critical component of each country's broader approach to addressing congestion, their commitment to serving customers and providing them with reliable travel times, and their recognition of the link among incidents, their duration, and their impact on mobility.

Priority of Operations in Planning, Programming, and Funding Processes

In an era of limited resources, active traffic management is a significant drain on the limited funds an agency has available each year. However, the Europeans recognize the impor-

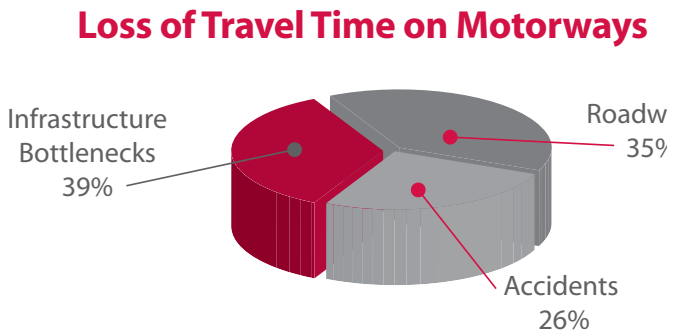

Figure 59. Causes of lost travel time on German motorways.[70]

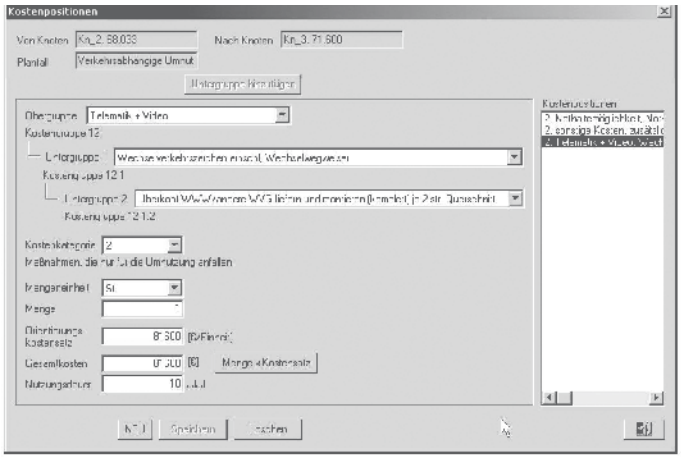

Figure 60. Economic assessment tool for temporary shoulder use in Germany.[29]

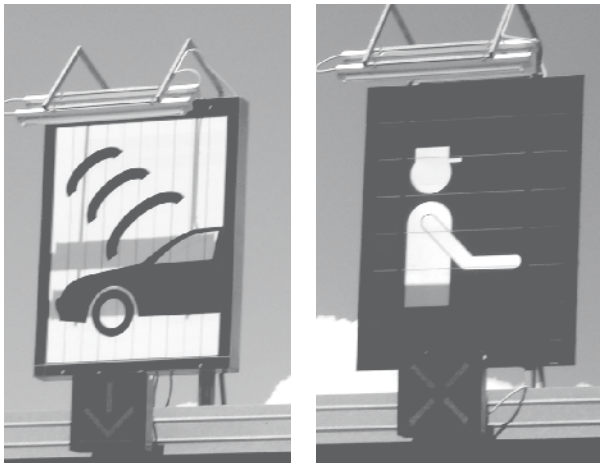

Figure 61. Toll-related signing in Greece.

tance of their investment and the need to fund the operation of deployed systems to realize the benefits of that investment. Thus, transportation and traffic management operations are a priority in planning, programming, and funding processes for transportation. To this end, the Netherlands developed the *Handbook for Sustainable Traffic Management* to help road authorities identify the best way to address transportation needs in a sustainable manner.[71] It serves as a link between the Dutch National Traffic Management Architecture and the accessibility needs of transportation users. Geared to personnel working at the policy level, it addresses the objectives of traffic management and assesses the costs and benefits of those investments to ensure sustainability and improved traffic operations.[71]

Cost-Effective Investment Decisions

As in the United States, European countries struggle to address growing congestion with increasingly limited resources and environmental restraints. All of the countries visited accept the fact that their ability to undertake major expansion projects on congested motorways is limited. Hence, they search for innovative ways to invest their limited resources.

The Federal Highway Research Institute (BASt) in Germany has developed a software tool to conduct an economic assessment on the implementation of temporary shoulder use on congested motorways.[29] This software tool has a general framework that measures the various costs and benefits of temporary right-shoulder use to determine project viability and economic effectiveness. These costs include capital investment, maintenance, traffic safety and incidents, speeds and travel time, and emissions.[29] The software (shown in figure 60) can assess numerous temporary shoulder-use applications at once to help identify the most effective locations for implementation. Once the user inputs the various data required of the software, the tool weighs costs against positive impacts to arrive at a benefit-cost ratio for each potential application. The agency can then select locations for implementation that have the best benefit-cost ratio and represent the best investment of limited resources.

The Ministry of Transport, Public Works, and Water Management in the Netherlands takes an even broader approach to assessing the impact of transportation investments. The LMS model, which stands for the National Model System for Traffic and Transport, is a tool the Dutch Ministry uses to strategically appraise different policy packages related to transportation.[46] Taking into account such factors as car ownership and trip characteristics, LMS—which is based on the traditional four-step planning model—serves as a strategic model for the entire country. Over the past 20 years, the ministry has used this model to assess the impacts of the entire transportation investment program for the country, influencing policy decisions at the national level.[46]

Diverse Financing Strategies

The Europeans, like Americans, struggle to manage increasing congestion with limited resources. Public-private partnerships (PPPs) and similar innovative financing approaches are emerging as strategies to solve the ever-growing funding shortfall. England has had such success with PPPs in all sectors, including transportation, that agency officials have identified critical factors important for long-term sustainability and benefit of such collaborations. For example, the Highways Agency is very selective of which projects it slates for PPPs—such as the construction and operation of the National Traffic Control Center—and notes

that the majority of benefits on transportation PPPs are realized in operations and maintenance savings over the life of the contract (up to 70 percent over 30 years).[72]

The inclusion of performance thresholds in the payment contract is essential to a successful project. Transportation-based performance measures tied to contract incentives include improved operations, reduced delay, fewer incidents, and similar measures important to users. Improvements on these measures can mean more money for the concessionaire, while such measures as substandard pavement and poor operations during winter events can cost the concessionaire.[45] The result is a PPP that holds the concessionaire accountable for operations and ensures that public resources are spent with the best interests of users in mind. In almost cases, concessionaires combine private funds with some level of public financial contribution for project investment packages.

