Innovative Traffic Control

Technology and Practice in Europe

International Technology Exchange Program

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FHWA INTERNATIONAL TECHNOLOGY EXCHANGE PROGRAMS

The FHWA's international programs focus 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. While the FHWA is considered a world leader in highway transportation, the domestic highway community is very interested in the advanced technologies being developed by other countries, as well as innovative organizational and financing techniques used by the FHWA's international counterparts.

INTERNATIONAL TECHNOLOGY SCANNING PROGRAM

The International Technology Scanning Program accesses and evaluates foreign technologies and innovations that could significantly benefit U.S. highway transportation systems. Access to foreign innovations is strengthened by U.S. participation in the technical committees of international highway organizations and through bilateral technical exchange agreements with selected nations. The program is undertaken cooperatives with the American Association of State Highway Transportation Officials and its Select Committee on International Activities, and the Transportation Research Board's National Highway Research Cooperative Program (Panel 20-36), the private sector, and academia.

Priority topic areas are jointly determined by the FHWA and its partners. Teams of specialists in the specific areas of expertise 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. Teams usually include Federal and State highway officials, private sector and industry association representatives, as well as members of the academic community.

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EXECUTIVE SUMMARY

Vehicular travel is increasing throughout the world, particularly in large urban areas. Accommodating the increased demand, while improving traffic safety, has led transportation officials to utilize a variety of innovative traffic control practices. These practices are used to control traffic movement and to provide road users with better information upon which to base travel decisions. By utilizing these practices, transportation professionals can operate the transportation system more efficiently and safely. In recent years, traffic engineers in the United States have implemented a number of practices to improve the overall quality of traffic flow. However, improved traffic control is a worldwide need and many countries have also implemented innovative traffic control practices. Recognizing the benefits that could result from an examination of international practices, a team of traffic engineers was formed to observe and document practices that might have value to U.S. practitioners. This scan team effort was jointly sponsored by the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the Transportation Research Board.

In May 1998, a team of ten U.S. traffic engineers traveled to Europe to observe innovative traffic control practices and identify those practices that could be implemented in the United States. The team members represented several different perspectives, including Federal, State, and local governments, and two research organizations. The team members are listed in appendix A. During a two-week period, the team visited with transportation officials in Gothenburg, Sweden; Frankfurt, Cologne, and Bonn, Germany; Paris, France; and London and Birmingham, England. These host officials presented information on a wide variety of traffic engineering and traffic control topics and the team observed many other interesting practices during the travel between visits. At the beginning, halfway, and end points of the trip, the team members met to discuss their observations and to identify those practices that might have implementation value in the United States. The team identified many noteworthy practices, several of which may have current or future value to transportation agencies in the United States.

The host officials presented information on a wide variety of traffic engineering and traffic control topics, and the team observed many other interesting practices during the travel between visits.

This report describes the findings and observations resulting from the scan trip. The information obtained from the trip is organized into five chapters (Traffic Control Devices, Freeway Control, Operational Practices, Information Management, and Administrative Practices). In each of these chapters, the material is organized into two categories: Primary Findings and Other Observations. The Primary Findings represent the material that the team feels has the greatest implementation value and/or that has significant benefits if implemented. The Other Observations represent other items that the team found interesting and which may also have potential implementation value in the United States. In some cases, the practices can be implemented with little or no change in current U.S. practices or standards. In other cases, implementation must follow research that addresses U.S. aspects related to a topic. The following sections of this summary describe the Primary Findings from each chapter and list the topics associated with the Other Observations. An introductory chapter precedes these five chapters and the team's recommendations are summarized in the last chapter. There are also several appendices that support the information in the report.

TRAFFIC CONTROL DEVICES

As the team traveled between and within countries, they had an opportunity to observe various European practices for traffic control devices. Many of these practices are significantly different from the equivalent U.S. practice, if one exists. The two that the team members believe would have the greatest potential value in the United States are the tiger tail marking used on freeway entrance and exit ramps and the all-white system of pavement markings used throughout Europe. These two practices are summarized below and described in detail in the Primary Findings section of chapter 2.

The tiger tail marking is an innovative pavement marking pattern that is used on multilane freeway entrance and exit ramps in England. The marking separates multiple lanes by using a wide painted buffer. The buffer separates the merge/diverge points of each lane, reducing turbulence and improving operations as traffic enters or leaves the mainline.

As the team traveled through Europe, there were very impressed by the quality of the pavement marking systems and the ability to communicate information to drivers through the use of only white markings. The Europeans use a wide variety of pavement marking patterns (line width, number of lines, line/gap ratio, etc.) to convey the necessary information to road users. They also use significantly more marking material than is commonly used in the United States. The team members feel that the European system of all-white markings could provide some benefits and deserves close examination to determine potential implementation value in the United States.

> Many European practices for traffic control devices are significantly different from the U.S. practice, if one exists.

The team also observed many other European practices related to traffic control devices. These practices include: countdown markers for exit ramps, more intensive sign colors, arrowhead shaped destination signs, internal sign illumination in urban areas, use of dotted sign border for trailblazing, variations in alphabet stroke width, horizontal signing, chevrons for vehicle spacing, colored pavements, raised crosswalks, flashing yellow on pedestrian clearance, audible pedestrian signals, worker visibility enhancements, vehicle visibility enhancements, work zone traffic control, freeway exit signs, and rotary intersections. These are described in more detail in the Other Observations section of chapter 2.

FREEWAY CONTROL

Many of the freeways (or motorways as they are known in Europe) in urban areas experience high levels of congestion. Practitioners in all four countries have implemented many different strategies for controlling traffic on these congested freeways. The three freeway control practices that the team members feel should be researched for possible implementation in the United States are variable speed control, lane control signals, and incident and queue detection and protection.

The three freeway control practices that the team members feel should be researched for possible implementation in the United States are variable speed control, lane control signals, and incident and queue detection and protection.

One of the most interesting observations of the trip was the extent to which the host countries use dynamic signs to present variable regulatory speed limits to drivers. Operating agencies were able to achieve considerable traffic flow and safety benefits on freeways by dynamically changing the speed limit based upon real-time traffic speed and flow data. The high level of compliance with these signs was attributed to the fact that the speeds reflect actual freeway conditions in real-time and the presence of photo speed enforcement on some freeways.

Lane control signals were also widely used on European freeways, most commonly in conjunction with dynamic message signs and variable speed limits. A signal is mounted above each lane to indicate traffic conditions downstream. These signals use red X, downward yellow diagonal arrow, and green down arrow indications to indicate that a lane is closed, closed ahead, or open, respectively.

Freeway queue detection and protection were observed in all four countries. Sensors (primarily loops) are placed in freeway mainlanes, and sometimes in the shoulder lanes, to identify when queues form and the location of the back of the queue. The operating agency uses this information to provide advance notice of the presence of a queue. The information presented to drivers may be an advisory speed, a speed limit, or a congestion warning message (symbol or words). Some of the response systems are fully automated. In some locations, another or additional form of queue protection is provided by placing incident response vehicles with flashing lights and/or dynamic message signs on the shoulder at the end of the queue. These vehicles back up as the queue proceeds upstream.

The team also observed many other European practices related to freeway control. These practices include the rolling freeway block and shoulder detection, and are described in more detail in the Other Observations section of chapter 3.

OPERATIONAL PRACTICES

Our European hosts informed the team of many unique and interesting operational practices that they utilize in their transportation systems to control traffic. The team members recommend research on two of those practices for possible implementation in the United States: intelligent speed adaption and self optimized traffic signal control.

Sweden has tested a system of intelligent speed adaption where drivers are alerted inside the vehicle when they are exceeding the posted speed. The system can also directly limit the vehicle's speed.

Team members recommend research on two European operational practices for possible implementation in the United States: intelligent speed adaption and self optimized traffic signal control.

An interesting traffic signal operational practice was presented by the Swedish officials. At isolated intersections, they are testing Self Optimized Signal Control (SOS) as a means to improve safety. SOS is a sophisticated system of detection and traffic signal controller logic which enables the change in right-of-way between opposing traffic movements to be made based on assessing and minimizing the safety risks for traffic on the approaches which will be stopped. It is a dilemma zone enhancement which translates stopping risks and cross street queue development to a cost algorithm.

The team also observed many other European practices related to operational practices. These practices include: use of historical loop data during loop failure conditions, innovative coordinated signal preemption strategies, automated speed enforcement, emergency phones, and elevated police patrol bays. These are described in more detail in the Other Observations section of chapter 4.

INFORMATION MANAGEMENT

The team members were impressed by the amount of information that European agencies provide to road users. They have placed a strong emphasis on presenting the information where drivers can best use it and in an easy-to-understand format.

Although the team members expected to see significant use of symbols, they were nonetheless impressed by the extent and success of symbol use. Symbols (or pictograms as they are more commonly termed in Europe) are widely used in variable message signs. Typical symbols that are presented in these signs include congestion, snow, danger, workers, and slippery pavement. Symbols are also widely used to indicate diversion routes. These diversion symbols are based on geometric shapes. When it is necessary to divert traffic from the freeway, variable message signs indicate the diversion symbol to follow. The symbol is presented at all decision points along the diversion route.

The team learned that freeway dynamic message signs are also used to provide drivers with travel time information. One of the most impressive examples of this practice was found on Paris freeways. There are over 200 dynamic message signs on the outer ring road freeway, its entrance ramps, and the inner ring road that provide real-time travel times to upcoming junctions. In a 1994 evaluation of this system, it was found that 65 percent of the motorists preferred travel time information over congestion information.

The team also observed many other European practices related to information management. These practices include: consistency in variable message signs, real time parking information, traffic information on FM radio, RDS-TMC, Tegaron, TrafficMaster,® MATTISSE, and private sector collection of traffic data for traveler information. European transport agencies are actively pursuing partnerships with the private sector, which includes the collection of traffic data. In several countries, private sector firms are allowed to install, operate, and maintain supplemental traffic detectors to enhance their own for-profit traffic information databases. These are described in more detail in the Other Observations section of chapter 5.

ADMINISTRATIVE PRACTICES

In addition to the benefits derived from discussion and observation related to traffic control practices, the team gained valuable insight into the administrative issues associated with operating a transportation system. The team found that European transportation officials place significant emphasis on "marketing" traffic engineering practices and improvements. One of the key observations of the team is that several of the countries use safety benefits and improved emergency services incident response times instead of improved operations or congestion reduction as primary justification for transportation programs when presenting them to policy makers and elected officials. This was particularly true for the heavily congested freeways and highways.

The team found that European transportation officials place significant emphasis on "marketing" traffic engineering practices and improvements.

The most prominent examples of the safety emphasis were found in Sweden. The Swedish government has adopted a safety strategy known as "Vision Zero." The objective of this strategy is to eliminate fatalities on Swedish highways. An example of the emphasis on business practices was found in England, where transportation improvements are evaluated using a "Value for Money" concept. Each improvement is carefully assessed with respect to expenditures and expected benefits.

Several of the interesting concepts identified by the team related to the effort to reintegrate Telematics (ITS) into the existing organizational structure and transportation system. This concept has been initiated to ensure that the utilization of technology is inherent within the traditional organizational components and more readily assimilated within the political, customer, and organizational arenas as a critical component of long-term transportation solutions.

The European emphasis on customer service was best exemplified in a French private sector toll facility. The facility reflected a quality product in terms of infrastructure, and demonstrated that construction, operation, and maintenance standards were actually being exceeded to promote the future acceptance and expansion for these types of facilities. The team was also very impressed with the administrative commitment to transportation research in several countries and the ability to manage high-speed freeways in a safe and efficient manner.

RECOMMENDATIONS

The members of the scan team were privileged to travel to four European countries and see firsthand many outstanding traffic control and traffic engineering practices. Following the meetings with the host countries, the team members met to review the findings from the trip and identify those practices which have the greatest potential for successful implementation in the United States. The practices described as Primary Findings represent the team's recommendations for practices that should receive strong consideration for implementation in the United States. In some cases, the practices can be implemented with little or no change in current U.S. practices or standards. In other cases, implementation must follow research that addresses U.S. aspects related to a topic. Team members have developed several problem statements to initiate the process of conducting that research. Team members have also begun the process of presenting the trip findings to various professional audiences. The implementation of the various traffic control practices will ensure our citizens receive the maximum benefit of innovative traffic controls to save lives, enhance operational efficiency, and improve the movement of traffic in the United States.

chapter one
INTRODUCTION

Vehicular travel is increasing throughout the world, particularly in large urban areas. Accommodating the increased demand has led transportation officials to utilize a variety of innovative traffic control practices. These practices are used to control traffic movement and to provide road users with better information upon which to base travel decisions. By utilizing these practices, transportation professionals can operate the transportation system more efficiently and safely. In recent years, traffic engineers in the United States have implemented a number of practices to improve the overall quality of traffic flow. However, the need for improved traffic control is a worldwide need and many countries have also implemented innovative traffic control practices. Recognizing the benefits that could result from an examination of international practices, a team of traffic engineers was formed to observe and document practices that might have value to U.S. practitioners. In May 1998, the team traveled to four European countries (Sweden, Germany, France, and England) to observe innovative traffic control practices and identify those practices that could be implemented in the United States. This report describes the findings and observations of that group and includes recommendations of practices that have potential implementation value in the United States.

TRIP PLANNING

Several years ago, the Federal Highway Administration (FHWA), in coordination with the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board (TRB), began sending teams of transportation officials to various countries to observe and document various practices. The basic concept of these “scan trips” is to identify technologies and/or practices that might have immediate or near-term implementation value in the United States. The cost of sending a team to one or more countries and documenting their findings in a report is significantly less than the cost of researching the technology or practice in the United States and preparing the appropriate documentation. In addition, the team has the benefit of observing firsthand how a technology or practice is utilized in a real-world setting.

A scan trip begins with FHWA identifying the need to observe international practices in a particular field. A team of experts in that field is created and meets to plan the key aspects of the trip and develop a series of “amplifying questions” that are submitted to the host countries. During the trip, team members meet as a group with representatives of various organizations in each host country. The hosting organizations are generally determined by the host country on the basis of the amplifying questions. At various times during the trip, the team members meet to clarify their observations and begin developing the team’s recommendations. Upon their return, the team prepares a report describing their observations and recommendations. Throughout the entire effort, the team’s activities are guided by an FHWA contractor, who is responsible for the pre-trip communications with the host countries and the logistical aspects of the trip.

Trip Objective

The basic objective that FHWA established for this trip was to identify, discuss, and document innovative traffic control (ITC) technologies, devices, and practices in four European countries that are already implemented or that will be in the near future (approximately 2 years). As such, the team was less interested in current research on future technologies. The study team's primary emphasis was on implementation, but they were also interested in planning, installation, operation, maintenance, and financing as it relates to innovative traffic control. In gaining an understanding of these innovative traffic control systems and technologies, the team hoped to identify both the similarities and differences between European and U.S. transportation systems that might affect implementation of innovative traffic control technologies. The team also wanted to identify problems associated with implementing the innovative technologies and systems and the role(s) that non-government, private entities had in both implementing and operating innovative traffic control systems. Finally, the team wanted to observe firsthand these systems and technologies in operation and obtain information that assesses the effectiveness of these systems and technologies.

Team Members

The team members represented several different perspectives including the Federal Highway Administration (Washington, D.C. and regional offices), three State departments of transportation (Utah, Virginia, and Wisconsin), a local transportation agency (Montgomery County, Maryland), and two research organizations (Transportation Research Board and Texas Transportation Institute). Appendix A lists the team members, along with their affiliations and a short biography. Figure 1 shows the team members during their visit to Sweden.

Figure 1. Team members. (From left to right) Ed Fischer, Lynwood Butner, Scott Wainwright, Pete Rush, Linda Brown, Mark Kehrli, Rich Cunard, Sam Tignor, Sterling Davis, and Gene Hawkins.

Meetings

The team members met four times during the course of the trip development and the actual travel. These meetings are listed in table 1. The first meeting provided an opportunity to define the areas of greatest interest and prepare a series of amplifying questions that the host countries could use to develop the program of presentations.

Table 1. ITC team meetings.

LOCATION	DATE AND TIME FRAME	PURPOSE
Washington, D.C. area	January 6, 1998 (four months before trip)	Determine emphasis areas and develop amplifying questions
Gothenburg, Sweden	May 3, 1998 (beginning of trip)	Plan trip actions and emphasis areas
Paris, France	May 10, 1998 (middle of trip)	Review findings
London, England	May 16, 1998 (end of trip)	Identify key findings and develop preliminary team recommendations

The other three meetings were held during the trip. The first meeting, held the day before the first visit with hosting officials, provided a chance to review the objectives of the trip and the agendas prepared by the hosting countries. Halfway through the trip, the team met to discuss the first week's findings and observations. Figure 1 shows the team members participating in this meeting. The team also met on the last day of the trip to discuss the second week's findings and observations and to decide upon the team's recommendations for implementation.

Questions

In order to provide our European hosts with a better understanding of the issues, technologies, and devices of greatest interest, the team prepared a series of amplifying questions that focused on six major topics (traffic control device systems, real-time traffic control, safety aspects, very high speeds, visibility and lighting, and administrative issues). Each topic included specific questions that were intended to provide the team with a better understanding of European application of the innovative technologies and systems. The amplifying questions developed by the team as a result of the pre-trip meeting are listed in appendix B.

Trip Itinerary

The trip took place in the first two weeks of May 1998. Table 1 lists the countries and associated cities visited during the trip. Appendix C lists the officials that the team met with during the trip. These host officials presented information on a wide variety of traffic engineering and traffic control topics and the team observed many other interesting practices during the travel between visits.

Figure 2. Mid-trip team meeting.

Table 2. Cities and countries visited.