Desire for Consistency Across Borders

With the establishment of the European Union, travel between European countries has risen dramatically. Hence, providing consistent messages to roadway users is more important than ever to reduce the impact of congestion on those travelers. All of the European countries have adopted the symbology policies established by the Vienna Convention, so roadway users can expect to see the same symbols on transportation facilities across Europe. This consistency has been applied to emerging technologies, such as electronic toll collection (ETC). As figures 61 and 62 show, ETC signs in Greece and Denmark, while not the same color, both use symbols featuring emitting radio waves. The symbol for an attended toll booth is also similar. Thus, users familiar with any ETC-related facility can easily identify which lane to use to pay their toll. Interoperability across countries is also a working goal for those countries the scan team visited.

Similar consistency is also seen across Europe for indicating variable speed limits to motorists. As shown in figure 63, speed limits are displayed on a DMS panel with a red circle. The display shown here is identical to those used in Denmark and Germany.

Pricing

Tolling and pricing are being considered in most countries across Europe. However, the underlying purpose of most of these strategies is overall financing of the roadway network rather than congestion management. The Attica Tollway in Greece is a lucrative toll facility that brings in significant revenue each month while working to reduce traffic on the other parts of the Athens roadway network. The first facility

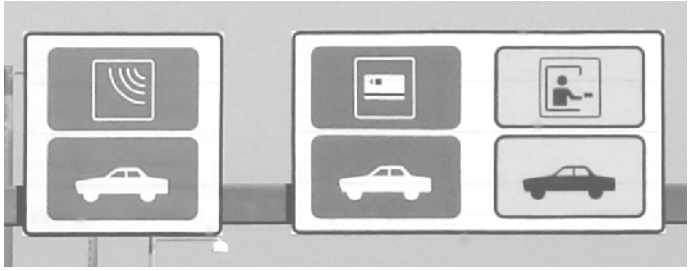

Figure 62. Toll-related signing in Denmark.

Figure 63. Variable speed limit displays in the Netherlands.

of its kind in that part of Europe, it has been an operational and financial success and will most certainly chart the way for additional facilities in the region.

Germany implemented heavy goods vehicle tolling on its motorways in 2006 to accomplish several objectives, one of which was to guarantee the financing of new roads and overall network maintenance.[34] Other motivations for this electronic toll system are to create a pricing scheme borne by the originators of road demand, create an incentive to change the modal split for freight, enhance the efficient use of trucks, and promote the implementation of innovative technology.[34]

Road pricing for all users is becoming more prevalent in Europe. Of the countries the scan team visited, the Netherlands and the United Kingdom are seriously considering implementing road pricing for the entire country in the near future. The success of congestion charging on urban streets in central London has illustrated that pricing potential. Essentially, it is seen as a smarter and more credible long-term option for maintaining the infrastructure and ensures that users pay an appropriate share based on their roadway use.[64] It is clear that road charging is on the horizon in

Europe and may be the long-term solution to transportation finance shortfalls and localized congestion management.

Examples of Managed Lanes

One purpose of this scan was to seek information on how agencies approach highway congestion and how they plan for and design managed lanes at the system, corridor, and project or facility levels. As evidenced by the scan team's findings, the European countries visited are aggressively looking to active traffic management systems and other strategies to address highway congestion, but have limited applications of managed lanes as defined in the United States. Most applications that would qualify as managed lane facilities in the United States are in the form of bus lanes and actively managed temporary shoulder use combined with speed harmonization. However, use of managed lanes as a congestion-management tool is gaining momentum in Europe, particularly in the United Kingdom where HOV projects are under development and as lessons learned about managed lanes emerge from the U.S. experience.

Managed Lanes Direction in Europe

The countries in Europe the scan team visited have a comprehensive approach to managing congestion that can easily incorporate managed lanes—as defined in the United States—to help meet mobility and safety goals. Primarily speaking, the infrastructure is already present to manage and operate managed lanes in corridors where active management has already been implemented. The addition of a managed lane strategy can be easily supported and optimized since these corridors are heavily instrumented and users are already familiar with dynamic operating conditions that reflect congestion levels. The governments' commitment to infrastructure investment and technology in managing congestion lays the groundwork for moving toward managed lanes as congestion and travel demand increase in the future. Furthermore, implementation of speed harmonization and temporary shoulder use would most likely be key companions to managed lanes, as they reinforce the efficient use and optimization of the existing network.

The commitment to the user and the presence of 24/7 operations for traffic management facilities and active congestion management also support the future implementation of managed lanes in Europe. Regional and national traffic management centers combined with comprehensive traveler information systems help provide motorists with accurate information about roadway conditions. This ability will be especially critical as managed lane strategies become prevalent and eligibility criteria vary according to changing travel conditions in a dynamic manner. Accurate information about operational strategies will be critical to ensuring the success of managed lanes. Supporting this information dissemination is the European movement to standardize active management, including consistent signing, pavement marking, operations, and geometric design. Consistency across jurisdictions helps reduce user confusion and helps optimize the potential of managed lane facilities. When actively managed, managed lanes can help agencies provide travel time reliability at any time of the day on any day of the year.