DATES[1]	COUNTRIES	CITIES
May 4-5, 1998	Sweden	Gothenberg
May 6-8, 1998	Germany	Frankfurt Köln Bonn
May 11-12, 1998	France	Paris
May 14-15, 1998	England[2]	London Birmingham

Note: [1]Only the dates on which the team members met with hosting officials are listed. This does not include travel days and weekend team meetings. [2]Information obtained from the Department of Transport in the United Kingdom pertained exclusively to England. Roads in Scotland, Wales, and Northern Ireland are operated and maintained by separate agencies.

REPORT ORGANIZATION

During the course of the trip, the team identified many noteworthy practices, several of which are felt to have current or future value to transportation agencies in the United States. This report presents this information in five chapters. Within each chapter, the information is divided into two categories: Primary Findings and Other

Observations. The Primary Findings represent those items that the team members feel have the greatest implementation value and/or which have significant benefits if implemented. The Other Observations are those items that the team found interesting and which may have some implementation value to U.S. practitioners.

AMERICAN–EUROPEAN CONTRASTS

As the team members traveled throughout the four countries, they were continually educated on some of the significant difference between the United States and the European countries visited. These differences were evident in many different areas, including cultural, language (both common and technical), and engineering practices. While the engineering differences were the focus of the trip, the other differences impacted the gathering of information and will also impact the ability of U.S. practitioners to implement promising technologies and practices.

Cultural Contrasts

During their travels through Europe, the team members were able to experience many different aspects of the countries that they visited. While the focus of the trip was on innovative traffic control, team members had the pleasure of experiencing the people and facilities in each country. As they traveled on planes, trains, subways, buses, taxis, and boats; and interacted with the people in each country, the team members were able to observe firsthand many significant cultural characteristics in the four countries they visited. As they did so, they were able to contrast these characteristics with those of the United States. Many of these cultural characteristics represent nothing more than a different way of living and give each area its unique identity. However, the team members feel that some of these cultural characteristics have a direct impact on the transportation systems in each country.

Probably the most significant cultural characteristic affecting the transportation system is the widespread use and support of public and multimodal transportation. While there were significant volumes of vehicular traffic in all of the countries, Europeans are not as reliant on the automobile as Americans. This factor was an important consideration when the team members began to evaluate innovative traffic control practices for potential implementation in the United States. The preservation of urban areas is also important to Europeans. Many European cities are much older than their U.S. counterpoints. Five-hundred-year-old cities are not at all unusual. As a result, the Europeans have a very strong sense of history and the preservation of that history. Europeans also appear to have a generally greater respect for authority than Americans. This leads to higher compliance with traffic control regulation and devices. In many cases, the team identified practices that were innovative or unique, but which have limited application in the United States due to the basic differences in the transportation systems of the United States and Europe.

Language Contrasts

The team members were continually amazed by the ability of their hosts to communicate with the team members in English. The majority of individuals that the team met with were fluent in English. Even so, there are numerous terms, both common and technical, that the team had to learn. A few of the most common

European terms are listed below, followed in parentheses by the U.S. equivalent and the European areas where the terms are used, if applicable.

- Motorway (freeway, all countries)
- Lorry (truck, England)
- Coach (bus, England)
- Carriageway (travelway or paved roadway, England)
- Dual carriageway (divided highway, England)
- Petrol (gasoline, all countries)
- Hard shoulder (paved shoulder, England)
- Vertical signs (post-mounted signs, all countries)
- Horizontal signs (pavement markings, all countries)
- Signal stage (signal phase, all countries)
- Telematics (ITS, Intelligent Transportation Systems)

Engineering Contrasts

The team was very impressed with the high level of experience, technical talent, and professionalism we found in our visits and travels in each of the four countries. It was obvious that their engineers have had many of years of experience in designing solutions and managing traffic operational problems in cities and rural areas on all classes of roadways. The team found their solutions practical, effective, and, more often than not, new and creative. The European engineers are probably utilizing new technologies faster than many of their U.S. counterparts. European transportation agencies appear to be more progressive in testing and implementing new technologies and applications of traffic control devices than in the United States. The difference may be in large part due to the aggressive and progressive research programs which the individual countries have, and that they are, in fact, acting as individual entities in many of the applications they do implement. Many of the solutions we observed on freeways are certainly more advanced than are used on U.S. freeways. Examples include: variable speed limits with photo enforcement; rolling freeway blocks by enforcement personnel to aid incident clearance; greater use of pavement markings to supplement driver guidance; dedicated freeway traffic enforcement with vividly marked enforcement vehicles; lane control systems which are operated in real-time to balance variable traffic demands in the merging areas of major joining routes; and the ability to respond to freeway incidents quickly.

Overall, the team found the use of telematics or ITS solutions more readily accepted by European engineers and departments than in the United States. In Sweden, for example, the engineers integrate an ITS solution directly into their operations and do not call special attention to its use. They find that when they include it as a regular traffic engineering tool, these approaches are less likely to be questioned for budgetary or other non-technical reasons. They essentially have embraced telematic solutions for enhancing both safety and operations.

And one of the greatest engineering contrasts between European countries and the United States is the integration of the different modes of transportation. Transportation is designed as an integrated system made up of different modes for the purpose of serving the traveler–the customer. In the United States, while we are doing more of this today than we did 20 years ago, we are no where near the level of modal integration found in any of the four countries visited.

Chapter Two

TRAFFIC CONTROL DEVICES

During their trip to the four European countries, the team members found many traffic engineering practices that were different from equivalent U.S. practices. Among the most obvious and visible were the system of traffic control devices used in Europe. There is a significant amount of uniformity among traffic control devices used in the four European countries visited by the team.

The team members observed two traffic control device system practices that they felt may have implementation value in the United States. These items include all-white pavement markings and the tiger tail freeway entrance ramp markings. They are described in the Primary Findings section. The team also observed many other practices which are worth noting to U.S. practitioners. These practices are described in the Other Observations section and are classified as signs, markings, signals, pedestrian treatments, and work zones.

PRIMARY FINDINGS

With respect to the traffic control devices, the team members identified two pavement marking practices that they recommend for evaluation in the United States: "tiger tail" markings for freeway entrance and exit ramps and an all-white system of pavement markings.

Tiger Tail

In England, the team found that the Highways Agency has created a special pavement marking pattern for freeway entrance and exit ramps.[1] This marking, known as the "tiger tail" or "anti-swooping" marking, separates two entrance ramp lanes by using a wide painted buffer between the two lanes. As a result, the merge location for each lane is separated, as is the turbulence due to the two entering maneuvers. Although this treatment requires a wider and longer entrance ramp than a side-by-side, two-lane ramp, it increases capacity and reduces conflicts. Figure 3 illustrates several applications of tiger tail markings on entrance ramps in England.

Tiger tail markings have also been implemented on freeway exit ramps in England. Evaluations of these markings have found they result in smoother traffic flow, less driver stress, and increased exit capacity, all due to a decrease in the number of erratic gore maneuvers. Figure 4 illustrates a before and after photo of exit ramp markings.

Figure 3. Tiger tail pavement markings on entrance ramps to English freeways.

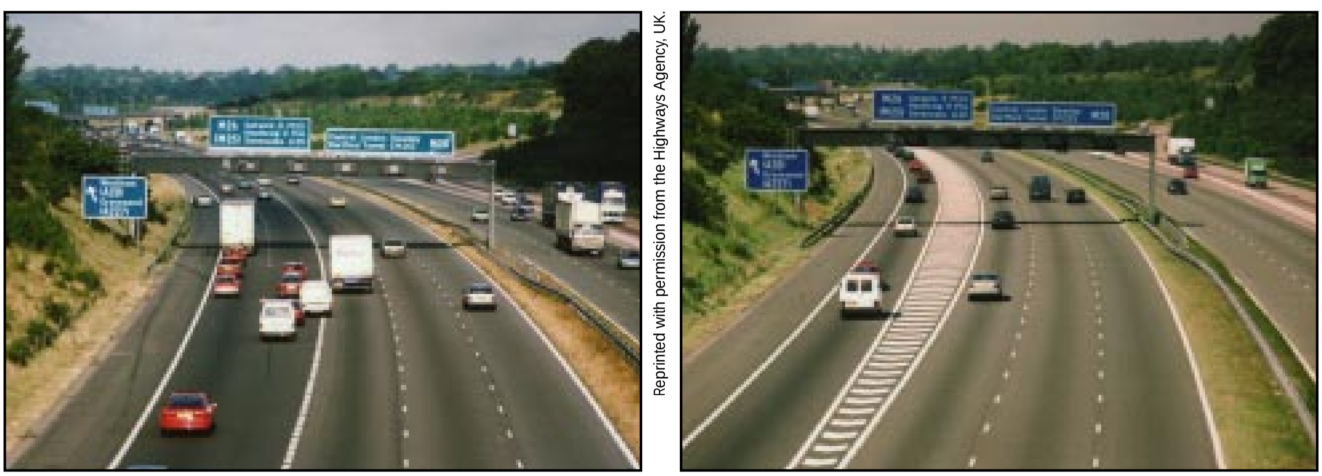

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Figure 4. Before-and-after application of tiger tail marking on exit ramp.

All-White Pavement Markings

One of the most striking differences between the United States and the four European countries is the lack of yellow pavement markings for centerline and left edgelines in Europe. Each of the countries visited used a primarily all-white system of pavement markings, including applications for separating opposing traffic. While other colors were used on a limited basis, the team found considerable advantages in how white markings were used.

In Europe, white lines are used to separate opposing directions of traffic. However, individual application and meaning were not totally consistent between the countries. Some of the white centerline applications included a double white line, a single white line, and a single wide broken line. Differences in stripe/gap ratios were also observed between centerlines and lane lines. In France, the team also observed that short skip lines were used to mark the end of a no passing zone. The short skip lines were complemented with small curved arrows which directed passers to return to their side of the road. Figures 5 through 22 illustrate various applications of white pavement markings.

Other applications of white pavement markings we observed include:

- The separation of traffic lanes in the same direction.
- Use of dotted edge line carried across entrance and exit ramp (see figures 8, 11, 20)
- Double-lines for parking prohibition.
- Parking spaces.
- Marking of pedestrian crosswalks.
- Island designation.
- The marking of lane lines through intersection (the intersection of the lane lines appear as + symbols in figure 22).
- Short and closely spaced dashed lanes to show how the main motorway lanes are carried through the interchange and separated from the beginning of the on-ramp lane and end of the off-ramp.

The team found that yellow marking applications were used on a limited basis. In work zones in France and Germany, yellow markings are used to indicate travel paths. The yellow markings are placed on top of the white markings, which are not removed during the work zone activity. Figures 23 through 25 illustrate this use of yellow markings. In London, a yellow crosshatch within the intersection indicates where vehicles are not permitted to queue. This is shown in figure 26. Yellow markings are also used to denote curbside parking restrictions.

Figure 5. Edge line in Lundby Tunnel, Sweden.

Figure 6. Airport markings near Frankfurt, Germany.

Figure 7. Intersection markings, France.

Figure 8. Markings on rural freeway, France. (Note edge line marking carried across ramp.)

Figure 9. Markings on freeway exit ramp, France.

Figure 10. Markings on rural freeway, France.

Figure 11. Markings for exit ramp on rural freeway, France. (Note edge line marking carried across ramp.)

Figure 12. Markings for rural highway, France.

Figure 13. Markings for rural intersection, France.

Figure 14. Markings on rural freeway, France.

Figure 15. Markings for rural highway, France.

Figure 16. Demarcation of passing/no passing zone, France.

Figure 17. Photo 1 – Approach to rural intersection with no passing zone, France.

Figure 18. Photo 2 – Approach to rural intersection with no passing zone, France.

Figure 19. Photo 3 – Approach to rural intersection with no passing zone, France.

Figure 20. Photo 4 – Approach to rural intersection with no passing zone, France.

Figure 21. Approach to rural intersection with countdown markers, England.

Figure 22. Lane line extensions carried through intersection (both directions), Germany.

Figure 23. Yellow markings in work zone, Germany.

Figure 24. Yellow markings in work zone, Germany.

Figure 25. Yellow markings in work zone, Germany.

Figure 26. Crosshatch in intersection, England.

OTHER OBSERVATIONS

In addition to the Primary Findings described above, the team members identified many other traffic control device practices that U.S. practitioners might be interested in learning about. These are described in the following pages within five major categories: signs, markings, pedestrian treatments, work zone visibility, and rotary intersections as shown in table 3.

Signs

There are significant differences in the signing systems of the United States and Europe. Round white signs with a red border indicate a prohibition or a mandatory action. Round blue signs with a white legend indicate a mandatory requirement. Warning signs are white triangles with a red border. Freeway (motorway) guide signs are typically blue, while guide signs for conventional highways are typically green. There are some variations in the use of color in the guide signs in different countries.

One basic difference in the systems between the four countries is that Sweden uses yellow instead of white in its prohibitive, mandatory, and warning signs.

Table 3. Other observations for traffic control devices.

MAJOR CATEGORIES	TRAFFIC CONTROL OBSERVATION	PAGE
Signs	Countdown Markers for Exit Ramps More Intensive Sign Colors Arrowhead Shaped Destination Signs Internally Illuminated Signs Use of Dotted Border for Trailblazing Guide Sign Sheeting Types Variations in Alphabet Stroke Width Freeway Exit Direction Signs	16 18 19 20 20 20 21 22
Markings	Horizontal Signing Chevrons for Vehicle Spacing Colored Pavements	24 26 27
Pedestrian Treatments	Raised Crosswalks Flashing Yellow on Pedestrian Clearance Audible Pedestrian Signals Advance Pedestrian Pavement Markings	27 28 29 29
Work Zone Visibility	Worker Visibility Enhancements Vehicle Visibility Enhancements Work Zone Traffic Control	29 30 30
Rotary Intersections		33

Countdown Markers for Exit Ramps

In all four countries, countdown markers are used in advance of exit ramps to inform road users of the presence of and distance to the exit. The first panel observed was placed 300 meters in advance of the exit, was set in the shoulder, and had three closely spaced white diagonal stripes. The second panel was placed 200 meters in advance of the exit, was set in the shoulder, and had two closely spaced white diagonal stripes. The third (and last) panel was placed 100 meters in advance of the exit, was set in the shoulder, and had one white diagonal stripe. In some countries, the distances (300 m, 200 m, and 100 m) were also shown within the marker. In England, the markers were placed at 300, 200, and 100 yards from the ramp. These markers seem to give the road user a more comfortable feeling about the location of the next exit. On freeways, the markers used white lines on a blue background. Figure 27 illustrates the use of countdown markers on a German freeway. The vertical panels along the edge of the travelway are not related to the countdown markers.

Figure 27. Countdown markers for exit ramp, Germany.

More Intensive Sign Colors

In observing the traffic signs in the four countries, the team members felt that some of the sign colors appeared to be more intense than those used in the United States. Figure 28 compares the xy color boxes from the most common U.S. sign sheeting standard with one of the European standards.[2,3] As this figure shows, the European boxes are tighter than the U.S. boxes and there is greater separation between the colors in the yellow-orange-red portion of the spectrum. Another sign color difference is that England uses a darker green (referred to as "Worboy green") for its guide signs.

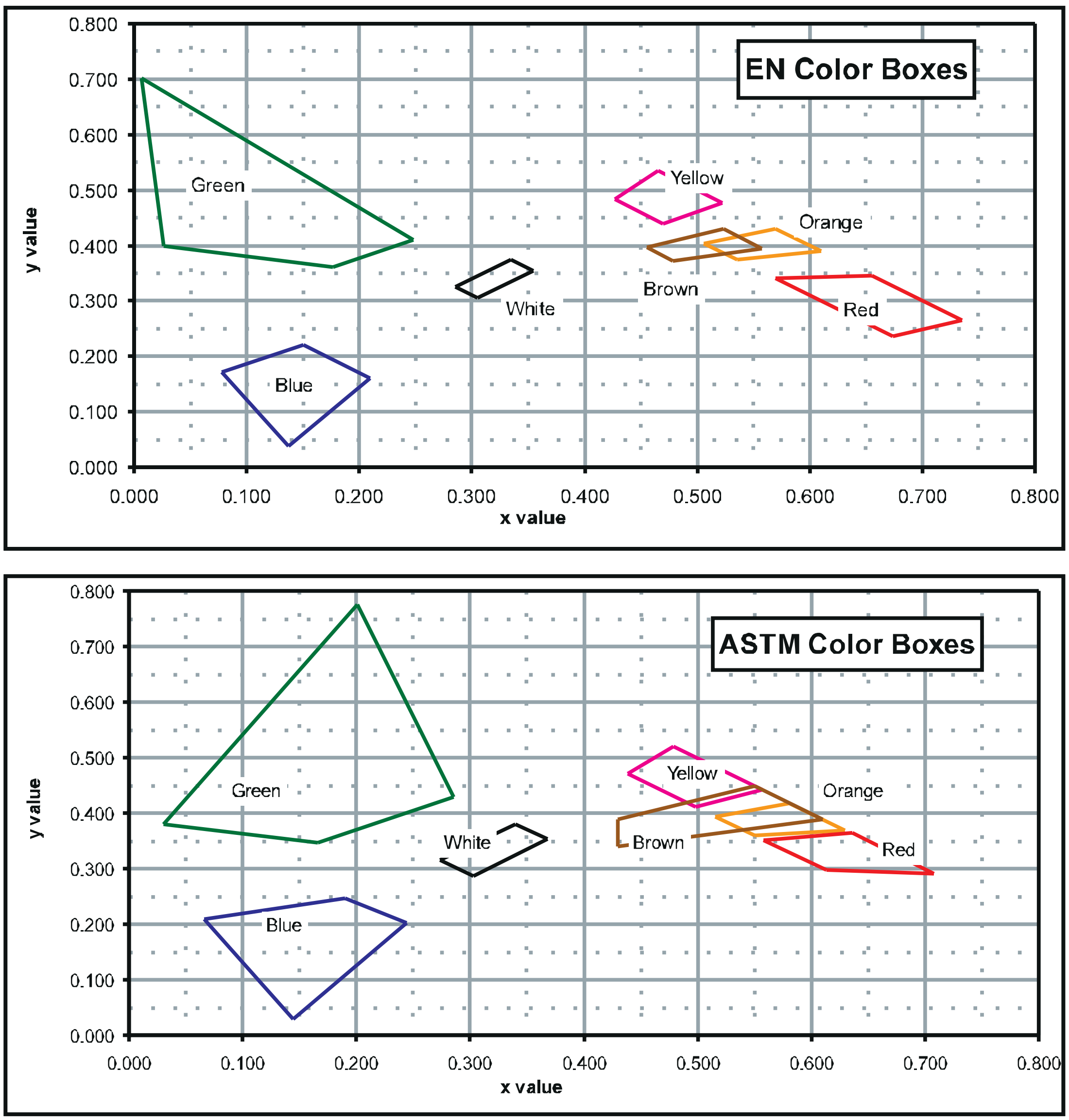

Figure 28. Comparison of xy color plots for U.S. and Europe.

Arrowhead Shaped Destination Signs

Throughout Europe, team members observed directional signs that use an arrow shape to emphasize the directional information presented in the sign. The signs are a rectangular shape, with an arrow point much like the end of a crayon, and point in the direction of the destination named on the sign. These arrow shaped signs were observed in single and stacked installations. The primary effect of these signs is that they may give more advanced recognition of the direction of the destination than provided by a true rectangular sign.

Figure 29. Arrow shaped sign at exit ramp gore, Germany.

Figure 30. Arrow shaped sign, England.

Figure 31. Arrow shaped signs at rotary intersection, France.

Figure 32. Arrow shaped signs mounted on backboard, England.

Figure 33. Use of dotted border (for E45) in sign, Sweden.

Figure 34. Use of parenthesis in sign, England.

Figure 35. Use of parenthesis (for A41) in pavement markings, England.

Internal Sign Illumination

In all four countries, extensive use is made of internally illuminated regulatory, warning, and guide signs on conventional roads and streets in urban areas. These types of signs provide excellent target value at night, especially when ambient commercial lighting and advertising signs compete for drivers' attention. The team members found these signs to be effective in increasing the conspicuity of the signs and messages. Due to the high costs and electrical energy consumption, some of the countries are considering reducing the use of internal illumination in favor of brighter retroreflective sheeting.

Use of Dotted Border for Trailblazing

The team observed several locations where dotted borders or parenthesis were used with a route number to indicate a road that connects to the indicated route (a TO or trailblazer message). The practice is usually applied at freeway exit lanes. The benefit of this practice is that it de-emphasizes the number of the connector route in order to emphasize the route of greater importance. In England, a parenthesis is used to indicate the same TO message. Figures 33 through 35 illustrate the application of this practice in signs and pavement markings.

Guide Sign Sheeting Types

In Germany, the team members had some extended discussion with their hosts about the use of retroreflective material in guide signs. The current German practice is to use a high intensity legend on a high intensity background for ground-mounted signs. Overhead signs currently use a high intensity legend on an engineering grade background with sign illumination.

For their ground-mounted guide signs, the Germans are changing to an engineering grade background, while keeping high intensity as the legend material. One of the factors supporting the change is that they feel this will result in an immediate and long-term cost savings. More importantly though, their research indicates that, due to a better contrast ratio, the legibility of ground-mounted signs is improved by using a high intensity legend on an engineering grade background.

For the overhead guide signs, the Germans are eliminating sign illumination and using super high intensity microprismatic sheeting (Diamond Grade™) for both the legend and background. Their research indicates that the legibility of their overhead signs will not be compromised, even with the low cut-off of European vehicle headlights. A key factor supporting this change is the continual need for maintenance and the operational costs of the sign lighting used with their current overhead guide signs.

Variations in Alphabet Stroke Width

Throughout their travels, the team members found that countries use sign alphabets that are different from those used in the U.S. While there appears to be some differences between the alphabets used in each country, the alphabet used in England appears fairly typical of those observed in each country.

The MUTCD equivalent in England is The Traffic Signs Regulations and General Directions document.[(4)] This document identifies two primary alphabets for highways signs, one for positive contrast signs (light legend on a dark background) and one for negative contrast signs (dark legend on a light background). A separate document refers to these alphabets as the Transport Medium alphabet for positive contrast signs and the Transport Bold alphabet for negative contrast signs. There are also two other alphabets that are used on a more limited basis: Motorway White for white legend on a blue background and Motorway Black for black legend on a yellow background. Both of these alphabets consist of numbers and a limited number of letters (mostly compass directions).

The interesting aspect of the British alphabets is that the Transport Medium alphabet (for white letter on a green, blue, brown, or black background) has a narrower stroke width than the Transport Bold alphabet (for a black letter on a white or yellow background). It should be noted that the green in British guide signs is much darker than the green in U.S. guide signs. Since the performance characteristics of positive and negative contrast signs are different, the use of different alphabets for each is logical and is a feature absent from U.S. signs. Table 4 compares key letters from these two alphabets to the U.S. Series E (Modified) alphabet.

Table 4. Comparison of British and U.S. alphabets.

U.S. SERIES E (MODIFIED)	BRITISH TRANSPORT HEAVY	BRITISH TRANSPORT MEDIUM
A C E G O P S	A C E G O P S	A C E G O P S
a e g h m p s t y	a e g h m p s t y	a e g h m p s t y

Freeway Exit Direction Signs

As they traveled on the freeways in each country, the team members observed several different designs and layouts in freeway guide signs. In general, these signs are blue. Ground-mounted signs were mostly, but not always, vertical rectangles, while overhead signs were horizontal rectangles. These signs often used a combination of word legends and diagrammatic arrows to indicate directional information to the road user. Figures 36 through 44 illustrate several different applications of freeway exit direction signs.

Figure 36. Freeway exit direction sign, Sweden.

Figure 37. Freeway exit direction sign, Sweden.

Figure 38. Freeway exit direction sign, Germany.

Figure 39. Freeway exit direction sign, Germany.

Figure 40. Freeway exit direction sign, Germany.

Figure 41. Freeway exit direction sign, France.

Figure 42. Freeway exit direction sign, France.

Figure 43. Freeway exit direction sign, England.
(Note countdown marker)

Figure 44. Freeway exit direction sign, England.
(Note lane control signals over right two lanes)

Markings

In addition to the pavement marking aspects of the Primary Findings described at the beginning of this chapter, team members were impressed by many other pavement marking applications that are not used in the United States. These include horizontal signing (essentially specialized pavement markings), colored pavements, and chevron markings for vehicle spacing.

Horizontal Signing

The team members found that all of the countries visited use pavement markings to provide or enhance a wide variety of information for road users. These markings can take the form of symbols or words on the pavement. This information often supplements information presented in other types of traffic control devices. This practice is known as horizontal signing, and European traffic engineers feel very strongly that the redundancy provided by horizontal signing applications is a very important element of attaining and improving both efficiency and safety for road users. England uses this concept quite liberally in addition to providing redundant or dual messages in many warning and regulatory sign applications. The team members observed that the European practice of horizontal signing provides road users with a significantly greater amount of information than is provided by pavement markings in the United States. In addition, the information provided by pavement markings is always directly in the driver's line-of-sight, which is a safety benefit. This is particularly useful to drivers in moderate to heavy traffic.

Some of the most prominent examples of the horizontal signing that the team observed are listed below. Figures 45 through 54 illustrate a few of these applications. Many horizontal signing applications are also illustrated in other figures in this chapter.

- Highway numbers, with arrows where necessary, at intersections and on off-ramps leading to the highways where two or more highways converge/diverge.
- Stop and Yield markings on the approaches to intersections, roundabouts, and pedestrian crossings.
- Markings indicating traffic or parking prohibitions.
- Bus lane markings.
- School markings.
- Lane markings carried through intersections.
- Dotted edge lines through exit and entrance ramps at interchanges. This concept was universal in all the countries visited, and often the markings were wider than the normal edgeline.

Figure 45. Highway numbers in lanes, England.

Figure 46. Highway numbers in lanes, England.

Figure 47. Highway numbers and destination names in lanes, England.

Figure 48. Stop marking, England.

Figure 49. Yield pavement markings, Sweden.

Figure 50. Bus lane marking, Sweden.

Figure 51. Intersection directional and crossing markings, Sweden.

Figure 52. Intersection marking, England.

Figure 53. Bike marking, France.

Figure 54. Abbreviated markings carried through intersection, Germany.

Chevrons for Vehicle Spacing

In England, transportation officials have placed chevron markings in traffic lanes to indicate the proper spacing between vehicles. The chevrons are placed 40 meters apart. The sign shown in Figure 55 informs drivers to keep two chevrons between them and the vehicle in front. Evaluations found the following benefits:

- A reduction of about 15 percent of drivers "close-following."
- Fewer accidents as driver awareness increased over the site.

Reprinted with permission from the Highways Agency, UK.

Figure 55. Chevron marking sign, England.

- Fifty-six percent fewer injury accidents.
- Eighty-nine percent fewer single vehicle accidents.
- Forty percent fewer multiple vehicle accidents.
- $1.2 million accident savings (1993 prices).
- The effect can last at least 18 km.
- Benefits are 80 times the installation cost.

Colored Pavements

Pavement surface coloring was observed in France and England to indicate lanes for specific classes of vehicles. In London, a red pavement surface was used to indicate a bus only lane. In France, a light green marking was used to indicate where a bike lane intersected with a traffic lane at a rotary intersection. These applications are illustrated in figures 56 and 57.

Figure 56. Bus lane colored pavement, England.

Figure 57. Green pavement where bike lane intersects vehicle lane, France.

Pedestrian Treatments

Throughout the four countries visited, the team members observed much higher degree of pedestrian traffic than is found in equivalent U.S. situations. In part, this can be attributed to the greater use of public transportation in Europe than in the United States, and the resulting pedestrian traffic from the public transportation stop to the destination. The European countries have developed several interesting treatments for addressing pedestrian-vehicle conflicts.

Raised Crosswalks

In all four countries visited, raised crosswalks were observed at various locations, in residential areas as well as commercial districts. A raised crosswalk is basically a flat-top style speed hump with a marked crosswalk on the plateau portion of the hump. Figure 58 illustrates a raised crosswalk in Gothenburg. The purpose of a raised crosswalk is three-fold: to enhance the visibility of the crosswalk (and pedestrians who are crossing), to reduce the speed of vehicles as they approach the crosswalk, and to increase the chances of an approaching driver deciding to stop for a pedestrian in the crosswalk.

Figure 58. Raised crosswalk, Sweden.

The safety improvement for pedestrians, especially at mid-block crosswalks, is impressive. A City of Gothenburg publication indicates that, "*At a normal crossing, only about 8 percent of the drivers stop for a waiting pedestrian. This figure is around 30 percent at raised crosswalks. The far stronger tendency of drivers to stop at raised crosswalks is related to their having slowed down so much before the hump anyway. Then the loss of speed and time feels less bothersome when they stop [for the pedestrian]. And the lower speed means that the driver and pedestrians have more mutual contact, so it becomes embarrassing to drive past as if nothing were happening. Lower speed is the most effective measure to prevent accidents. If a pedestrian is run over at 50 km/hr (30 mph) the risk of death is 50 percent. But if the driver keeps to 30 km/hr (18 mph) the risk decreases to around 5 percent.*" (5)

Flashing Yellow on Pedestrian Clearance

At some mid-block signalized pedestrian crossings in England, an unusual signal operation and display is used to reduce vehicular delays. For the pedestrian, the operation is no different than a standard mid-block pedestrian signal in that the pedestrian pushes the button, waits for the "walk" signal to be displayed, and crosses the street while the "walk" and its associated pedestrian clearance interval are timed. In the normal mid-block pedestrian signal operation, traffic on the street has a circular red signal display throughout the time that the pedestrian "walk" and pedestrian clearance intervals are being provided. In this unusual operation in England, the normal operation and display for traffic on the street is modified. A circular red is displayed to traffic on the street during the "walk" interval but then it changes to a flashing yellow display during the pedestrian clearance interval. Green is displayed upon conclusion of the pedestrian clearance interval.

The advantage of this operation is that it reduces unnecessary delays by allowing vehicular traffic to legally proceed (with caution) on the flashing yellow when there is no conflict with pedestrians. This occurs when:

- All pedestrians crossing in a given cycle are crossing in only one direction across the road. After they have crossed halfway, there is no conflict with traffic that will be driving over the half of the crosswalk they are no longer occupying, so traffic in that one direction can proceed.

- If the pedestrians crossing in any given signal cycle are fast walkers or they have run across the road, vehicular traffic does not have to wait on red while the unnecessarily long (in this case) pedestrian clearance interval times out.

The disadvantage of this operation is that overly aggressive drivers may start to move too soon or may have "close calls" with pedestrians who may not have completely finished crossing.

Audible Pedestrian Signals

In some cities in Europe, there are combination sight and sound indications provided at crosswalks. These combined visual and audible indications let pedestrians know when to walk in the crosswalk and give consideration to both visual and hearing impaired individuals. Different sounds are used in the different countries.

Advance Pedestrian Pavement Markings

In England, the team members observed a unique means of informing drivers that they are approaching a pedestrian crossing. These zig-zag markings, shown in figure 59, provide more warning of the crosswalk than do the crosswalk markings alone.

Figure 59. Markings on approach to pedestrian crossing, England.

Work Zone Visibility

During their travels between countries and between meeting locations within the countries, the team members passed through and observed several work zones. Work zone issues were also the subject of some discussions with the hosts. In general, the team observed that Europeans use few traffic control devices in work zones, but that they employ several visibility enhancing treatments. These treatments include worker visibility enhancements, vehicle visibility enhancements, and work zone traffic control devices.

One of the most noticeable differences with the United States is the lack of orange. In Europe, yellow is used for work zone signing and markings. The use of yellow for work zone pavement markings in Germany and France is discussed and illustrated in the "all-white" section of this chapter (see page 11).

Worker Visibility Enhancements

In their travels and discussions, the team members found that the transportation agencies visited have made significant strides toward increasing the visibility of workers, vehicles, and devices in work zones. Worker visibility was strongly emphasized. Team members learned that Swedish law requires anyone working on a road to wear a high visibility vest or jacket. Violators can be cited and fined by the police. Furthermore, their high visibility clothing is more visible than the orange vest typically used in the United States. Figure 60 illustrates one of these garments, which

Figure 60. Worker vest, Sweden.

Figure 61. Worker vests, France.

is strong yellow-green in the torso area, orange in the sleeves and sides, and dark blue on the shoulders. There are also silver retroreflective stripes around the sleeves and torso. This combination of high visibility colors ensures that a worker will stand out against any color of background. In the other countries, high visibility vests tended to be predominately strong yellow-green, as shown in figure 61.

Vehicle Visibility Enhancements

The team found that many of the transportation agencies place significant emphasis on the visibility of work zone and maintenance vehicles. Figures 63 through 65 illustrate several of these visibility enhancing vehicle treatments. Although not technically a work zone or maintenance vehicle, the team also observed that police vehicles are also treated to increase their visibility. These vehicles are often used in conjunction with work zone/maintenance vehicles in responding to an incident. Figures 66 through 68 illustrate examples of police vehicles.

Work Zone Traffic Control

In their observations of work zone traffic control, the team found that the Europeans do not typically use advance traffic control to the same extent as used in the United States. However, many of the devices within the work zone itself utilize visibility enhancing treatments.

Figure 62. Maintenance vehicle, Sweden.

Figure 63. Maintenance vehicle and trailer, France.

Figure 64. Incident response vehicle, France.

Figure 65. Work zone vehicle, France.

Figure 66. Police vehicle, England.

Figure 67. Police and incident response vehicles, England.

Figure 68. Incident response vehicle, England.

Figures 69 through 71 illustrate the approach to a work zone in France. The initial advance sign (figure 69) is yellow with red at the top. The legend in the red portion is “Attention/Travaux.” The main legend indicates the travel path through the work zone. This sign is located 200 m in advance, and is repeated at 100 m. Near the work zone, yellow pavement markings (figure 70) provide channelizing guidance for traffic. In this situation, the normal white markings have been removed, in comparison to

Figure 69. Photo 1, Advance work zone, France.

Figure 70. Photo 2, Channelizing transition to work zone, France.

figures 23 to 25, where the white markings were not removed when the yellow work zone markings were installed. The red and white work zone barriers are visible in the background of this figure. At the work zone (figure 71), the barriers are alternating red and white, with red/white chevron-type devices above the barriers. There are also two flashing warning lights within each of these chevron-type devices.

Other treatments are also used to increase the visibility and/or conspicuity of devices in the work zone. Figure 72 shows two cones in England. The area of retroreflective sleeve on these cones is significantly larger than is used on cones in the United States.

To highlight the location of a traffic lane modification in a work zone, strobe lights are located on top of signs which indicate the change in travel path. Figures 73 and 74 illustrate two applications of strobe lights. Figure 73 also illustrates how the European agencies use colors and patterns in a backboard to increase the conspicuity of the main message in work zone signs.

Figure 71. Photo 3, Work zone protection, France.

Figure 72. Retroreflective area on cones, England.

Figure 73. Strobe lights above work zone signs, Sweden. (Note strobe lights on for left sign and off for right sign)

Figure 74. Strobe light above temporary gore sign, Germany.

Rotary Intersections

The team members also observed numerous rotary intersections as they traveled through the four countries. Although the team did not develop any recommendations regarding traffic control at rotary intersections, they felt that U.S. practitioners might be interested in seeing some of these practices. Figures 75 through 81 illustrate various applications of markings and signing for rotary intersections.

Figure 75. Rotary intersection, France.

Figure 76. Rotary intersection, France.

Figure 77. Rotary intersection, France.

Figure 78. Rotary intersection, France.