Managed lanes are on the horizon in Europe and facets of them are already being deployed. The temporary use of the shoulder sets the stage for the flexible use of the cross section, which is a cornerstone of managed lane operations. Speed harmonization supports the optimization of pavement use and helps increase throughput during times of congestion. In addition, the use of managed lanes to address bottleneck problems, vehicle restrictions, and the potential benefits of pricing and occupancy-based strategies all indicate a movement toward managed lanes. As agencies plan and develop major motorway improvement projects, active management and managed lane strategies are becoming part of the decisionmaking process. Furthermore, agencies are integrating managed lanes and strategies that accomplish similar goals and objectives into their overall agency policies, strategic plans, and planning processes. Thus, as congestion becomes an ever-increasing problem and travel demand grows, Europe has the tools readily available to easily integrate managed lanes into its approach to congestion management.

Critical Observations

Europe faces similar mobility challenges as the United States, including an increase in travel demand, growth in congestion, a need to improve safety, and the reality of limited resources to address these challenges. Given these similarities, the scan team identified seven key approaches to congestion management that have the potential to ease congestion in the United States. The purpose of this scan was to examine the congestion management programs, policies, and experiences of other countries and to seek information on how agencies approach highway congestion and plan for and design managed lanes at the system, corridor, and project or facility levels. The following are the critical findings and observations of the scan team in response to this charge:

- Active management is the foundation of the European approach to managing congestion. It builds on advancements in technology and traffic management experience, works to make the best use of existing capacity, and provides additional capacity during periods

of congestion or incidents.

- The road user/customer is a focal point of European mobility policy. Congestion management strategies center on the need to ensure travel time reliability for all trips, regardless of the time of day.
- Transportation and traffic management operations are priorities in the planning, programming, and funding processes and are seen as critical needs to realize the benefits of investment in the transportation infrastructure and deployed systems for congestion management.
- Agencies use tools to support cost-effective investment decisions at the project level to ensure that the operational strategies implemented have the best benefit-cost ratio and represent the best investment of limited resources.
- Public-private partnerships and similar innovative financing strategies are emerging to solve the ever-growing funding shortfall.
- Agencies acknowledge the criticality of providing consistent messages to roadway users to reduce the impact of those travelers on congestion.
- Tolling and pricing are being considered as potential long-term solutions to transportation finance shortfalls and congestion management.
- Managed lanes, on the horizon in Europe and a reality in the United States, foster the flexible and efficient use of the existing roadway cross section and are critical components of overall active management of congestion facilities.

Chapter 4

Moving Toward Active Traffic Management In The United States

Europe faces similar mobility challenges as the United States, including an increase in travel demand, growth in congestion, a need to improve safety, and the reality of limited resources to address these challenges. Given these similarities, the scan team recommends moving toward active traffic management in the United States to better manage congestion. While not a substitute for large-capacity expansion projects, active traffic management is a cost-effective means of prolonging the life and maximizing the efficiency of the infrastructure that can postpone the need for major expansions projects. It is also flexible enough to be implemented under temporary conditions in work zones and later be incorporated into the permanent operational infrastructure of a facility to extend the benefits to everyday operations.

Recommendations

The purpose of this scan was to examine the congestion management programs, policies, and experiences of other countries and to seek information on how agencies approach highway congestion and how they plan for and design managed lanes at the system, corridor, and project or facility levels. The following are the primary recommendations of the scan team in response to this charge:

- Promote active traffic management to optimize existing infrastructure during recurrent and nonrecurrent congestion.
- Emphasize customer orientation and focus on trip reliability.
- Integrate active management into infrastructure planning and programming processes.
- Make operations a priority in planning, programming, and funding processes.
- Develop tools to support active management investment decisions.
- Consider public-private partnerships and other innovative financing and delivery strategies.
- Provide consistent messages to roadway users.
- Consider pricing as only one component of a total management package.
- Include managed lanes as part of the overall management of congested facilities.

Promote Active Traffic Management

Active management is the ability to dynamically manage recurrent and nonrecurrent congestion based on prevailing traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility. It increases throughput and safety through the use of integrated systems with new technology, including the automation of dynamic deployment to optimize performance quickly and without the delay that occurs when operators must deploy operational strategies manually. When the combined operational strategies are implemented in concert, they fully optimize the existing infrastructure and provide measurable benefits to the transportation network and the motoring public. Potential benefits include increased throughput, increased capacity, decreased primary and secondary incidents, more uniform speeds, decreased headways, more uniform driver behavior, increased trip reliability, and the ability to delay the onset of freeway breakdown. For this reason, the scan team firmly believes that active traffic management is the next evolution in congestion management in the United States and that transportation agencies should promote and facilitate its implementation across the country.

Customer Orientation

A key component of active traffic management is the focus on customers and their needs. All of the operational strategies under the umbrella of active traffic management work to improve travel time reliability. They address the impacts of recurrent and nonrecurrent congestion while working proactively to prevent incidents that are major contributors to travel delays. While many of these strategies are not new to transportation professionals in the United States, their deployment in a coordinated and comprehensive manner within the framework of active traffic management represents a broader approach to addressing congestion by exhibiting a commitment to users and providing them with reliable travel times. They also signify the recognition of a link among incidents, their duration, and their impact on mobility for all users. Thus, customer reliability should be a critical gauge for all operational strategies as the United States moves forward with active traffic management.

Planning for Active Traffic Management

Whether to implement active traffic management and its operational strategies is a policy decision that must be made at the appropriate governing level. To that end, policymakers should develop both short- and long-range plans that incorporate active traffic management into the framework of transportation alternatives. Furthermore, agencies should approach active traffic management proactively by including it in current and future plans for target corridors. They should assess what active traffic management capabilities already exist in those corridors and what components need to be added to facilitate active management, even if conditions do not currently warrant such operational strategies. This forward-thinking approach will ensure that the infrastructure is put into place during future projects so that active traffic management can be implemented when warranted by congestion levels and mobility needs. In some regions, legislative support may be necessary to make this operational approach possible.

Operations Priority

In an era of limited resources, active traffic management is a significant drain on the limited funds an agency has available. However, it also represents an investment that should not be wasted so that its benefits can be realized. Thus, transportation and traffic management operations need to be a priority in the planning, programming, and funding processes for transportation. Legislation, policy, and financial resources are critical to the long-term success of active traffic management. Such resources help maintain and operate the system and ensure it adapts to new technologies to better serve customers. Thus, transportation agencies need to make the commitment to operations and make it a priority to maximize the benefits of infrastructure investment and to ensure sustainability and customer satisfaction through improved traffic operations.