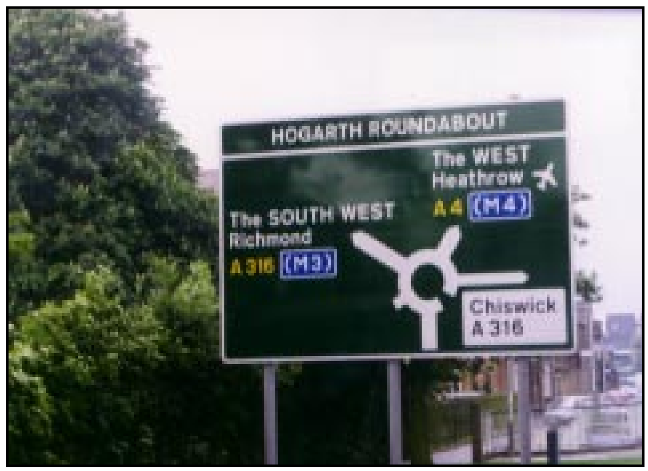

Figure 79. Rotary intersection, England.

Figure 80. Rotary intersection, England.

Figure 81. Rotary intersection, Sweden.

Chapter Three

FREEWAY CONTROL

The FHWA team observed many different freeway facilities during their travels through Europe. In Europe, these facilities are known as motorways. Many of these facilities are operating very near capacity levels, and demand exceeds capacity in some locations. The team found that the operating agencies have developed several practices for optimizing freeway operations.

PRIMARY FINDINGS

The team found that the four European countries visited have developed sophisticated methods of controlling vehicular flow in freeway lanes and providing freeway users with information that helps optimize freeway operations. Among the key features that the team members observed in the various countries are variable speed control, incident/queue detection, queue protection, and lane reduction controls.

Variable Speed Control

In Sweden, Germany, and England, the transportation authorities were able to achieve considerable traffic flow and safety benefits on freeways by dynamically changing the speed limit based upon real-time traffic speed and flow data. Sudden disturbances in traffic flow are detected by loop sensors and appropriate reduced speed limit messages are displayed to approaching traffic (well in advance of the queue or disturbance) by variable message signs.

Reprinted with permission from the Highways Agency, UK.

Figure 82. Variable speed control, England.

The speed limits consist of a red circle with a white number inside the circle and typically use light emitting diodes. These speed limits are regulatory and are enforceable. Figures 82 through 85 present various examples of variable speed limit displays. In all cases, the variable speed limit is displayed as a number within a red circle. As such, its appearance is the same as the standard European speed limit sign (illustrated in figure 86). Figure 87 provides a close-up view of one of these indications. Each of the upper corners in this photo contains two flashing warning lights that activate when the speed limit has been lowered. These variable speed control practices are closely integrated with the queue and incident detection

Figure 83. Variable speed limits, England.

Figure 84. Variable speed limit, England.

Figure 85. Variable speed limits, Germany.

Figure 86. Standard speed limit sign, France.

Figure 87. Close-up of variable speed limit indication, England. (Note flashing warning lights in corners)

technologies, described later in this chapter, to reduce the incidence of secondary accidents (rear-end at start of queued traffic).

The team members learned of two key elements to the success of the variable speed limits. One is the accuracy of the indicated speed limit. For drivers to respect and comply with the indicated speed limit, they have to recognize the accuracy of the message. The second key element was automated enforcement of the variable speed limits (see page 35). The team members feel that the ability to adjust the regulatory speed limits on freeway facilities is a critical element of achieving significant operational benefits from the system. It is also a capability which is not currently available in the United States.

Lane Control Signals

In addition to the variable speed limits, the team observed that lane control signals are widely used to control traffic on freeways. The most common use of these signals is to indicate lane closures for incident management and maintenance activities as part of real-time “controlled motorway” systems. Such signals are also used in the United States, but are not nearly as extensively as in Europe. The display concepts used in Europe to indicate an impending freeway lane closure are also slightly different from those in current use in the United States. The sequence of indications used in these signals is different from that used in the United States. The initial indication of a closed lane is a downward diagonal yellow arrow pointing toward the lane that road users should move to. This is followed downstream by a red X.

The team members learned of an innovative use of lane control signals in Germany. The signals were used where two freeway mainlines or entrance ramps merge, but the number of downstream lanes is less than the sum of upstream lanes. The traditional treatment for this situation would be a lane drop for one of the outside lanes or a merge of two inside lanes. Either treatment is static (i.e., in effect 24 hours a day) and would typically be imposed on the upstream roadway that carries a lower volume. This static control does not allow for changes in control based on changes in relative volume of the approaches in different periods of the day. The dynamic solution utilized by German officials is to install lane control signals over both upstream approaches well in advance of the merge, and operate them with variable displays at different times of the day. During any given time period, the approach with the higher volume is provided with signals indicating all lanes open, while a lane closure is displayed for the lesser-volume approach. As the relative volumes of the two approaches change throughout the day, the lane closure is switched from one approach to the other as needed. This dynamic system (which can be operated on a pre-scheduled basis or a real-time basis using detectors) makes the most efficient use of the available roadway infrastructure, as well as improving safety by imposing the lane reduction at a place where drivers do not have to contend with other lane changes associated with the merge of two roadways. It could be used on a permanent basis or as an interim solution until the downstream roadway can be widened. Figure 88 illustrates the use of a red X and green arrow in lane control signals.

Figure 88. Lane control signals, Germany.

Team members also observed the use of lane control signals in England on a seven-lane section of freeway with no median. The use of lane control signals allowed the capacity of the freeway to be adjusted to balance the demand. Figure 89 illustrates this application in Birmingham, England.

Incident and Queue Detection and Protection

Freeway queue detection and protection is an innovative real-time traffic control technique utilized in all four countries. It has documented benefits in accident reduction and travel time reduction and has potential for U.S. implementation. It involves instrumenting stretches of freeway with traffic detection equipment for determining characteristics of traffic queues as they begin. Armed with that information, the operating authority then alerts traffic approaching the back of the queue so that speeds are reduced and rear-end accidents are reduced. The systems vary in technology up to fully automated ones that involve variable speed limits, lane control signals, and variable message signs that slow traffic upstream of the queue. In some locations, incident response vehicles provide additional protection with flashing lights or variable message signs that trail the back of the queue from the shoulder(s). As the queue grows longer, the incident response vehicles back up on the shoulder, always positioning themselves as advance warning of the queue.

Figure 89. Lane control signals on freeway with no median, England.

Sweden utilizes a traffic management system of detection, lane control signs, variable speed signs, and variable message signs called Motorway Traffic Management (MTM). In Gothenberg, it is used in the Lundby Tunnel, where it utilizes loop detectors and video camera detection. The system is able to measure volumes and speeds; classify vehicles; and detect incidents, “ghost drivers” (wrong-way vehicles), disabled vehicles, and pedestrians. It utilizes individual lane control signals to provide smooth transitions for lane closures. It also utilizes variable speed limit signs to control speeds. Variable message signs provide relevant information to approaching motorists.

The benefits of these freeway queue protection systems have been fairly well documented. In Sweden, the team learned that the Motorway Traffic Management (MTM) system being used in the Lundy Tunnel and planned for other sections of Swedish freeways is the same as the system demonstrated in Amsterdam. That system resulted in a decrease in overall accident rates of 23 percent, reduction of serious accidents of 35 percent and secondary accidents of 46 percent. On a stretch of the German A5 autobahn between Bad Homburg and Frankfurt/West using variable speeds and lane control signals, accident rates fell by 20 percent. On a comparable section of autobahn without control, accidents increased by 10 percent in the same time period. The financial calculations of the reduction in serious and injury accidents of 29 percent on the A5 in Germany equated to an annual savings of approximately 7 million DeutschMarks ($4 million U.S.) annually. Secondary accidents (resulting from traffic disturbances) were decreased by two-thirds. The Germans estimate that the payback in savings from the reduced accidents equals the cost of the systems in 2 to 3 years. Additional benefits cited by the Germans are reduced travel times, decreased fuel consumption, and lower exhaust emissions.(6)

Motorway Incident Detection and Automated Signaling (MIDAS) is a system used in England for automated control of speed limits. It is a typical incident detection and traffic data collection system. MIDAS uses loops located at 500-meter intervals in all lanes. Roadside processors (outstations) analyze the data to detect queues and slow moving traffic resulting from freeway incidents or capacity constraints. When an outstation detects a queue or other specified condition, it sends an alert to the appropriate Police Control Office via the freeway communications network. The MIDAS "subsystem" assesses the alert and sets the appropriate speed(s) on the variable speed limit signs. A queue protection feature of MIDAS on the M25 (and possibly other freeways) uses occupancy and speed control alerts to determine which speed signals should be set to best manage the traffic and protect the back of the queue. The system has been shown to be very effective at protecting drivers in congested queuing traffic. It has proved effective at detecting the queue arising from an incident or capacity constraints (frequently setting signals several minutes before police operators), and then tracking the queue as it spreads back from its source, automatically maintaining protection and freeing police resources to deal with the incident. In a 2-year study of system performance, it was found that driver compliance with posted speeds was very high, lane utilization was improved both laterally (distribution across lanes) and longitudinally (more even headway spacings), and there were indications that safety had improved. Police records for the first year showed a reduction of 28 percent in injury accidents and 25 percent in damage-only accidents, compared with the previous year. Data for the second year indicate that safety improvements had been maintained. Reaction from the public has been positive, with a majority of M25 drivers reporting they prefer to drive under controlled conditions on busy, congested freeways and would support wider use of controlled freeways.(7)

Immediate Detection of Stopped Vehicles (DIVA) is a system for the automatic detection of incidents through video processing. The system was developed and used by a toll road operating company (COFIROUTE) in France.(8) The system uses cameras installed on high poles along emergency lanes. Each camera covers a stretch of 100 to 500 meters. They are connected to the toll road operations center via fiber-optic communication lines. Digital image processing tracks pixel movements of images and generates alarms for specific incident types. Operators can view images transmitted by the cameras and determine the type of intervention that might be required. Just 30 seconds elapse from the moment the vehicle stops to the issuance of the incident-specific alarm. The operating company claims a 99 percent detection rate with false alarm rate under 1 percent in tunnels (90 percent with 5 percent false alarms on open highways).

OTHER OBSERVATIONS

In addition to the Primary Findings associated with variable speed limits, freeway lane control signals, and incident/queue detection, the team members observed two other practices that may be of interest to U.S. practitioners: rolling freeway blocks and detection systems on the freeway shoulder.

Rolling Freeway Block

In England, instead of waiting approximately an hour, or longer, to remove smaller debris from the roadway, the police remove the objects by a technique referred to as the rolling freeway block. In advance of the debris, one or more police vehicles slow down traffic in the obstructed lane(s) to approximately 20 to 30 mph. An officer on the passenger side of one vehicle opens the door and picks up the debris while traffic remains moving. They have found that this technique is very cost-effective as it can be quickly implemented, requires only minimal staffing, and is generally well accepted by the public.

Shoulder Detection

Many European countries, England in particular, are establishing as a design standard the installation on loops on the shoulder in addition to the mainline locations. This change was prompted by the lower cost at the construction stage and facilitating traffic monitoring and incident and breakdown detection. This option should be considered on new construction projects if traffic management is in place or being considered in the future.

Chapter 4
OPERATIONAL PRACTICES

PRIMARY FINDINGS

The team members were extremely impressed by the many advanced operational practices utilized by the host countries. Each of the host countries has utilized strategies that help them optimize the operational aspects of their respective systems. Although impressed by many different practices, the team members identified two that demonstrate the greatest potential for implementation in the United States: intelligent speed adaption and self optimizing signal control. Team members also observed other practices which may have value to U.S. practitioners, including practices for signal operations, safety, and design features.

Intelligent Speed Adaption

Intelligent Speed Adaption (ISA) consists of processes which monitor the relationship between a vehicle's current speed and its suitable speed, and instigate a corrective action if the relationship is out of balance. If a vehicle is being driven at too high a speed, a “road beacon” transmits a signal to a receiver in the car. The driver is warned by a sound or light signal which tells him that he is driving too fast.

Speed adaption systems can also be totally automatic, like the system tested in Eslov, Sweden. The urban area of Eslov provided a test area where radio beacons at access points turned on/off a function in test vehicles. When turned on, the speed of the vehicle was limited to a maximum of 50 km/hr. The driver experienced this speed limiting activity in the form of resistance in the accelerator and the fact that it was not possible to increase speed, even if the accelerator was depressed still further.

Interviews of Eslov test drivers indicated clear-cut benefits: the system was regarded as a safety measure and not as an unpleasant control or source of irritation. Behavior studies also clearly revealed that the driving behavior of the test drivers improved in the interplay with other road users.

A large scale ISA field trial will start in 1999 in four cities in Sweden. The budget for the 2-year test is 75 million SEK (about $10 million U.S.) and approximately 5,000 vehicles will be equipped with ISA. This trial will be conducted primarily in urban environments with complex traffic situations in which many different groups of road users interact. The trial will also make it possible to test and develop the interplay between the major players in the road transport sector.

Some early findings from users in a test in Umea include: 1) the percentage of drivers who actually comply with a 30 km/hr speed limit increases from just over 20 percent to just over 80 percent, 2) more than 50 percent say “comfort increases,” 3) 75 percent feel that the mental pressure is less, 4) almost 100 percent think this will lead to “safer traffic,” and 5) interaction with other road users improved.

Self Optimizing Signal Intersection Control

Traffic engineers in the U.S., particularly those with rural high speed highway responsibilities, are often faced with operational and or safety problems at traffic control signal installations. Even with the most sophisticated traffic signal controllers and detection systems in current use at rural, isolated, high speed installations, crashes (particularly the rear end type) continue to occur during the change of right-of-way between mainline traffic and the cross street traffic. At rural, high speed traffic signal installations with high volumes, the risk of rear end collisions increases significantly.

Sweden, faced with the same operational and safety issues at isolated high speed traffic signal installations as their U.S. counterparts, has developed an advanced traffic signal control system to minimize the potential of rear end crashes and red light running. The system is called SOS for Self Optimizing Signal Control. Development of the SOS control system began in 1992 with 24-hour field operation of the system and evaluation beginning in 1995. The SOS control system is an enhancement of several other European traffic signal control systems, including the British MOVA and Swedish LHORVA which have been in use for some time. Two reports describe various aspects of the SOS, MOVA, and LHORVA systems of control. [9, 10]

The SOS control system consists of a typical actuated traffic signal controller operating in parallel with a microcomputer. The software within the microcomputer operates the optimization package which can be structured to assess one or all of the following criteria: safety, delay, emissions, or fuel consumption. The main function of the SOS strategy is to decide when to end traffic signal phases, similar to the gap reduction of typical controllers, but in a much more sophisticated manner. The SOS software optimization within the microcomputer is continually performed between the moment when a queue gathered at a red/stop condition is discharged and that moment when all traffic on the approach is stopped. During this time, the SOS microcomputer software seeks the optimum moment to change from green to yellow. The controller itself takes care of its typical functions including the green demand, phase selection, etc.

The optimization function is a difference function that calculates the benefit for an extension of the present phase compared with stopping the phase immediately. These benefit calculations are performed two or more times per second. From the optimization strategies chosen by the traffic engineer, the microcomputer software develops the benefit calculation in the form of a cost algorithm. The safety component of the optimization, or incident reduction strategy, assesses the number and position of vehicles within the dilemma zone, striving to keep the potential risk for a rear end collision between any two vehicles to a minimum, as shown in figure 90. Optimization is based on the calculation of one, all, or any combination of delay, emissions, or fuel consumption costs for vehicles on the cross street, and the potential for delay, emissions, or fuel consumption for vehicles at any point in time if the mainline would be stopped. These factors can also be weighted to meet the needs of the traffic engineer. The SOS can call for the extension of the maximum green time of a phase that would apply under normal traffic signal controller operation, to a pre-selected

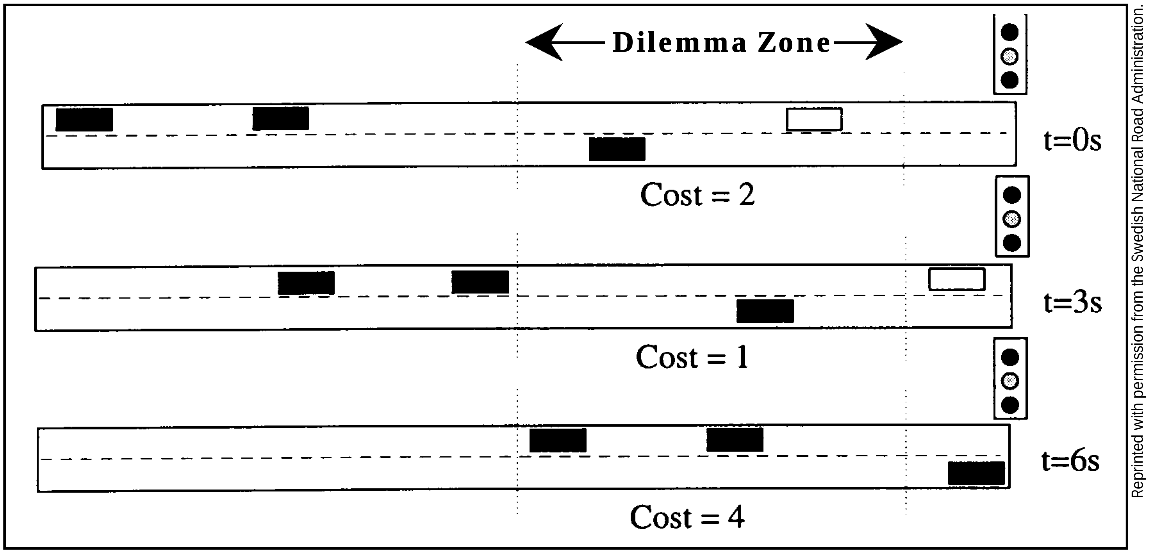

Figure 90. Incident reduction signal control strategy. SOS checks the number of vehicles in the option zone. Single vehicles in a lane have a lower cost than others. SOS also makes a forecast for the future in order to find the best moment to end green. (Source: Reference 9)

time. This system offers significant potential for enhancement of the operation of a high speed isolated traffic signal installation.

The advantages of the SOS control system include:

- The number of vehicles within the dilemma zone on an approach is kept to a minimum and the number of vehicles at risk of a rear-end collision at the time of the change from green to yellow for a change in right of way is kept even lower. This is made possible by the optimization algorithm and the advanced incident reduction function in combination.
- By using a mathematical optimizing algorithm, SOS adapts very well to the instantaneous traffic condition. One key example would be a platoon of vehicles arriving near the max out of normal signal control. The SOS assesses the cost impacts of the arrival and potential of stopping that platoon compared to the costs associated with vehicles queuing on the red. The SOS can extend the green or terminate it depending on the results of the optimization.
- Left turns in mixed traffic can be helped by an intelligent algorithm giving an early cut-off of one of the directions of flow. The optimization routine assesses each direction of travel independently. The early cut-off allows the SOS system to serve the traffic stream with the biggest need at any moment. This variation of phasing, which means a lead or lagging left turn phase can come up on an approach, even in a protected/permitted mode of operation, can be safely accomplished as described at the end of this discussion.
- The mathematical optimization algorithm makes it possible to change control strategies according to the needs identified by the traffic engineer. This is accomplished simply by changing the costs associated with the safety, emissions, delay or fuel consumption parameters of the optimization model.

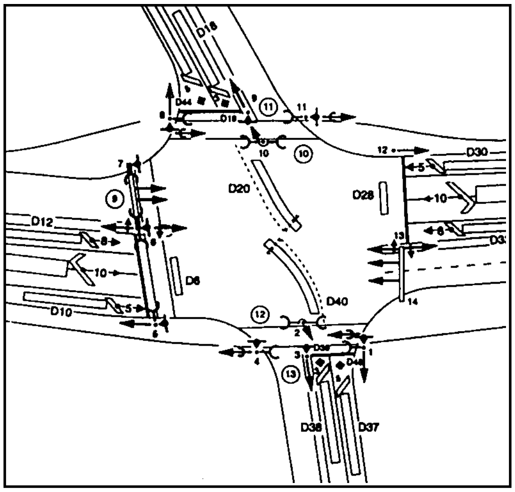

Figure 91. Banana detectors for left turning. (Source: Reference 9)

- The SOS allows the user to obtain intersection performance expressed in monetary terms. This can be different for different times of the day.

The SOS system does of course have some disadvantages, including:

- The system requires more detection and more costly control equipment than the typical actuated traffic signal installations in use in the United States, and is not suitable for multi-intersection coordinated signal systems.
- The model does not work particularly well in congested conditions. According to the Swedish authorities, however, this disadvantage can be overcome with more advanced detection systems using video or radar tracking giving speed and vehicle type.
- The present version of the SOS system needs an improved interface between the microcomputer and the controller to allow more flexibility to use different types of controllers.
- The algorithms for over-saturated control have not been tested in the field as yet.
- The SOS control has only been field tested in one location.

To safely accomplish the protected/permitted lead, lag left turn phasing on an approach at an intersection under the early cut-off described earlier, the Swedish detection designs use “banana detectors” as shown in figure 91. This type of design will of course pick up those vehicles who self position themselves beyond the normal stopping point in the left turn lane to get a clearer view of conflicting traffic. Without this type of detection, operating in a lead/lag, protected/permitted mode could result in the “left turn trap” for the turning vehicles when their direction of through traffic terminates and the opposite direction of through traffic which they are attempting to turn across continues.

One of the key results the Swedish traffic engineers have found with the SOS control system is that number of vehicles in the dilemma zone at the time the SOS system determines to change the right of way, is reduced by 38 percent compared to their LHORVA system under the same conditions. This means of course, that the potential to reduce rear end crashes is improved considerably. While there is no direct comparison with the LHORVA system in the United States, it is very likely that our typical system of traffic control at high speed, isolated, signalized intersections is no better or no worse than the Swedish LHORVA which is currently installed at 800 intersections in Sweden. The LHORVA system also has optimizing algorithms, but not as sophisticated as the SOS system, particularly regarding safety. It could be expected then that there would be safety gains in the United States by using the SOS control system at high speed, isolated, traffic control signals.

OTHER OBSERVATIONS

In addition to the Primary Findings described above, the team members identified many operational practices related to signals, safety, and design that represent innovative traffic control practices.

Signals

The team members found some very sophisticated signal operation strategies among the countries visited during the trip. Two of the more applicable to U.S. practitioners are the use of historical loop detector data when a loop fails, and coordinated signal preemption strategies.

Use of Historical Loop Data During Loop Failure Conditions

As a part of the SOS advanced traffic signal control strategy project in Sweden, the Swedish National Road Authority (SNRA) has developed advanced signal controller algorithms to improve signal operation during conditions of vehicle detector failures. In traditional traffic signal controllers, when a detector fails, a "constant call" is automatically placed on the signal phase. This results in the actuated signal phase green being called in every cycle and extending out to the maximum every cycle, regardless of actual traffic demand on that phase. When aware of a detector failure, agencies sometimes reduce the maximum green settings for the phase as a temporary measure until the detector can be repaired or replaced. This "compromise" timing setting (intended to reduce delay to other traffic in off-peak times resulting from the failure) nevertheless increases peak-period delay to the phase with the failed detector. Overall, the detector failure results in significant additional delays to all traffic at the intersection.

The Swedish algorithm and control strategy addresses this problem very effectively. During normal operation of the detector, the controller software collects and stores "historical data" on how much green time is provided to the phase (based on the actuations) each cycle and averages this data over a predetermined time period (such as for each hour of the day or each 15-minute period of the day.) When the detector on that phase fails, instead of just going to a "constant call/maximum green time each cycle" condition, the controller provides differing amounts of green time for that phase at different times of the day, based on the historical phase green time data it has collected. Particularly for intersections with approaches having widely variable traffic volumes, this control strategy is extremely beneficial in reducing intersection delays during the detector failure condition.

The SNRA reported that the cost of Swedish controllers is relatively high, due in part to their capability to perform functions such as this. However, such increased equipment costs are small when compared to the savings to road users associated with reduced delays at intersections.

Coordinated Signal Preemption Strategies

In Sweden, transit priority and preemption of signals in urban areas is widely used. This is a result of political decisions to give transit vehicles blanket priority over private vehicles. However, in Gothenburg, Sweden, the political leadership has come to recognize that providing such an over-riding priority to transit vehicles has eliminated the benefits that coordinated traffic signal systems would otherwise provide along urban arterials and in urban grid systems. The very frequent signal preemptions (currently an average of 4 preemptions every 10 minutes at typical downtown intersections, projected to grow to 12 every 10 minutes as the tram system expands) causes extreme disruption to progression patterns between signalized intersections and has resulted in serious “gridlock” conditions. In response, local politicians asked traffic engineers to develop a system that would give transit priority without causing as much disruption to private vehicle travel.

The “SPOT” system, which was developed to address these concerns, incorporates the following features:

- Priorities for preemption are weighted in terms of relative need versus disruption. An emergency vehicle is considered the equivalent of 2000 non-emergency private vehicles, a tram or bus that is behind schedule equals 500 vehicles, while a tram or bus that is on schedule is equal to one private vehicle (and thus in essence receives no priority.)
- Queue lengths are monitored on all links in the grid. If the queue exceeds 80 percent of the link length, it is considered “at risk” for backing into the next signalized intersection and the control strategy is adjusted to reduce the queue.
- Each intersection approach is separately controlled and can be provided with green or red phases independently of each other. Pairs of approaches (such as northbound and southbound through) that would ordinarily operate together on a single common phase are controlled separately so that preemption can be applied to individual approaches and progression can be established on individual links between intersections.
- Every 3 seconds the system tries to re-establish “green waves,” not necessarily on the cycle and offset pattern that was in effect prior to the preemption occurring. This is claimed to be an advancement over “SCOOT” and other similar systems.

SPOT has been implemented and evaluated at eight intersections in downtown Gothenburg and has been found to reduce delays to private vehicles in peak hours by up to 15 percent, compared to previous conditions with unweighted priority preemption.

Safety

The team members learned that safety is an inherent consideration in all transportation related decisions made by the various agencies. The administrative practices chapter of this report addresses the safety orientation of the agencies in more detail. However, the team members observed two operational practices that have a primary safety emphasis that might be of value to U.S. practitioners: automated speed enforcement and emergency phones.

Automated Enforcement

Throughout their trip, the team members observed a widespread use of automated enforcement. The most commonly observed application of automated enforcement was for speed. In this use, enforcement cameras were observed on several classes of roadways. Automated enforcement is also used for red light running.

Officials in England indicated that automated enforcement of the freeway variable speed limits (see page 35) was the key to obtaining driver compliance with the indicated speeds. They used cameras mounted on the backs of the overhead freeway signs above each lane. Detectors identify vehicles traveling above the speed indicated in the variable sign and the cameras take pictures of the license plate on the back of a vehicle. Laws were established that set the vehicle owner as being responsible to either accept the ticket given by the automatic speed enforcement system or to identify the driver of the vehicle when it was photographed. This system has proven to be very beneficial in that it has caused a very high compliance with the speed limit, a slight increase (5 to 10 percent) in the roadway capacity, and a very dramatic decrease (25 to 30 percent) in the number of rear-end accidents on the approaches to freeway queues.

These enforcement cameras use flashes to provide the lighting for the photograph. Officials found that, if the flashes continue to operate, they only needed to keep cameras in a relatively small number of the camera containers. The camera flash alone (operating without a camera) provides drivers with sufficient indication of enforcement to ensure compliance. The small number of cameras were rotated frequently so that motorists would not know if the flash coming from the camera box meant a picture was actually taken. Figures 92 and 94 indicate typical signing that is used with the automated enforcement cameras.

Figure 92. Variable speed limit sign, England.

Figure 93. Variable speed limit ends sign, England.

Figure 94. Enforcement camera sign, England.

Emergency Phones

The team members found widespread use of emergency phones in several of the countries they visited. In Germany, emergency telephones are located every 2 km on each side of the autobahn system. Emergency calls at any hour are routed to the telephone exchange of central road maintenance depots who further arrange for help. In the case of accidents, calls are relayed to the police. In the case of breakdowns, the services of the automobile associations are summoned by radio.

In France, freeway emergency telephones are installed every 1, 2, or 4 km depending on location and type of facility. Emergency telephones are connected with Emergency Centers via proprietary cable, PTN, or radio. Europe has a standard mobile telephone number for emergencies (112). In France, 15 is the mobile phone number for medical aid and ambulances, 17 is the number for police services, and 18 is the number for fire services.

In England, there are approximately 5,500 existing freeway emergency telephones linked to the police-run Operations Centers. Normally these are sited in pairs (one for each direction), at approximately 1.5 km intervals. This means that the nearest telephone is always within 750 m. Additional telephones are provided along more busy stretches such as freeway interchanges and in tunnels. This enables the user to reach a telephone without having to cross a roadway. Telephones are positioned so that the user is facing the on-coming traffic or, where a crash barrier is installed, facing the roadway. Inside the telephone housing are step-by-step instructions on how to use the telephone system. The telephones have inductors in their circuits so they can be used by a caller wearing a hearing aid; they also display the World Deaf logo on the housing door. As a further aid to telephone users, marker posts are provided adjacent to the shoulder, or attached to bridge parapets, at 100-m intervals. Marker posts bear a telephone handset symbol with an arrow showing the direction of the nearest freeway telephone. Each post is marked in kilometers and tenths of kilometers from a normal start point, thus permitting accurate identification of any location anywhere on the freeway.

The Highways Agency is in the process of redesigning the Emergency Roadside Telephone (ERT), which it provides on freeways and some trunk roads in England. Although the present telephones have served well over many years, they are no longer suited to large scale production. Some improvements in the new phones include: ergonomic design (everyone knows how to use them), ease of use for short and tall callers including people in wheelchairs, an ear piece that reduces background noise, and a better microphone to improve communication.

Design Features

The team members observed many different design features of highways and roadways in the countries visited. However, very few of these related to the subject of the scan trip. The one design feature identified by the team for inclusion in this report is the police patrol bay.

Elevated Police Patrol Bays

On the freeways in England, the team members noticed elevated police bays along the edge of the road. These bays place the patrol vehicle approximately one meter higher than the road surface. This provides personnel in the vehicle with a better view of the roadway traffic. Figure 95 illustrates one of these patrol bays.

Figure 95. Police patrol bay, England.

Chapter Five

INFORMATION MANAGEMENT

One of the keys to optimizing the efficiency of a transportation system is getting the right information to the system users at the right time at the right location so that they can use it to influence travel decisions. In all four of the countries they visited, the team members found outstanding examples of transportation information management. Some of the most noteworthy are described in this chapter.

As a result of the existence of multiple languages within relatively small geographical areas, one of the key components of European information management practices is a widespread use of symbols. Other important components are the integration of information from different transportation modes and the use of advanced technologies for communicating information to users.

Two aspects of information management were identified by the team as Primary Findings that have potential implementation value in the United States: the display of travel information and the widespread use of symbols in presenting information. Team members also observed other information management practices that may be of interest to U.S. practitioners.

PRIMARY FINDINGS

In Europe, transportation modes function as a complete system, and much of the information management aspects of the system relate to integrating information from public transportation, single user vehicles, and other modes. Because of the significant contrasts between transportation systems in the United States and Europe, the team members believe that much of the information management strategies have limited short-term implementation value in the United States. Two practices that do have value are greater use of symbols in presenting information and the display of travel information.

Symbolics

Symbols are used extensively throughout the four European countries visited. The European system of traffic signs is almost exclusively symbol-based. In addition, the Europeans also employ widespread use of symbols in variable message signs (VMS). The variable messages fall into the following categories:

- Danger instructions and indications such as speed reduction.
- Lane assignment such as lane closures or shifts.
- Directional information such as route detours.
- Information regarding the reason for delays, such as congestion.

The VMS display regulations require the use of symbols (or pictograms as they are more commonly termed in Europe) for speed control and lane assignment. These applications were discussed as Primary Findings in the Freeway Control chapter of the report. The speed control symbol is used to moderate speeds and help prevent stop and start conditions for smoother flow of traffic. The lane assignment symbol (red X or green arrow) is particularly helpful when a lane closure situation exists. For all situations that require action on the part of the driver, symbols are used.

There are times when additional messages may be appropriate for informing the driver about the particular nature of the incident. Research conducted in Europe has shown that the drivers' journeys are less stressful when they are told the reason for unexpected delays. Figure 96 illustrates several symbols that are commonly used in variable message signs in Europe.

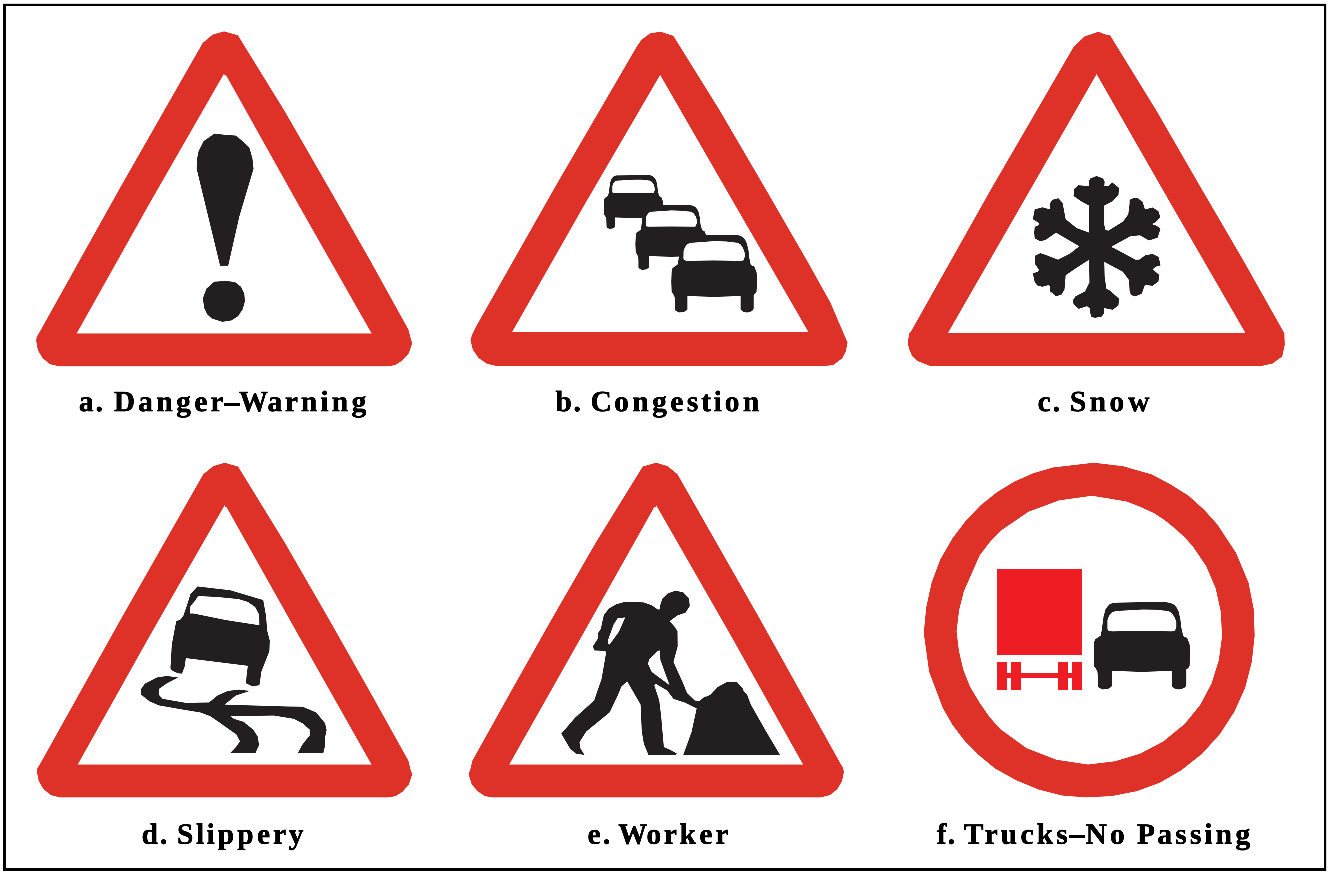

Figure 96. Symbols used in variable message signs.