Cost-Effective Investment Decisions

U.S. agencies constantly struggle to address growing congestion with increasingly limited resources and environmental restraints. The United States needs to develop tools to support active management investment decisions similar to those in use in Europe. These tools would help agencies conduct economic assessments of active traffic management by measuring the costs and benefits of its deployment in a corridor to determine project viability and economic effectiveness. The result would be a step-wise approach to assessing the best use of limited dollars to address critical congestion problems in a region.

Diverse Financing Strategies

The potential for diverse financing strategies to solve an ever-growing funding shortfall is significant. European success with PPPs in transportation has demonstrated the majority of benefits in operations and maintenance savings over the life of a contract. The inclusion of performance thresholds in the payment contract is essential to a successfully run project. Transportation-based performance measures tied to contract incentives include improved operations, reduced delay, fewer incidents, and other measures important to users. The result is a PPP that holds the concessionaire accountable for operations and ensures that the public entity spends resources with the best interests of users in mind. Thus, U.S. transportation agencies should pursue the feasibility of diverse financing strategies that meet funding needs while ensuring that customer needs and related performance measures are a priority throughout the life of the project.

Consistent Messages

As urban areas move toward active traffic management, there is a need to provide consistent messages to roadway users to reduce the impact of those travelers on congestion. The United States should adopt uniform symbology policies for active traffic management that resemble those used in Europe. Such uniformity would ensure that roadway users see the same symbols in Texas that they see in Minnesota, Virginia, or Washington.

Pricing and Managed Lanes

Road pricing for all users is being considered both in Europe and domestically as a smarter and more credible long-term option for maintaining the infrastructure. It ensures that users pay an appropriate share based on their roadway use, serves as a long-term solution to transportation finance shortfalls, and may also help with localized congestion management. However, it is only one component of a total management package and should not be seen as a cure-all for congestion problems.

In addition, active traffic management can easily support existing managed lanes strategies and incorporate new ones since active traffic management corridors are heavily instrumented and users are already familiar with dynamic operating conditions that reflect current congestion levels. Furthermore, managed lanes are a likely companion to active traffic management as they reinforce the efficient use and optimization of the existing network. Thus, managed lanes should be considered an operational strategy under the umbrella of active traffic management as part of the overall approach to managing congestion on U.S. roadways.

Active Traffic Management Strategies

Based on its observations, the scan team recommends nine

strategies that members believe will move the United States toward comprehensive active traffic management to manage congestion. Table 3 outlines the potential benefits of these strategies, and the following sections present the critical components the team believes are necessary for successful and effective implementation. While some strategies are already used in regions across the country, it is the combined application of these strategies in a corridor that represents a cultural shift in the way transportation agencies operate freeways. Furthermore, these strategies can be applied to address both recurrent and nonrecurrent congestion to more effectively combat their impacts on trip reliability. Although these strategies are described individually, it is the combined, holistic application of the strategies for an entire network or region that will provide the most benefit.

Speed Harmonization

The United States should implement speed harmonization on freeways as a strategy to actively manage the network and delay the onset of congestion under normal operating conditions. The system should include the following elements:

- Sufficient sensor deployment for traffic and weather monitoring to support the strategy.
- Adequate installation of sign gantries to ensure that at least one speed limit sign is in sight at all times.
- Placement of speed limit signs over each travel lane.
- An expert system that deploys the strategy based on prevailing roadway conditions without requiring operator intervention. It is critical that this expert system be reliable and accurate to gain the trust and acceptance of the public.
- Connection to a traffic management center that serves as the focal point for the system.
- Passage of enabling legislation and related laws to allow for dynamic speed limits.
- Uniform signing related to speed harmonization and its components.
- Modeling tools to assess the impacts of speed harmonization on overall network operations.
- Closed-circuit television cameras to support the monitoring of the system.
- Dynamic message signs to provide traveler information and regulatory signs as appropriate.
- Automated speed enforcement to deter violations.

Temporary Shoulder Use

Temporary shoulder use should be implemented where appropriate to temporarily increase capacity during peak

Table 3. Potential benefits of active traffic management strategies.

Active Traffic Management Strategy	Potential Benefits												
	Increased throughput	Increased capacity	Decrease in primary incidents	Decrease in secondary incidents	Decrease in incident severity	More uniform speeds	Decreased headways	More uniform driver behavior	Increased trip reliability	Delay onset of freeway breakdown	Reduction in traffic noise	Reduction in emissions	Reduction in fuel consumption
Speed harmonization	●		●		●	●	●	●	●	●	●	●	●
Temporary shoulder use	●	●							●	●			
Queue warning			●	●	●	●	●	●	●		●	●	●
Dynamic merge control	●	●	●			●		●	●	●	●	●	●
Construction site management	●	●							●		●	●	●
Dynamic truck restrictions	●	●				●		●	●			●	●
Dynamic rerouting and traveler information	●		●	●				●	●			●	●
Dynamic lane markings	●	●							●				
Automated speed enforcement			●		●	●		●	●			●	●

travel periods. Specific elements of the operational strategy should include the following:

- Deployment in conjunction with speed harmonization.
- Passage of enabling legislation and related laws to allow the shoulder to be used as a travel lane.
- A policy for uniform application of the strategy through entrance and exit ramps and at interchanges.
- Adequate installation of sign gantries to provide operational information and to ensure it is in sight at all times.
- Placement of lane control signals over each travel lane.
- Uniform signing and markings related to temporary shoulder use.
- Closed-circuit television cameras with sufficient coverage to verify the clearance of the shoulder before deployment.
- Provision of pullouts at regular intervals with automatic vehicle detection to provide refuge areas for minor incidents.
- Provision of roadside emergency call boxes at emergency pullouts.
- Special lighting to enhance visibility of the shoulder.
- Advanced incident detection capabilities.
- Comprehensive incident management program.
- Connection to a traffic management center that serves as the focal point for the system.
- Dynamic message signs to provide guide sign information and regulatory signs to adapt to the addition of the shoulder as a travel lane.