The European countries also use symbols to inform drivers of detour directions. Alternative routes are "pre-signed" with geometric shapes in changeable message signs to define specific alternative routes. Figure 97 illustrates several of these shapes. When it is necessary to divert traffic from the main road, one geometric shape is displayed on a guide sign on the main road. In Germany, this was done through the use of a rotating drum within the sign. The same geometric shape is displayed at all decision points along the detour route. Figure 98 illustrates the use of a geometric shape at a decision point along the detour.

When direction, detour routes, or other similar information is necessary, text messages may be used with the pictograms. The text message length and phrasing

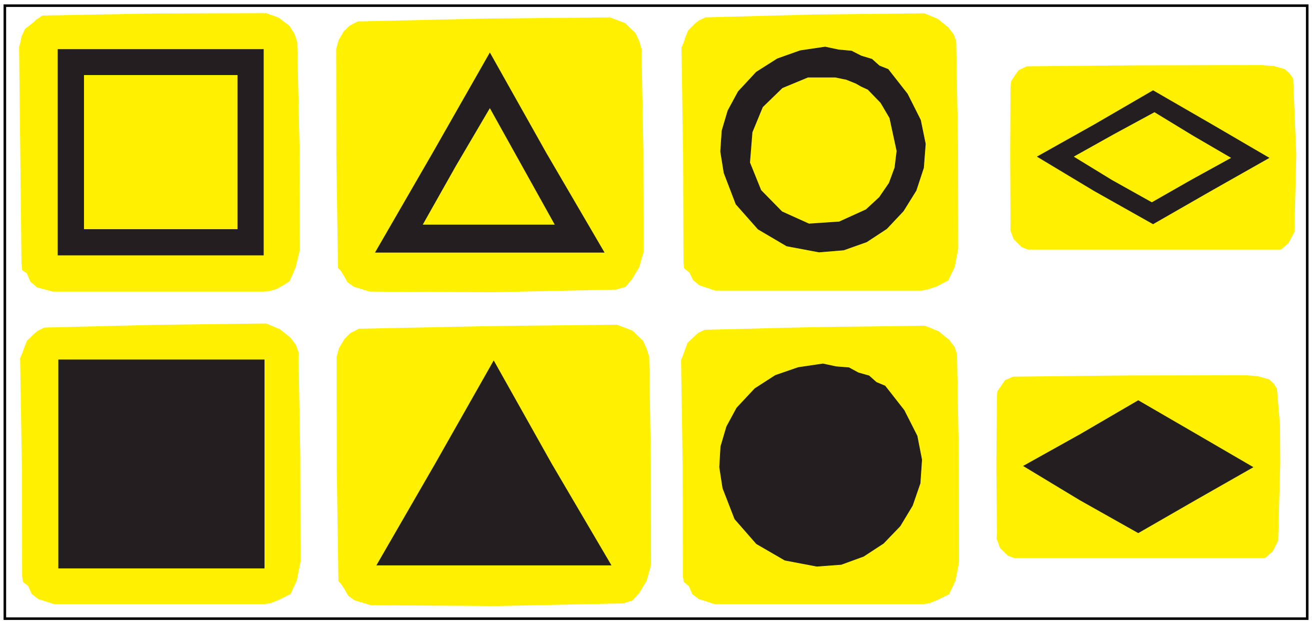

Figure 97. Diversion symbols.

rules vary in the four countries. For example, in England the text displays use two lines with a maximum of 12 characters per line. In France the text displays use only one line with 10 characters maximum.

This practice of displaying symbols is particularly useful in overcoming language barriers to international travel and motorist comprehension. Research is underway to develop additional symbols for inclusion in the European standards for traffic control devices. Two specific conditions for which symbols are being explored are “fog” and “accident.”

Display of Travel Time Information

Each country had various systems of displaying travel information, including the use of variable message signs. France’s use of variable message signs that incorporated up-to-date traffic conditions gave an excellent example of real-time travel time information for motorists around Paris. Variable message signs have been installed at 204 locations on the Paris ring freeway, its ramps, and the inner city ring freeway. Figure 99 illustrates one of these signs. Travel times to upcoming major junctions are calculated by an algorithm (which has been calibrated and tested for accuracy), displayed on variable message signs, and are updated every minute so that real-time data is provided to the motorists. Flow rate, congestion rate, and speed are detected by 680 sensors and provide the data necessary to keep the messages displayed up to date. Surveys of drivers in the Paris area found that they find the real-time travel time information much more useful

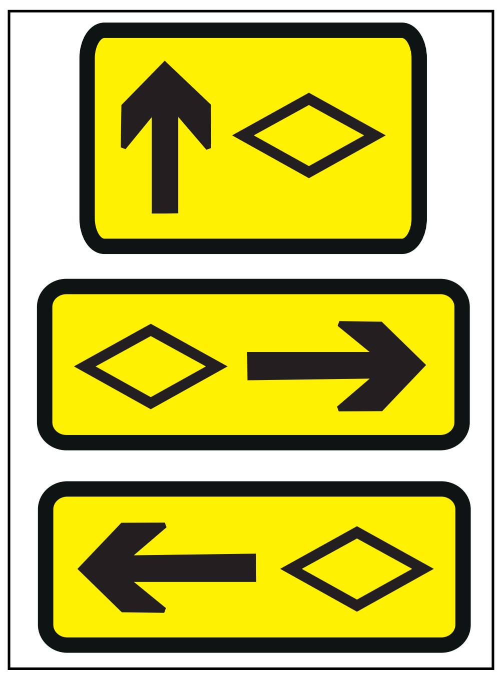

Figure 98. Detour symbol signs.

Figure 99. Real-time travel time information, France.

than general messages such as “congestion ahead.” A 1994 evaluation of this system found that 65 percent of the motorists preferred travel time information over congestion information.

OTHER OBSERVATIONS

In addition to the Primary Findings, the team members observed and learned about many other aspects of European information management. These practices address both the visual presentation of information through signing, communication of information through the radio and other auditory mediums, and private sector involvement in collecting and distributing transportation information.

Consistency in Variable Message Signs

European systems providing for centrally controlled VMS displays for incident management and congestion information appear to be farther advanced than U.S. counterparts in terms of assuring consistency and understandability of the messages displayed. European standard symbols have been developed for a variety of messages that, in the United States, would be displayed with text. Also, software systems have been developed and implemented in several countries to either automatically generate standardized VMS legends based on the situation detected or to assist Traffic Management Center (TMC) console operators by checking for consistency the messages they enter manually and suggesting changes.

Several officials stated that manually-generated VMS messages had not been giving drivers consistent legends. That is, for a given incident situation such as an accident with a lane blocked, different TMC operators would create and display different VMS messages in their attempts to convey the information to drivers. Also, TMC operators typically are not trained in “human factors” regarding what types of legends and messages are more readily understood when conveying any given piece of information. As a result, driver response to the VMS messages had not been optimized.

The use of symbols as the key part of VMS displays is being given emphasis in new deployments of VMS in Europe. Symbols have been developed for “congestion,” “icy road,” and other messages for which U.S. practice (static signs or VMS) does not yet use symbols. A symbol for “fog” is currently being developed and researched. Because of the many languages of Europe, symbolization is a very high priority. However, this is increasingly important in the United States as well, with increasing immigration of non-English speaking people and increasing tourism from many foreign countries.

The software systems (such as “SATIR” in France) incorporate human factors knowledge into an “expert system” that reviews the facts of the incident (type, location, level of inconvenience, detours, etc.) and generates the appropriate VMS message from a “pre-approved,” pre-formatted set of available messages which conform to rules governing message format, length, and allowable phrases. The message can be either displayed automatically or presented to the TMC operator for verification and authorization before being displayed. Other software systems do not generate messages but instead serve as a check for the TMC operator. The operator types in the message he or she intends to display and the “expert system” software checks the message for consistency with pre-approved standard messages for various incident conditions. This “check” is automatically performed by the system and cannot be bypassed by the operator. However, if circumstances dictate, the operator can override the system-generated message and use his or her own wording.

Real-Time Parking Information

The team observed extensive implementation of systems that collect and display real-time information on parking availability for drivers in a variety of European cities. These systems are typically part of larger efforts to promote and preserve the economic viability of city centers and/or projects to enhance information to travelers on all modes of travel into the city.

The real-time parking information systems typically utilize detectors or other means of counting vehicles as they enter and leave parking garages or lots. This allows the number of vacant spaces to be calculated for each parking facility on a real-time basis. Although predominantly publicly owned parking facilities are included in the systems, in some cities privately owned facilities have also been included, through agreement with the owners.

Display of the real-time information to drivers is via variable message signs (VMS) and parking trailblazers with integral VMS panels. On major routes leading to the city center, drivers first encounter a VMS on the outskirts of town that generally advises either that parking downtown is available or is full. In the case of a “full” or nearly full condition, some systems give messages advising drivers to use transit and giving them directions to the nearest park-and-ride lot.

Figure 100. Real-time parking information, Germany.

As drivers get closer to downtown and approach “decision points” where they can choose among routes to various parking facilities, they encounter parking trailblazers with VMS panels displaying real-time numbers of available spaces in two or more garages or lots. Figures 100 through 102 illustrate real-time parking information signs. Figure 100 illustrates a sign on the outskirts of a city that indicates that parking is available (frei indicates availability, not cost). Figures 101 and 102 illustrate signs that indicate the parking availability for specific parking areas. Some of these signs may display the actual number of available spaces instead of simply indicating general availability of parking. These trailblazers are deployed comprehensively at all decision point intersections and at the entrances to individual parking facilities. For example, in Cologne, Germany there are 90 such locations of real-time parking trailblazer assemblies.

Figure 101. Real-time parking information, Germany.

Figure 102. Real-time parking information, Germany.

This real-time information has produced the following benefits:

- Enhanced economic viability of the downtown. People who would have otherwise not come downtown to shop or eat because they feared parking problems are making trips downtown.
- Enhanced use of transit due to timely messages that all downtown parking is full and diversion of trips to park-and-ride lots serving transit lines to downtown.
- Reduction of 25 percent in downtown traffic volumes related to “searching for a parking space.”

Traffic Information on FM Radio

In France, the entire 4,000-mile national network of freeways is being instrumented with FM radio transmitters, centrally programmed and operating 24 hours a day on a single frequency, 107.7 FM. The traffic information station concept has been in place since 1988 and has been growing. As of 1998 about 60 percent of the freeway mileage is covered by the transmitters. The series of privately-operated but government-regulated radio stations is known as “Autoroute FM,” and it is dedicated to providing real-time traffic and incident information to freeway motorists. The stations broadcast routine reports every 15 minutes for the whole network on traffic and weather conditions, construction locations, etc. In between these reports, the stations broadcast safety advice, tourist information, music, and advertising. Whenever an incident, accident, congestion, or adverse weather event occurs and is detected automatically or manually on any section of freeway, “news flashes” are broadcast immediately (no more than 5 minutes after detection) on 107.7 FM. Signs spaced at about 4-mile intervals contain beacons and/or VMS panels that are activated to alert motorists not already tuned to 107.7 that a flash is about to be broadcast. Similar to "expert systems" that assure consistency of VMS messages, the French "Autoroute FM" system also utilizes software to maintain consistency and accuracy of the "traffic flash" oral messages broadcast.

The French officials feel that the use of a dedicated FM frequency for incident traffic information is much more cost effective than can be achieved with VMS signs in sufficient quantity to equal the coverage of radio transmitters. Broadcasting also affords more flexibility of messages and more information can be conveyed quicker than with VMS.

RDS-TMC

The radio data system-traffic messaging channel, or RDS-TMC, is a radio-based traveler information system that is in wide use in Europe. RDS adds a digital data channel to existing analogue FM radio broadcasts. This silent subcarrier automatically tunes the radio to the strongest signal for the chosen station, identifies stations that carry traffic announcements, and then interrupts radio programs, cassettes, or compact discs with local traffic news. RDS-TMC inserts a stream of the latest traffic bulletins into the RDS signal. These messages are coded and can be delivered to the driver through a number of means including synthesized voice, alpha-numeric character displays, and graphic screen displays. RDS-TMC improves the ease of obtaining information and it can provide information more timely as it does not have to be squeezed into a broadcaster's program schedule. The coded messages can be translated into any language regardless of what country they are sent or received in. Filtering can be applied so that drivers are not bothered by traffic news that is not relevant to them. RDS-TMC has the potential to transform driving in Europe. Navigation systems will no longer have to be static. They will provide directions which are dynamic, updated with incident warnings. While RDS technology has been on the market since 1987 and there are large numbers of cars that are equipped with RDS, there are still some technical, quality, and commercial issues that must be resolved before there is widespread operational use of RDS-TMC. Technical issues center on the codes that make the message automatically translatable into any language. Service quality issues revolve around the requirements that the Traffic Information Centers need a continuous feed of up-to-date data themselves to make the transmissions valuable. The cost of RDS-TMC has introduced the prospect of paying for the service by means of commercial ventures. Officials anticipate that these issues can be resolved because there is enough will and commitment in many European countries to utilize RDS-TMC to improve the quality and timeliness of driver information and give Europe safer and more efficient traffic and travel services.

MATTISSE

MATTISSE will enable up-to-the-minute travel information to be exchanged, allowing nine local authorities in England-Birmingham, Leicestershire, Warwickshire, Coventry, Sandwell, Walsall, Solihull, Dudley, and Wolverhampton (with five urban traffic control centers, a freeway control center, a public transit center, the National Exhibition Center, and the International Convention Center) to respond more quickly and efficiently to travel problems. The system will also allow the public access to this information. People will be able to plan their journeys with more confidence by choosing the most convenient and efficient method of travel and finding the quickest route. The system will therefore help to reduce traffic congestion, exhaust pollution in urban areas, and the stress of travel. The system will benefit authorities by allowing greater cooperation.

MATTISSE is partly funded by the European Commission and is expected to make a significant contribution to the Europe-wide objective of promoting a more integrated transportation system in urban areas. Other sites selected by the European Commission to demonstrate the benefits of an integrated system are: Athens, Greece; Turin, Italy; Stuttgart, Germany; Gothenburg, Sweden; and Toulouse, France.

Private Sector Collection of Traffic Data for Traveler Information

Private sector companies have developed many telematics solutions throughout Europe. An outstanding example of this was observed in Germany, where a company named TEGARON has developed many telematics solutions including: a traffic information service that automatically calls you back before you get stuck in a traffic jam; an integrated information and emergency assistance package that provides drivers with comprehensive traffic information services plus full roadside assistance and breakdown services; a fully automated emergency call system; and an intelligent car navigation system that works out the shortest and quickest route to the driver's destination.

The key to the high standard of service provided by these companies is instant access to accurate and up-to-the-minute data. Infrared sensors installed by a private company along autobahns and expressways monitor current traffic densities and provide a detailed breakdown of the traffic in terms of vehicle numbers and vehicle types. For a small annual permit fee, state governments allow private sector companies to install and maintain these detectors on the state's existing bridge infrastructure. In Germany, one private sector company plans to install these detectors on 8,000 kilometers of the freeway network at a typical spacing of 4 kilometers. Multiple detectors will be installed at each of these 2,000 locations. Currently, the private sector company is not required to provide the government the real-time data from these detectors; rather, it is archived and then available for planning purposes.

Chapter Six

ADMINISTRATIVE PRACTICES

The team members identified a number of specific areas of discussion and recommendations, which are presented in detail in this report. In addition, it is also important to elevate several items, which either did not fall within the context of the selected areas of emphasis or that related to the philosophies that established an organizational culture that generated and/or supported innovation.

Prior to addressing the selected administrative issues in more detail, it is important to understand that there are distinctive differences as well as remarkable similarities between the European Community and the U.S. Nationally, the use and acceptance of mass transit and multimodal transportation options are much more accepted by the citizens of Europe. They have long term acceptance and transportation practices that reflect this philosophy. To emphasize this fact it is acknowledged in Sweden that the motor vehicle is actually secondary to pedestrians, bicycles, and mass transit. This was apparent in signing practices and the use of innovative traffic management techniques. For most areas of the United States, this is an unacceptable priority and reflects the need to market these types of ideas even in our most congested areas. Finally, it was also interesting that the motorists in each country seemed to be more willing to obey and conform to traffic controls and regulations. It was not the purpose of this tour to focus on societal issues, but rather on traffic engineering design and operational practices that are different from those used in the United States.

The similarities are more consistent with, and in some cases more advanced than those facing transportation professionals in the United States. The environmental considerations in each country visited are critically important to the decision process and dictate to a great extent the rapid development and deployment of innovative traffic controls and traffic management philosophies to address safety, congestion, and operational efficiency in lieu of major road construction projects. The funding clearly seemed to be more constrained and resulted in more acute organizational reengineering, staff reductions, and justification strategies as transportation initiatives often affected funding availability.

The environmental considerations in each country visited are critically important to the decision process and dictate to a great extent the rapid development and deployment of innovative traffic controls and traffic management philosophies.

The tour members identified a comprehensive listing of all administrative issues from each country and established priorities of those which either reflected consensus or achieved a level of support among the group that suggested identification and amplification would be beneficial to the content of this report. It is important to note that there are no recommendations specifically identified in the Administrative Issues segment of this report (no Primary Findings) and although each selected area represents important findings, the focus of this report and the recommendations presented relate to more transferable traffic control innovations. The group did, however, identify a number of important initiatives or philosophies which were very basic to the understanding and integration of all the innovations in traffic control which are addressed in this report.

PRIVATE SECTOR

In each country visited the relationship between the private sector and government was quite advanced. In fact, the line of demarcation between government functions and the private sector was often difficult to identify. In Sweden the city government performed many of the functions that private enterprise embraces in the United States. As an example, Gothenburg made their own signals and even competed in the market place in other countries with their products. In each visited country the collection of traffic data was generated by both public and private sector and even though there were differences in how these data were collected, the basic purpose was to provide the motorist with real-time and effective traffic and congestion information. Perhaps the most impressive demonstration of this type of partnership was with COFIROUTE, a private freeway company in France. This company essentially completed a design-build-operate facility, which was as impressive and efficient as any such facility any team member had knowledge of. The organizational culture of this private sector group was such that any future expansion or additional toll facilities in an environment of reduced road construction would be the result of customer service and marketing skills.

As a result of reengineering initiatives and reductions in the strength of available human resources, each country visited had moved the contracting of some of the traditional public sector activities to the private sector.

Perhaps the most impressive aspect of this operation was the marketing of the facility both prior to construction and after its opening. It was apparent that COFIROUTE considered marketing and corporate citizenship as guiding principles in all aspects of this operation. They had developed extraordinary processes of “selling” the product at all levels of government and citizen groups. As this type of business practice continues to expand in the United States, this operation should be carefully studied and lessons learned adopted as appropriate.

As a result of reengineering initiatives and reductions in the strength of available human resources, each country visited had moved the contracting of some of the traditional public sector activities to the private sector. This element of administrative process was found to be consistent with the efforts underway in the United States, and innovation and reassessment were the standards rather than exceptions. Each country retained the responsibility for policy and standard development to manage the national roadway infrastructure.

TECHNOLOGY DEVELOPMENT

One philosophical difference found that was of particular interest to the group was discussed at length in Germany and also found to be prevalent in other countries. In the United States, as the technology activities became more recognized as an integral part of transportation initiatives, the individual States and Federal Government made every effort through research, early deployment projects, and organizational structure realignments to better accommodate this significant change in the way they did business. This has normally resulted in the segregation of these types of activities into technology groups within existing organizational structures. This has worked very well in elevating ITS into the application of technology solutions for transportation problems. This process was also prevalent in the European Community, but recent developments in this area are very interesting and should be formally considered in this country. Germany has begun the process of reintegrating telematics (ITS) into the more traditional operational, maintenance, and construction areas, while retaining the emphasis on safety and traffic management.

This reflects the evolution of transportation technology and indeed makes good business sense as communications are enhanced and ITS becomes a normal part of transportation and transit management practices. This is a very critical management philosophy if the integration of technology is to continue to advance and become accepted as another important tool by planners, designers, traffic engineers, and maintenance staff. This concept would also increase the marketability and customer acceptance of ITS.

SAFETY

In Sweden the national government and the Swedish National Road Administration (SNRA) have adopted a fundamental guiding principal identified as Vision Zero. This principal essentially equates to some of the national goals in the United States relating to accident and severity, but was clearly integrated throughout the SNRA organization. The purpose of this concept was to establish a national road traffic safety target, which would provide a fundamental element in all business decisions to achieve this goal. This philosophy has become a marketing tool for communicating with the customers as well as being adopted throughout the organizational culture as the basic goal of the organization. In England a similar organizational strategy was used, which was identified as "Value for Money." This concept again is not unusual in this country but represents the focusing of attention on an organizational value that is prevalent and considered in all business decisions. This focus area was critical in England as road and transportation funds competed with other important national program areas, and

> The safety focus area was critical in England as road and transportation funds competed with other important national program areas, and very clear financial assessments were both necessary and consistent with national policy directives.

very clear financial assessments were both necessary and consistent with national policy directives.

OTHER OBSERVATIONS

In addition to the administrative issues described previously in this chapter, the team members observed or learned of other administrative activities that may be of interest to U.S. practitioners.

Integration of Transportation Modes

The tour group found additional administrative issues both interesting and consistent with the group's interest in innovative traffic controls. These issues also related to the long and successful history of the European Community in the integration of modal transportation and inter-jurisdictional cooperation. The involvement of the customer in solicited input, information distribution to the user, and consistency in meeting schedules have all added to the effectiveness of jurisdictional cooperation and customer satisfaction. For example, we observed this in their integrated terminals for buses, trains, and subways and their accommodation of vehicles, buses, bikes, and trollies in the traffic signal control.

Policy

The Europeans also stress translating policy into legislation, a mind-set also consistent with the needs in traffic control strategies in the United States. In Germany the national legislation related to variable speed limits was the fundamental element in the implementation process as well as the success of the program.

Coordination

Perhaps some of the most meaningful discussions for the group were held in Germany with the Federal Highway Research Institute (BASt). BASt is a research and technical institute that began in the highway construction field and expanded through the years to become the focus for highway transportation research in that country. The quality and comprehensive nature of many of their projects were very consistent with much of the ongoing research in the United States, and the tour group felt it would be very beneficial for the Federal Highway Administration (FHWA) and Transportation Research Board (TRB) to pursue a closer relationship with this excellent program to help maximize the research funds available and not duplicate compatible projects.

In-Vehicle Messages

From an administrative perspective the group found it interesting that one common, serious concern between the tour group and our hosts was that the in-vehicle and road side messages had the potential to be incompatible. The work going on in these areas is being conducted without regard to the need for future consistency.

Chapter Seven

RECOMMENDATIONS

The ten members of the Innovative Traffic Control team were privileged to travel to four European countries (Sweden, Germany, France, and England) and see firsthand many outstanding traffic control practices. The team unanimously believes that traffic engineers and transportation professionals from the United States can significantly benefit from the team's experiences on the trip. The most significant of those experiences are described in the preceding chapters of this report.

Following the meetings with the host countries, the team members met to review the findings from the trip and identify those practices which have the greatest potential for successful implementation in the United States. This chapter describes the recommendations that have evolved from the team's experiences on the trip. The recommendations in this chapter are organized by major topics (consistent with the chapters of this report). Within each major topic, the recommendations are divided into Primary Recommendations and Additional Recommendations (consistent with the Primary Findings and Other Observations within each chapter). This chapter also includes a section on Implementation Efforts, which describes team members' activities to implement their findings and recommendations.

TRAFFIC CONTROL DEVICES

The team members learned about and observed many interesting applications of traffic control devices. In some cases, the applications were described by the hosts during meetings with representatives from the various countries. In other cases, team members directly observed applications as they traveled within each country.

One team recommendation concerning pavement markings involves an application that could be implemented without significant changes in U.S. standards or guidelines; the other would represent a major change from how pavement markings are currently used in the United States.

Primary Recommendations

The team developed two primary recommendations that relate to applications of traffic control devices. Both relate to pavement markings. The first represents an application that could be implemented without significant changes in standards or guidelines. The second would represent a major change from how pavement markings are used in the U.S.

Tiger Tail Marking

In England, team members observed special markings that were used on multilane freeway entrance and exit ramps. These markings separate the merge/diverge point associated with each lane, thereby improving the operational characteristics at the entrance/exit ramp. This type of marking could be immediately implemented in the

United States. The major implementation obstacle is that multilane ramps that use this marking require greater pavement area than normally found on U.S. freeways. Therefore, implementation of this concept would require revision of geometric design standards for multilane entrance ramps. This type of marking may be especially useful at locations where the freeway entrance ramp is fed by two turning lanes from the cross road.

All-White Pavement Markings

The concept of an all-white system of pavement markings has been the subject of much discussion in the United States in recent years. Several of the team members are very familiar with the issues and arguments associated with U.S. discussion of the issue. As they traveled through Europe, the team members were very impressed with the European all-white system and felt that such a system could work in the United States, although there would be a significant effort associated with implementation. Standards would have to be changed, new marking put in place, and drivers would have to be educated. Appendix D contains a problem statement developed by the team that describes the research needed to initiate a change to an all-white system of markings.

Two key characteristics of the European all-white system must be considered when evaluating whether such a system has potential application in the United States. The first is that European countries use a wide variety of pavement marking patterns (line width, line/gap ratios, number of lines, symbols, etc.) to convey various messages. Implementation in the United States would require that new marking patterns be used to distinguish the messages currently conveyed by yellow and white markings. The second key characteristics is that team members observed that, on many of the roadways they traveled, there were significantly greater amounts of markings than used on U.S. roadways, and the markings appeared to be better maintained system-wide than in the United States (on all classes of roads and at all levels of government jurisdiction). Europeans place a significant emphasis on using markings to communicate information (see horizontal signing section). Implementation of all-white in the United States would likely require that agencies devote greater resources to markings than they currently do. The potential benefits, however, are significant, and include:

- White markings have greater visibility than yellow markings.
- White markings offer better contrast than yellow markings.
- White markings offer economic incentives, including:
  - White material is less expensive.
  - Use of only one color improves application efficiency, reduces storage demands, and reduces hardware requirements.
- Use of an all-white system would increase U.S. consistency with international practices.

The most significant of the disadvantages of an all-white system would be the extensive educational efforts that would be required prior to and during its implementation of an all-white system. Another disadvantage includes coordinating the change with other countries that use a yellow/white system (Canada and Australia),

Finally, it should be noted that the use of yellow in pavement markings has changed continually in the United States since the early days of traffic control devices. Prior to 1961, white was the primary color used in the United States, with yellow being used only to mark no passing zones. It was not until 1978 that current practices for yellow pavement markings (yellow indicates the left side of the roadway) were established. Research in the United States has shown that large percentages of drivers do not understand the difference between yellow and white markings. For these reasons, change to an all-white system may actually be welcomed by some drivers.

Additional Recommendations

In addition to the Primary Recommendations described above, the team members identified several applications of traffic control devices that may have value to U.S. practitioners. Some of these can be implemented relatively easily and others will require some research and changes to current standards. The key aspects associated with these additional recommendations are described below.

- **Countdown Markers for Exit Ramps** – Special markers are used in advance of exit ramps in all four countries. These markers indicate when a driver is 300, 200, and 100 meters from the exit.
- **Sign Colors More Intensive** – As the team members viewed signs in each of the countries, they developed an opinion that the European sign colors are more intensive than those used in the United States. Researchers should determine if these colors are more effective than the U.S. sign colors.
- **Arrowhead Shaped Destination Signs** – In many of the directional signs in Europe, the direction is indicated by an arrow in the sign legend and by the fact that the sign has an arrowhead shape that reinforces the direction indicated by the legend. This concept is already used with One-Way signs in California and could be easily incorporated into destination and directional signs.
- **Internal Sign Illumination in Urban Areas** – The team members observed a large number of internally illuminated signs in the urban areas. In areas with complex visual fields, these signs appear to have much better target value than retroreflective signs.
- **Use of Dotted Border for Trailblazing** – In a guide sign, a dotted border around a route marker indicates that the exit or road leads to that route. This is a more simplified means of trailblazing than is used in the United States (TO marker).
- **Guide Sign Sheeting Types** – In Germany, officials are utilizing combinations of different sheeting types in ground-mounted signs and super high intensity sheeting in overhead signs.
- **Variations in Alphabet Stroke Width** – The sign alphabets used in European signs are different from the standard U.S. alphabets. A significant difference in application can be found in the relationship between stroke width

and sign background. The English alphabet uses a bolder stroke width on signs with a light colored background. Because of the significant differences in performance between positive and negative contrast signs, the use of different stroke widths is inherently logical.

- **Horizontal Signing** – The Europeans utilize pavement markings to communicate information to a much greater extent than used in the United States. This use is so prevalent that it is referred to as horizontal signing. The team members believe that many of these horizontal signing applications could have significant benefit in the United States.
- **Chevrons for Vehicle Spacing** – Information provided by England's Highways Agency indicated that some English highways feature regularly spaced chevron markings in lanes. Associated signing informs drivers to keep two chevrons between them and the vehicle they are following.
- **Colored Pavements** – Team members saw applications of colored pavement that indicate lanes for a specific type/class of vehicle. The applications observed related to bus lanes and bike lanes.
- **Raised Crosswalks** – In many locations, team members observed raised pedestrian crosswalks. This treatment serves to increase the visibility of the crossing and also functions as a speed hump to slow approaching vehicles.
- **Flashing Yellow on Pedestrian Clearance** – After the red indication at the start of the pedestrian clearance interval, some crosswalks in England display a flashing yellow signal indication to vehicles. The flashing yellow allows vehicles to proceed if pedestrians have cleared the travel lane.
- **Audible Pedestrian Signals** – Many of the European cities, particularly Gothenberg, utilized audible pedestrian signals.
- **Worker Visibility Enhancements** – Work zone and maintenance workers in Europe utilize more visible garments than their U.S. counterparts. European work vests tend to emphasize strong yellow-green and often use two contrasting colors to prevent workers from blending in with the background.
- **Vehicle Visibility Enhancements** – Both agency and police vehicles in Europe utilize vehicle visibility enhancements such as large amounts of retroreflective sheeting and fluorescent colors. This makes these vehicles significantly more visible than the U.S. counterparts.
- **Work Zone Traffic Control** – Team members observed various applications of work zone traffic control that may enhance the effectiveness of the devices. These include greater retroreflective material on traffic cones and the use of strobes on devices that indicate a change in the travel path.
- **Freeway Exit Signs** – European agencies employ a broad range of practices in the use of freeway guide signs. Several photos present typical European freeway guide signs.
- **Rotary Intersections** – Rotary intersections are receiving increased attention in the U.S. Several photos present typical European practices for the use of traffic control devices at rotary intersections.

FREEWAY CONTROL

In the major urban areas, the freeways (or motorways as they are known in Europe) utilize many traffic control practices that improve operations and/or safety of the system. The team members identified three of those practices as primary recommendations and two others as additional recommendations.

In all four countries, team members found advanced systems for monitoring and controlling the traffic on the most heavily traveled freeways.

Primary Recommendations

In all four countries, team members found advanced systems for monitoring and controlling the traffic on the most heavily traveled freeways. Three of the traffic control practices have potential value in the United States. Implementation of these practices should be considered as a system, rather than individual practices. The benefits realized from implementation of the system will be greater than the sum of the individual practices.

Variable Speed Control

A major difference between U.S. and European freeways is their ability to adjust the regulatory speed limit to reflect traffic conditions. This is done quite successfully using variable message signs that display the European speed limit graphic (a number inside of a red circle). A supporting element of the variable speed control is automated camera enforcement. This was used in all the countries. In at least one country, automated enforcement was cited as a major reason why drivers obeyed variable speed limits.

The team believes that U.S. freeway operations could be significantly improved through the use of variable speed limits. However, there are many issues that need to be addressed before such a practice can be implemented. Among these issues are the design of the speed message, the legalities associated with variable speed limits, procedures for selecting and displaying speeds, and enforcement of variable speed limits. Appendix D contains a problem statement developed by the team that describes the research needed to move toward the use of variable speed limits. This problem statement also addresses lane control signals (see the next recommendation).

Lane Control Signals

Lane control signals are already in use on many U.S. freeways as a traffic control practice. However, there are at least two differences between the U.S. and European practices. In Europe, the lane control signals function in coordination with the variable speed limits to slow vehicles down and move them to the desired lane in advance of an incident or capacity reduction. The other difference is the European use of the diagonal down yellow arrow. This symbol is not currently allowed by the U.S. MUTCD, and should be reevaluated for application in the United States.

Lane control signals can be easily implemented on U.S. freeways with a minimal amount of change to U.S. standards. Those standards should be modified to provide the use of a downward pointing diagonal yellow arrow. Research recommending this use of this display has already been conducted in the United States. [11, 12] In addition to the variable speed limit issue, the problem statement in appendix D also addresses the coordinated use of lane control signals with variable speed limits.

Incident and Queue Detection and Protection

Although not technically a traffic control device or practice, the ability of European agencies to detect incidents and queues are an important element of their freeway control systems. The most heavily traveled freeways have extensive detection capabilities and well-developed algorithms for detecting incidents and queues. Once identified, various measures are used to implement control strategies. The primary measures are the variable speed control, the lane control signals mentioned previously, and back-of-queue detection. The use of these control measures are often automated into the overall system so that the delays associated with human intervention are eliminated.

U.S. transportation agencies should design new freeway information and control systems to more systematically protect against the safety problems associated with queues. Incident management schemes should provide greater warning of queues through the use of warning vehicles and devices.

Additional Recommendations

In addition to the Primary Recommendations described above, the team members identified two other aspects of freeway control that may have value to U.S. practitioners. The key aspects associated with these additional recommendations are described below.

- **Rolling Freeway Block** – In England, the police sometime use a rolling freeway block to clear debris or other obstacle from the freeway. Police vehicles occupy all the lanes across the freeway and slow to a speed that allows the desired operation (lane closure, debris removal, etc.) to be conducted.
- **Shoulder Detection** – Incidents on freeway shoulders can have a noticeable impact on the overall operations of the facility. European officials have addressed this issue by placing detectors on freeway shoulders. This option should be considered for new construction in the U.S. on facilities that have traffic management systems.

OPERATIONAL PRACTICES

During the meetings with representatives from each country, the team members learned much about how the four countries operate their respective transportation systems from a traffic control perspective. The team members believe that two of these operational practices have potential value in the United States. There are also other operational practices that may be of value to U.S. practitioners.

Primary Recommendations

The team members learned of two operational practices that function in a traffic control manner. The first provides the ability to influence the speed of vehicles in target areas. The second is an improved operational strategy for increasing the safety of traffic signals operation at isolated intersections.

Intelligent Speed Adaption

In Sweden, the team members learned that Swedish authorities have developed systems that can directly or indirectly influence the speed of vehicles in target areas. Within these target areas, vehicle speeds can be monitored. When a vehicle's speed exceeds a threshold, two options are possible in vehicles equipped to receive the signal. The system can set off an alarm within the vehicle, alerting the driver to a speeding violation. Or the system can physically reduce or limit the speed of a vehicle so that the driver is not capable of driving faster than the speed limit.

To make it possible to introduce these systems in the United States, large-scale tests must demonstrate that the voluntary systems have a positive effect on the road traffic system, the users accept the systems, people are prepared to pay for the systems, and the relevant authorities will support the necessary infrastructure.