Queue Warning

Queue warning message displays should be implemented at regular intervals to warn of the presence of upstream queues based on dynamic traffic detection. Specific elements of the operational strategy should include the following:

- Deployment in conjunction with speed harmonization.
- Sufficient sensor deployment for traffic monitoring to support the strategy.
- Adequate installation of sign gantries to ensure that at least one queue warning sign is in sight at all times.
- An expert system that deploys the strategy based on prevailing roadway conditions without requiring operator intervention. It is critical that this expert system be reliable and accurate to gain the trust and acceptance of the public.
- Uniform signing to indicate congestion ahead.
- Connection to a traffic management center that serves as the focal point for the system.

Dynamic Merge Control

At merges from major interchange ramps, consideration should be given to dynamically metering or closing specific upstream lanes, depending on traffic demand. This could easily incorporate existing ramp metering systems and could offer the potential of delaying the onset of main lane congestion and balancing demands between upstream roadways. Specific elements of the operational strategy should include the following:

- An expert system that deploys the strategy based on prevailing roadway conditions without requiring operator intervention. It is critical that this expert system be reliable and accurate to gain the trust and acceptance of the public.
- Closed-circuit television cameras to support the monitoring of the system.
- Installation of lane control signals over the main lanes and the ramp lanes with a signal over each travel lane.
- Adequate installation of sign gantries upstream of the deployment to ensure sufficient advance warning is provided to roadway users through the use of dynamic message signs.
- Adequate installation of sign gantries with dynamic message signs upstream of the deployment to provide guide sign information and regulatory signs to adapt to the changes in lane use.
- Uniform signing to indicate merge control is in use.
- Automated enforcement to deter violations.
- A bypass lane for emergency vehicles, transit, or other identified exempt users.
- Connection to a traffic management center that serves as the focal point for the system.

Construction Site Management

Agencies should undertake the strategic management of construction projects. Whenever possible, tools should be developed or existing ones used to assess the impacts of short-term construction projects on congestion and optimize the timing for such efforts. In addition, agencies should consider the use of active traffic management during a construction project to help offset the negative impacts of the work zone and to facilitate the permanent installation of active traffic management at the conclusion of the project.

Truck Restrictions

Truck restrictions implemented on a regional or national basis offer the opportunity to better segregate vehicles when implementing a variety of proactive lane management strategies that may not allow for safe operation in particular lanes. Specific elements of the operational strategy should include the following:

- Enabling legislation and related laws to allow dynamic truck restrictions.
- An expert system that deploys the strategy based on prevailing roadway conditions without requiring operator

intervention. It is critical that this expert system be reliable and accurate to gain the trust and acceptance of the public.
- Uniform signing and marking to indicate truck restrictions are in effect.
- Adequate installation of sign gantries to ensure that at least one restriction sign is in sight at all times.
- Deployment in conjunction with speed harmonization.
- Connection to a traffic management center that serves as the focal point for the system.

Dynamic Rerouting and Traveler Information

Dynamic rerouting and provision of reliable traveler information are critical components of a successful active traffic management system. They provide users with viable alternatives and are especially beneficial to reducing the impact of nonrecurrent congestion. Specific elements of the operational strategy should include the following:

- A commitment to providing alternate route information to roadway users in response to nonrecurrent congestion.
- Adequate installation of sign gantries along a facility at critical locations to ensure that sufficient advance notice of alternate routes is provided.
- Deployment in conjunction with speed harmonization and temporary shoulder use.
- Connection to a traffic management center that serves as the focal point for the system.
- Connection to adjoining traffic management centers to coordinate alternate route information based on roadway conditions and special events in adjoining regions.
- Coordination with local communities to minimize the impact of alternate route information on the arterial network.

Dynamic Lane Markings

Dynamic lane markings show promise in providing support to active management strategies, particularly temporary shoulder use. The possible applications of dynamic lane markings related to active management and their use in providing clear information to the driver should be explored fully to optimize their potential.

Automated Enforcement

Automated enforcement of speeds and other active traffic management strategies has the potential to ensure compliance with these strategies and their safe and effective operation to reduce congestion, the impact of incidents, and the impact of transportation on the environment. Specific elements of the operational strategy should include the following:
- Passage of enabling legislation and related laws to allow for automated speed enforcement.
- Uniform signing to indicate the presence of automated enforcement.

Chapter 5

Implementation Strategy

The scan team firmly believes that much can be gained in the United States by implementing the various congestion management strategies discussed in this report on congested roadway networks. To that end, the scan team plans a number of activities and initiatives to disseminate information from the scan and move the recommendations forward within the context of congestion management in the United States.

Implementation Action Plan

The implementation initiatives and strategies identified by the scan team include, but are not limited to, the following items.

Executive Strategy Forum

To obtain the highest success for adoption and implementation of the recommended management strategies, the scan team recommends holding an executive strategy forum with selected and invited agency stakeholders who are pursuing innovative managed lane programs. The purpose of this forum would be to present results of a feasibility study from one candidate location, seek support for studies from several other areas, and involve some of the forum participants in a followup meeting of AASHTO members and FHWA staff to explore more widespread adoption and implementation. The specific actions comprising the executive strategy forum are described below.

Strategic Highway Research Program II Capacity Operations Research

In future meetings of this group, agencies will work to ensure that capacity operations and other issues related to active traffic management are considered for research topics.

White Paper

With a heavy emphasis on transportation planning, this paper will provide an overview of the congestion challenges in Europe and the United States. Because of constraints to building more capacity, European countries have shifted to a focus on active traffic management. This paper will focus on planning processes and tools to make the cost/benefit case for active traffic management. Planning study areas will be both corridor- and systemwide.

NCHRP Synthesis

A proposal was submitted to NCHRP for a research synthesis on the state of the practice of managed lane applications in the United States. It was determined that a more prudent use of the money would be to host a peer exchange on managed lanes that includes areas where managed lane activities are underway.

NCHRP Research

This proposed research project will develop guidance to allow practitioners to identify the operational concepts, requirements, and other special needs associated with planning, designing, and implementing advanced pricing, eligibility, and access control strategies for flexible operations and active system management. The project will identify operational and design issues associated with meeting these requirements under different environmental conditions (e.g., type of network, urban characteristics, levels of congestion, available right of way) and develop technical guidance on approaches to overcome them. Expected deliverables include technical guidance and a report of recommendations for additional research on issues that could not be resolved within the scope of the effort.

FHWA and FTA Guidance

The FHWA Offices of Planning and Operations are developing guidance on the congestion management process. Included in this guidance will be a discussion on how active traffic management can be considered within the congestion management process.

FHWA Analysis Tool

The FHWA Offices of Planning and Operations are continuing the development of technical analysis tools to support operational and ITS investments. Simulation and sketch tools under development include ITS Deployment Analysis System (IDAS), Dynasmart-P, and VISUM/VISSIM.

Marketing and Outreach

Marketing and outreach materials, such as an audio-visual presentation, executive briefings, and an informational one-pager or brochure, will be developed to increase awareness of the active management concept and other findings and recommendations from this scan.

FHWA Group

The FHWA Office of Operations will initiate an interdisciplinary work group to focus on the planning, design, and operations aspects of managed lanes and identify

national initiatives to promote active management.

Public-Private Partnerships

The current testing of alternate project delivery systems, particularly those involving major managed lane initiatives in various States, offers the opportunity to mainstream recommended strategies from this scanning study. However, an understanding and application of strategies will need to be disseminated to both proposers and agency owners. Activities such as creating a template for solicitations and negotiations that include performance goals and measures, financing active traffic management, and training are recommended to accomplish this objective.

Managed Lanes Domestic Scan

The purpose of the domestic scan is to examine the programs, policies, and practices of various States that are either in the planning phase or have implemented and are operating managed lane facilities on freeways. This domestic scan will supplement the international scan to promote the benefits of active management. The scan will provide States that are ready to deploy managed lanes an opportunity to gather and compile technical and institutional best practices, lessons learned, and peer exchange information on the planning, design, implementation, operations, and management of managed lanes through site visits and group discussions.

FHWA Managed Lanes Program Plan

Update the FHWA Freeway Management Program Plan and Roadmaps based on the findings and recommendations from this scanning study.

Conclusion

The scan team saw active traffic management in action in Europe. It was clearly evident that through the deployment of this congestion management approach and its component strategies, agencies overseas have control over entire facilities and are able to fully optimize their investment in the infrastructure to meet the needs of customers. The benefits realized because of the deployment of active traffic management are a testament to its potential for the United States. Countries have been able to implement active traffic management and gain acceptance from the public and policymakers because they see real results. There is no reason why this approach to congestion management cannot be implemented in the United States with similar results. For this reason, the scan team firmly believes that active traffic management is the next evolution in congestion management in the United States and we have much to learn from the experiences in Europe to make it a reality at home.

Glossary

active traffic management. The practice of dynamically managing recurrent and nonrecurrent congestion based on prevailing traffic conditions. Focusing on trip reliability, it maximizes the effectiveness and efficiency of the facility, and increases throughput and safety through the use of integrated systems with new technology, including the automation of dynamic deployment to optimize performance quickly and without the delay that occurs when operators must deploy operational strategies manually.

dynamic rerouting. The provision of route information on overhead sign gantries along a roadway in response to recurrent and nonrecurrent congestion. The signs provide en route guidance information to motorists on queues, major incidents, and appropriate routes.

dynamic message sign. A permanently installed or portable electronic traffic sign used on roadways to give travelers information about roadway conditions, including traffic congestion, crashes, incidents, work zones, speed limits, alternative routes, or special events on a specific highway segment. It can be changed or switched on or off as required and can be used to provide roadway lane control, speed control, and operational restrictions. Also known as a **changeable message sign** or a **variable message sign.**

merge control. A variation of the temporary shoulder used in Germany. Typically, it is applied at entrance ramps or merge points where the number of downstream lanes is fewer than the number of upstream lanes. Lane control signals are installed over both upstream approaches before a merge. They provide priority to the facility with the higher volume and give a lane drop to the lesser volume roadway or approach. Also known as **junction control** or **mainline merging control.**

managed lanes. Highway facilities or a set of lanes in which operational strategies are implemented and managed (in real time) in response to changing conditions to preserve unimpeded flow. They are distinguished from traditional lane management strategies in that they are proactively implemented and managed and may involve using more than one operational strategy with the goal of achieving unimpeded flow.

plus lane. The practice of opening up the shoulder next to the inside lane of traffic for temporary use to address capacity bottlenecks on the freeway network during times of congestion and reduced travel speeds. Travel on the shoulder is permitted only when speed harmonization is active and speed limits are reduced. Signs indicate when travel on the shoulder is permitted.

queue warning. The display of warning signs and flashing lights along a roadway to alert that congestion and queues are ahead.

ramp metering. Procedures used to reduce congestion by managing vehicle flow from local-access on-ramps. The entrance ramp is equipped with a traffic signal that allows vehicles to enter the freeway at predetermined intervals.

speed harmonization. The practice of using an expert system to monitor data coming from field-deployed sensors on a roadway and automatically adjust speed limits when congestion thresholds are exceeded and congestion and queue formation are impending. Sign gantries that span the facility provide speed limits and additional information, depending on roadway conditions. Also known as **line control.**

symbology. The use of graphic symbols to represent information pertinent to roadway users. The European practice of using symbology follows the Vienna Convention.

temporary shoulder use. The practice of opening up the shoulder next to the outside lane of traffic for temporary use to address capacity bottlenecks on the freeway network during times of congestion and reduced travel speeds. Travel on the shoulder is permitted only when speed harmonization is active and speed limits are reduced. Signs indicate when travel on the shoulder is permitted. Also known as hard-shoulder running or a rush-hour lane.

truck restrictions. Any restrictions along a roadway on the operation of trucks or heavy goods vehicles. Examples include restricting trucks to specific lanes, prohibiting them from using particular lanes, limiting their operating speed, or prohibiting their use of the entire facility during specific periods of the day.

variable speed limits. Speed limits that change based on road, traffic, and weather conditions. Also known as **dynamic speed limits.**

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First International Symposium on Freeway and Tollway Operations

The scan team began its trip in Greece with participation in the First International Symposium on Freeway and Tollway Operations in Athens. This symposium was jointly sponsored by a host of European and U.S. associations, including the Transportation Research Board (TRB) and the International Bridge, Tunnel, and Turnpike Association (IBTTA). The objectives of the symposium were to capture the state of the practice in freeway and tollway operations, identify innovative strategies and techniques to improve the proactive management and control of traffic, and explore the potential benefits of using managed lanes, tolling, pricing, and other strategies to improve traffic operations on congested freeways.

The symposium was successful with more than 400 participants attending the 4-day event. More than 200 presenters from 18 countries gave technical presentations that centered around four major tracks:

- Expressway management and congestion solutions
- Tollway development, tolling operations, technologies, and issues
- Technologies and issues for operations and control centers
- Managed lanes

The following sections summarize the distinguished sessions and four major tracks held during the symposium.

Opening of Distinguished Sessions

The distinguished sessions that opened the symposium were divided into U.S., European Union, and IBTTA perspectives. The U.S. session, "Improving Mobility and Managing Congestion," provided insight into the American approach to managing congestion. Presenters provided highlights on the future direction of congestion management in the United States and specific regional perspectives from California, Texas, and Virginia. The IBTTA session, "Improving Policies, Practice, and People," outlined the worldwide mission of IBTTA, regional perspectives from Florida and Texas, Spain's foray into toll road interoperability, and the criticality of using tolling to help ensure the success and advancement of transportation across the globe. "Priorities in Europe," presenting the perspective of the Association Européenne des Concessionaires d'Autoroutes et d'Ouvrages à Péage (ASECAP) and the European Union, presented European toll-related priorities in France, Belgium, France, Switzerland, and the United Kingdom.

Expressway Management and Congestion Solutions

This track provided cutting-edge information on the various methods used to manage freeways to solve congestion problems. Specific sessions highlighted successful practices in the following areas of operations:

- Ramp metering
- Freeway speeds and variable speed limits
- Congestion and bottlenecks
- Traffic management tools and centers
- Travel time estimation and dissemination
- Incident management
- Operations in emergencies and special events

Presentations focused on projects and programs from across the globe, including Canada, France, Germany, Greece, Switzerland, and the United States.

Tollway Development, Tolling Operations, Technologies, and Issues

This track focused on recent developments and trends in tolling and tollway operations, technologies that enhance their success, and issues that challenge operators and users of these facilities. Speakers from Austria, Chile, France, Greece, Israel, the United Kingdom, and the United States spoke on numerous topics related to the following:

- Open-road tolling
- High-occupancy toll (HOT) lanes and congestion charging
- Road user charging systems and concerns
- Issues with tolling and financing methods
- Toll pricing, tendering, and forecasts

Technologies and Issues for Operations and Control Centers

The third track in the symposium centered on advancements in technology and their use with tollway operations and control centers for freeways. Topics of discussion addressed during the track's sessions included the following:

- Integrated toll and traffic management
- Freeway and tollway traffic simulation
- Sensors for automated data collection
- Technologies in the service of operations
- Notable examples of international freeway operations

Presenters highlighted advancements in the application of technologies in freeway operations and tolling in such countries as Canada, China, France, Germany, Greece, Israel, Montenegro, Portugal, Serbia, Spain, the United Kingdom, and the United States.

Managed Lanes/Expressway and Tollway Development and Issues

The final symposium track was split between addressing issues related to managed lanes and the development issues surrounding expressways and tollways. Sessions on managed lanes provided recent research results and practical experience—mostly from the United States—related to the following:

- Developing and designing freeways for the 21st century
- Managed lane strategies enhancing freeway performance
- Managed lane tools, deployment, and evaluations

Sessions devoted to expressway and tollway development highlighted critical issues and experiences in Canada, France, Greece, Spain, and the United States in the following areas:

- Large bridge and toll highway projects
- Concerns with systems, decisions, and costs
- Safety issues

Roundtable Panels

In addition to the technical tracks discussed above, the symposium featured a number of roundtable panel discussions to bring focused attention to critical issues related to freeway and tollway operations. These panel sessions, which followed the same topical areas as the tracks, were the following:

- "Past, Present and Future of Greek Motorways: How Far Have We Come and How Much is Left to Go?"
- "Speeding and Speed Limits: Are Drivers out of Control?"
- "Proactive Management"
- "Early Bird: Agency Approaches to Congestion Management"

In each panel discussion, experts provided critical insight into the topic and presented potential solutions to challenges agencies face in these areas.

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Jon Obenberger *(FHWA cochair)* is the Preconstruction Group Team leader in the Office of Infrastructure for the Federal Highway Administration (FHWA) in Washington, DC. Obenberger directs and manages FHWA's Preconstruction Program, including geometric design, Interstate Highway System design (e.g., standards, access control, rest areas), context-sensitive solutions, value engineering, employing engineering services, utility accommodations, and subsurface utility engineering. Before joining the Office of Infrastructure in 2004, he served for 8 years as the Freeway Management and Operations Program manager in FHWA's Office of Operations. For more than 2 years he was the technical lead for the ITS Program, and he worked four years as a Design Team leader for the Wisconsin Department of Transportation. Before that, he worked as the traffic engineer and metropolitan planning organization coordinator for the city of Beloit, WI. Obenberger has bachelor's and master's degrees from the University of Wisconsin Department of Civil and Environmental Engineering. He is a Ph.D. candidate finalizing his dissertation requirements in the Advanced Transportation Systems Program of Civil and Environmental Engineering at Virginia Polytechnic Institute and State University. He is a licensed professional engineer in Wisconsin and serves on several committees of AASHTO and the Transportation Research Board (TRB).

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Amplifying Questions

The continued growth in travel along congested urban freeway corridors is exceeding the ability of transportation agencies to provide sufficient roadway capacity in major metropolitan areas with limited public funding for roadway expansion and improvement projects. High construction costs, constrained right-of-way, and environmental factors are pushing agencies to explore context-sensitive solutions, such as managed lanes, to mitigate the detrimental effects of congestion while optimizing the use of limited public funding.

The purpose of this scan is to examine the congestion management programs, policies, and experiences of other countries that are planning, have implemented, or are operating managed lanes on freeway facilities. This scan will seek information on how agencies approach highway congestion and how they plan for and design managed lanes at the system, corridor, and project or facility levels.

Managed lanes are defined as highway facilities or a set of lanes in which operational strategies are implemented and managed (in real time) in response to changing conditions to preserve unimpeded flow. They are distinguished from traditional lane management strategies in that they are proactively implemented and managed and may involve using more than one operational strategy.

Approach to Highway Congestion

The questions in this section are targeted to learn how European agencies define and address congestion. How are congested roadway facilities considered in establishing, prioritizing, and funding initiatives to enhance the condition (e.g., pavement, bridges) and performance (e.g., remove bottlenecks, add capacity, manage traffic) of these facilities? What aspect of an organization's strategic planning, infrastructure investments, and operational strategies are considered to address these congested facilities?

1. How do you define congestion? Do you have a congestion level threshold to determine whether a roadway is deficient? If so, what is that threshold?
2. What performance measures do you use to assess congestion?
3. What tools, methods, techniques, and/or modes are used to forecast travel demand and analyze and evaluate surface transportation investments? Are these tools used at the country, regional, or corridor level?
4. Do you have a systematic process to evaluate and monitor surface transportation investments for addressing congestion? What is the process?
5. What is the priority of congestion improvements in relation to other issues (i.e., safety, roadway improvements/maintenance, security) in your surface transportation plan? What is the process or procedure in projects/alternatives prioritization?
6. What is your long-range vision for surface transportation? Which agency develops the long-range vision and plan? What role do congestion improvement strategies play in moving the surface transportation system toward that vision?

Approach to Managed Lanes

The following questions focus on the agency's approach to managing the transportation supply using the managed lane concept.

1. What managed lane facilities are (1) in your strategic plans, (2) in development, or (3) currently operating?
2. Where did the concept of implementing managed lanes originate? Who provided the leadership to advance the concept? Who is responsible for planning, designing, constructing, and operating the managed lane facility? What was unique about these particular corridors and projects that the managed lane concept and strategies are being applied?
3. What other congestion management strategies are often planned and implemented in association with managed lanes? If managed lanes have not been planned or implemented, what other strategies are applied?
4. Is carpooling promoted on any managed lanes through access, eligibility, or pricing incentives?
5. What objectives and performance measures have been developed for managed lane facilities? What models have you used to predict managed lane performance? Have you validated these models with real operating data?
6. How are operational strategies and facility performance integrated into the planning for and design of the managed lane facility?
7. What techniques and approaches have you used to estimate the demand for different types of managed lane operational strategies or facilities? What assumptions were made relating to shifts in traffic

patterns (e.g., trips attracted to managed lane from adjoining lanes, other facilities, other modes) in the planning process? What shifts in traffic patterns have you realized?

8. What operational strategies of managed lanes (access control, vehicle eligibility, and pricing) have you implemented? Do you vary or allow tolls to dynamically change based on traffic demand or roadway conditions (e.g., congestion)? Do you charge a flat fee to use the managed lane or does the fee change based on distance traveled? For dynamic pricing strategy, how are changes in the toll to be charged for using the facility conveyed to the driver?
9. How do you balance (compromise) between designing for safety and designing for mobility? Are you making design decisions that may impact safety and mobility differently?
10. What is your experience with implementing managed lanes in an existing roadway facility? What impact have these facilities had on performance (e.g., mobility, safety)?
11. Has your agency developed any design standards or recommended practices relating to the geometric design of managed lane facilities? Has your agency initiated or conducted any research in support of developing managed lane-related design standards or guidance?
12. What are the major safety issues to consider when planning and design managed lane facilities? Are there any design provisions for incident management or for enforcement?
13. What technical and institutional barriers/challenges did the agency face? How were they overcome?
14. What techniques have been used to integrate transit (e.g., direct access ramps, transit stations, park-and-ride facilities) into various types of managed lane facilities that your agency has implemented or is planning?
15. How is the day-to-day operation of managed lanes being monitored? How are you evaluating its performance? Are you able to identify the impact or performance of specific traffic management or control strategies (e.g., different speed limits during periods of the day, restricting access)?
16. What tools, methods, techniques, and/or models are used to estimate managed lane benefits? Have you conducted any validation of the planning and/or simulation models with real experience results and "after implementation" data?
17. How is enforcement being performed? Is any dedicated enforcement provided specific to managed lanes? Are you considering different technologies or strategies to support different managed lane operational strategies (e.g., occupancy, trucks only, pricing, speed)?
18. What role has technology (i.e., electronic tolling, variable speed limits, and automated enforcement) played in the implementation of managed lanes?
19. What tools and methods of communication have been used to educate and promote the managed lane concept to the public and decisionmakers? How is public perception measured?
20. What role has the media played in public and political perceptions? What issues have decisionmakers raised and how have these been addressed?
21. What are the funding sources for planning, designing, and implementing managed lane facilities? How are the day-to-day management and operation of these facilities funded?
22. What laws and regulations have been used to support the pursuit of private financing or partnerships to implement and sustain the ongoing operation of managed lanes? What are the key provisions that have been included in agreements with the private sector in support of managed lanes? What are the financial and operational limits of your organization for these partnerships?
23. What are your overall experiences in managed lanes? Please provide your successes and lessons- learned experiences. What is your future vision?

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