Self Optimizing Signal Intersection Control

Also in Sweden, the team members learned of strategies that Swedish engineers have developed for operating traffic signals at rural, high-speed, isolated intersections. In essence, the Self Optimizing Signal (SOS) intersection control provides an improved strategy for ending the green phase. The strategy emphasizes safety and economical factors in determining the optimal time to terminate the green.

In essence, the Self Optimizing Signal (SOS) intersection control provides an improved strategy for ending the green phase.

The SOS control system, or at least the conceptual logic by which it controls traffic signal intersections, appears to offer much promise for application in the United States at high speed, isolated, traffic signal installations. While shortcomings with the current system, as developed to date, have been identified by Swedish officials, they are confident solutions to those deficiencies are attainable. In the meantime, there are temporary fixes for some of these shortcomings. For example, the temporary solution for the congested traffic condition problem is to disable the optimization function of the system when congested conditions exist. The many advantages provided by SOS control could be used at all other times.

Detection systems required for optimal SOS control could cost $10,000 to $20,000 more than the typical intersection detection systems in use in most areas of the United States. Given the potential safety benefits (significantly reducing the potential for rear end crashes and red light running) however, the extra costs for the detection required would be more than compensated for through a small reduction in crashes. Swedish experience indicates that the crash reductions needed for pay-off of the additional costs are likely.

Appendix D contains a problem statement developed by the team that describes the research needed to introduce SOS signal strategies into U.S. practice.

Additional Recommendations

In addition to the Primary Recommendations described above, the team members identified several operational practices that may have value to U.S. practitioners. These practices should be able to be incorporated into U.S. practices with little or no changes in current standards or without extensive research. The key aspects associated with these additional recommendations are described below.

- **Use of Historical Loop Data During Loop Failure Conditions** – In Sweden, signal controllers and detectors incorporate logic that allows them to use historical data for signal operation when a loop fails. This provides more effective signal operation than is realized from the continuous detector call associated with loop failure in the United States.
- **Coordinated Signal Preemption Strategies** – In Sweden, the use of signal preemption for transit vehicles became so common that the benefits of coordinated signal operation were lost. The SPOT system provides a means of coordinating preemption and progression.
- **Automated Speed Enforcement** – Automated photo speed enforcement is widely employed by European agencies. Enforcement cameras were observed on a wide range of roadways. Officials in England indicated that automated enforcement was a key factor in the effectiveness of the variable speed limits used on freeways. U.S. application of this practice is likely to be very controversial.
- **Emergency Phones** – The team members observed widespread use of emergency phones on European freeways. Even with the rise in cellular telephone use, these roadside phones continue to provide an important means of assisting motorists.
- **Elevated Police Patrol Bays** – In England, team members observed that police patrol vehicle bays alongside the freeway were elevated to provide enforcement personnel with a better view of traffic.

INFORMATION MANAGEMENT

As they met with practitioners in each country and as they traveled on each country's transportation network, the team members realized that the Europeans have devoted significant resources to communicating information to the system users. And the Europeans do an admirable job of managing that information.

Primary Recommendations

The team members recommend two practices related to information management for implementation in the U.S. One practice is wider use of symbols in variable message signs and identification of diversion routes. The other is the communication of travel time information to road users.

Symbolics

As expected, the Europeans make much greater use of symbols in their transportation system. However, the team was impressed by the extent to which symbols are used in variable message signs. Much of this information could be easily incorporated into variable message signs in the U.S. using the standard U.S. symbols. The Europeans also use symbols to identify freeway diversion routes. When it is necessary to divert traffic from the freeway, signs indicate the appropriate diversion symbol. This symbol is displayed at all decision points along the route. Road users need only to follow the symbol as they travel on the alternate route.

Display of Travel Time Information

The team members also observed outstanding examples of travel time information being communicated to road users. The best example of this practice was in Paris, where variable messages signs on the inner and outer ring roads, plus the entrance and exit ramps, inform road users of the real-time travel time to key points in the network. This information is updated on a minute-by-minute basis. This information is extremely useful to drivers and similar applications would be equally useful to U.S. drivers where congested conditions occur.

The best example of travel time information was in Paris, where variable message signs on the inner and outer ring roads, plus the entrance and exit ramps, inform road users of the real-time travel time to key points in the network.

Additional Recommendations

In addition to the Primary Recommendations described above, the team members identified several applications of information management that may have value to U.S. practitioners. Some of these can be implemented relatively easily and others will require some research and changes to current standards. The key aspects associated with these additional recommendations are described below.

- **Consistency in Variable Message Signs** – The Europeans achieve consistency in VMS sign information by operating VMS as a centrally controlled system. Consistency and standardization of VMS messages is viewed in Europe as an important safety issue and their work in this area should be a model for the United States in developing standards, operational practices, and software systems.
- **Real-Time Parking Information** – In Germany and England, team members observed variable message signs that communicate information about the availability of parking in various areas of the city. Such systems are also used in other parts of Europe. This information allows drivers to make informed routing decisions as they travel to available parking nearest their destination. This type of information system should be considered for U.S. deployment.

- **Traffic Information on FM Radio** – The French are using a dedicated FM radio frequency throughout the country to provide travelers with traffic information. U.S. practitioners should consider the use of an FM frequency instead of the AM frequencies currently used in highway advisory radios.
- **Radio Data System Traffic Messaging Channel** – The Europeans have developed this technology to provide traffic information throughout the continent. It is a radio-based traveler information system that automatically tunes the radio to the appropriate frequency, regardless of current radio operation (commercial station, cassette, or compact disc), to broadcast the information. The system provides coded information that can be easily translated to the appropriate language for the vehicle's occupants, regardless of the source of the data.
- **MATTISSE** – MATTISSE is a travel information system being developed in England. Its primary purpose is the exchange of information among multiple agencies and jurisdictions so that travel problems can be addressed more efficiently. The information will also be available to the public.
- **Private Sector Collection of Traffic Data for Traveler Information** – Throughout Europe, team members observed many outstanding examples of private sector companies collecting traffic data and providing it to subscribers. An outstanding example of this practice was observed in Germany. TEGARON is a private-sector company that provides travel information to subscribers. Team members were impressed by the high standard of service provided by this company and the cooperative agreements between the company and transportation agencies.

ADMINISTRATIVE PRACTICES

These highlights of administrative issues are not a comprehensive listing of the many and varied inputs provided by transportation, transit, and research hosts the tour group had the good fortune to encounter. Our group collectively and individually will always be indebted to the many professionals in Sweden, Germany, France and England for their hospitality and willingness in sharing both successes and failures. In the recommendations presented in this report and any future pilots or implementation strategies, team members cannot overemphasize the need to fully consider the administrative side, as well as the engineering and scientific aspects. It will be particularly important to do a much better job of marketing and determining what the customers really desire. The engineering community has never been as efficient in this area as will be necessary to implement innovative traffic control technologies. As previously noted there are also significant differences in the European community, as there are remarkable similarities. Care should be taken in each recommendation and assessment of all administrative issues, as there will not be a true relationship between functionality and application in all cases.

IMPLEMENTATION EFFORTS

Team members began implementation efforts almost immediately upon their return to the United States in mid-May 1998. Within a month of returning, the team members had produced a six-page summary of the preliminary findings and recommendations. This summary, along with the many photos and videos that team members took during the trip, served as the basis for several early presentations on the trip. Table 5 lists the presentations that team members have made or planned regarding the trip.

Finally, a key element in implementing some of the team's recommendations will require some research to adapt practices and technologies to function within the United States. This process begins with the development of problem statements that can be submitted to research organizations. Appendix D contains problem statements that have been developed by team members.

Table 5. Implementation presentations.

DATE	LOCATION	GROUP/MEETING	TEAM PARTICIPANTS
June 1998	San Antonio, TX	AASHTO Subcommittee on Traffic Engineering	Lynwood Butner, Sterling Davis, Gene Hawkins, Peter Rusch
June 1998	San Antonio, TX	Research Committee – National Committee on Uniform Traffic Control Devices	Linda Brown, Gene Hawkins, Peter Rusch, Scott Wainwright
July 1998 to September 1998	Washington, D.C.	FHWA Office of Highway Safety FHWA Office of Research Development FHWA Office of Traffic Management and ITS Applications	Linda Brown, Mark Kehrli, Sam Tignor, Scott Wainwright
September 1998	Falls Church, VA	Institute of Transportation Engineers Joint Section Meeting – Washington, D.C. and Virginia Sections	Linda Brown, Lynwood Butner, Sam Tignor, Scott Wainwright
October 1998	Washington, D.C.	FHWA International Coordination Committee	Mark Kehrli
January 1999	Washington, D.C.	Transportation Research Board Annual Meeting	Gene Hawkins and Sam Tignor
February 1999	San Antonio, TX	American Traffic Safety Services Association	Linda Brown, Gene Hawkins
August 1999	Las Vegas, NV	Institute of Transportation Engineers	Gene Hawkins, Sam Tignor, Scott Wainwright

Chapter Eight

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Appendix A
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Samuel C. Tignor, the Team Leader, is Chief of the Traffic and driver Information Systems Division, Office of Safety and Traffic Operations, Research and Development for the U.S. Federal Highway Administration (FHWA) in McLean, Virginia. As Division Chief, he is responsible for planning, budgeting, promoting, coordinating, and executing transportation research. He currently manages research pertaining to traffic signs, marking, signals, lighting, work zone safety, railroad-highway grade crossings, and speed control. He has served in the Office of Traffic Safety Research Division in the FHWA for over 36 years. He completed his undergraduate degree, B.S.C.E., at the Virginia Polytechnic Institute in 1958. He earned his M.S.E. and Ph.D. at the University of Michigan in Civil Engineering with a transportation major. He is Professional Lecturer in Engineering at George Washington University and a Registered Professional Engineer in the District of Columbia. He is a member of the American Society of Civil Engineers, Institute of Transportation Engineers, Society of Automotive Engineers, Operations Research Society, is past chair of the TRB Committee on Travelers' Services, and a member of the TRB Group 3 Council.

Linda Brown is a Transportation Specialist for the Office of Highway Safety, FHWA. She is a member of the Traffic Control Device Team and the Outreach Team within the Office of Highway Safety. Her responsibilities include developing and interpreting traffic control device policies and standards, collaborating with colleagues in the research and implementation of improved traffic control device technology, providing technical assistance transportation organizations both nationally and internationally, and establishing marketing and outreach strategies for improving highway safety and traffic control operations. She has done considerable work on establishing the direction and contents for the upcoming new Manual on Uniform Traffic Control Devices which contains the principles for design, application, and placement of traffic control devices which aid the driver tasks of navigation, collision avoidance, and route guidance. Ms. Brown received her B.S. degree in Transportation and Business Management from the University of Maryland. She is a member of the Institute of Transportation Engineers, and Women's Transportation Seminar. She also serves as a committee member of the Transportation Research Board, and as the FHWA liaison to the National Committee on Uniform Traffic Control Devices.

Lynwood Butner is the State Traffic Engineer and Division Administrator of the Traffic Engineering Division at the Virginia Department of Transportation in Richmond, Virginia. He is responsible for the safe and efficient movement of people and vehicles over the highways of the State Virginia. He is also responsible for the development of the State's traffic monitoring system, rail and highway safety programs, the oversized truck assessment program, traffic calming development, roadway system inventory, specifications and design of traffic control devices, maintenance and publication of accident data, and the agency's Intelligent Transportation System initiative. Mr. Butner has over 25 years service with the Virginia DOT and has served as a junior and senior engineer, program supervisor, and Assistant Division Administrator. He holds an undergraduate degree from the University of Richmond and a Masters in Public Administration from Virginia Commonwealth University. Mr. Butner is a member of the Institute of Transportation Engineers (ITE) and past president of the Virginia Section of ITE. He has held numerous leadership positions in civic organizations and is a recipient of the Commissioner's Award for Excellence. Effective March 1, 1999 Mr. Butner has moved to the Virginia Department of Motor Vehicles as Assistant Commissioner, Motor Carrier Services.

Rich Cunard is the Engineer of Traffic and Operations for the Transportation Research Board (TRB) in Washington, DC. In this capacity, he is responsible for the technical activities undertaken at TRB related to traffic engineering and control, traffic operations, intelligent transportation systems, and automated highway systems. He has authored numerous technical papers and articles on traffic control, operations, and safety issues. Mr. Cunard has served with TRB for more than 9 years and has over 20 years of experience in traffic engineering and safety for public and private agencies. He is a graduate of Wayne State University with B.S. and M.S. degrees in Civil Engineering and is a licensed Professional Engineer. Mr. Cunard is active in several national and international professional associations and societies and serves on international technical program committees in the areas of intelligent transportation systems, traffic control, traffic engineering, and traffic safety.

Sterling Davis is the Engineer for Traffic and Safety for the Utah Department of Transportation in Salt Lake City, Utah. He is responsible for developing Statewide policies and procedures for the establishment and use of standardized traffic control devices on all State highways. He has almost 30 years of experience as an engineer with the Utah DOT, and served as a District Director in two rural districts for a total of over 16 years, performing the traffic engineering duties for those districts. He has a B.S. degree in Civil Engineering and a Master of Engineering Administration, both from the University of Utah. Prior to working with the Utah DOT he spent 6 years as a Civil Engineering Officer with the U.S. Air Force. He currently serves on the National Committee on Uniform Traffic Control Devices. He is a Professional Engineer in the State of Utah.

Ed Fischer is the State Traffic Engineer for the Oregon Department of Transportation. In this position he is responsible for providing Statewide policies and guidelines for all traffic control devices; preparing traffic signal, illumination, signing and pavement marking design plans for State highway projects; providing technical analyses for operational and safety improvements on all State highways; managing Statewide priorities for safety improvements and traffic signal installations; and providing assistance and traffic engineering information to the public, the State legislature, and other state and local agencies. While on this scan tour Ed was the

Regional Transportation Management Engineer for FHWA's Pacific Northwest Region. He has a Bachelor and Master of Science degrees from Oregon State University. He is a registered Professional Engineer active on several committees of the ITE, TRB and ITS-America.

Gene Hawkins, the Team Reporter, is an Associate Research Engineer and Program Manager at the Texas Transportation Institute (TTI) of the Texas A&M University System in College Station, Texas. At TTI he supervises and conducts transportation engineering research with an emphasis on driver communication through traffic control devices and freeway operations. Much of his research is focused upon various aspects of traffic signing. Dr. Hawkins has developed extensive expertise of the evolution of traffic control and the Manual on Uniform Traffic Control Devices and has published several articles on the history of that document. Dr. Hawkins holds three Civil Engineering degrees (Ph.D., M.E., B.S.) from Texas A&M University and is a Registered Professional Engineer in Texas. He is also an active participant in several national organizations including the National Committee on Uniform Traffic Control Devices, the Transportation Research Board, the Institute of Transportation Engineers, and the Highway Innovative Technology Evaluation Center. He is a member of committees in each of these organizations.

Mark Kehrli is the Team Leader of the FHWA's Office of Traffic Management and ITS Application's West Program Delivery Team which is responsible for aggressively supporting implementation of traffic management and traveler information services and strategies in FHWA's Region 8 (Colorado, Utah, Wyoming, North Dakota, South Dakota and Montana), Region 9 (California, Arizona, Nevada and Hawaii) and Region 10 (Washington, Oregon, Idaho and Alaska). Prior to his current assignment, he was the Regional Transportation/ITS Engineer for FHWA's Region 9. Before coming to FHWA in 1995, he worked for the New York State Department of Transportation for 11 years as a Traffic/ITS Engineer and has significant experience in the design, construction, operations/management, and maintenance of traffic control systems. He has a Masters of Engineering degree in Transportation Engineering from Rensselaer Polytechnic Institute and a Master of Science degree in Public Administration from Russell Sage College. He is a licensed Professional Engineer and a member of the Institute of Transportation Engineers.

Pete Rusch is the State Traffic Engineer for the Wisconsin Department of Transportation in Madison, Wisconsin. In this capacity he is responsible for the development of traffic engineering policy and standards for the design, use, and application of traffic control devices on Wisconsin's highways and for the regulation and control of traffic. Mr. Rusch has over 30 years of experience as a practicing Traffic Engineer within the Wisconsin Department, the last 6 years as State Traffic Engineer. Mr. Rusch is a member of several national transportation organizations. He is the Department's representative to the AASHTO Traffic Engineering Sub-committee, is a member of the AASHTO Standing Committee on Highway Traffic, and is a member of the National Committee on Uniform Traffic Control Devices. Mr. Rusch has also been an active participant on several NCHRP project panels including serving as the chair of the project Improve Traffic Control Devices for the Aging Driver. In Wisconsin, Mr. Rusch is a member of the Governor's Task Force on Highway

Traffic Safety and several other task forces with traffic safety as a key emphasis area. He is a registered Professional Engineer in Wisconsin.

Scott Wainwright is Chief of the Division of Traffic and Parking Services for Montgomery County, Maryland. He is responsible for all traffic engineering and public parking functions for this major suburban jurisdiction of 800,000 population in the Washington D.C. area. In this capacity, he sets policies and procedures for the design, installation, maintenance, and operation of all traffic control devices on over 2400 miles of county streets and highways. Mr. Wainwright has 29 years of experience practicing traffic engineering with operational public agencies. He has a B.S. degree in Civil Engineering from Virginia Polytechnic Institute and State University and an M.S. degree in Civil Engineering from the University of Connecticut, and is a licensed Professional Engineer in Maryland. Mr. Wainwright is serving a 3-year elected term as District 2 Director on the Institute of Transportation Engineers (ITE) International Board of Direction. He has been in ITE, TRB, and other professional organizations, authoring technical papers and textbook chapters, as well as serving on panels related to traffic controls. He is a longstanding member of the National Committee on Uniform Traffic Control Devices (NCUTCD) as an ITE delegate and is the Chairman of the Signal Technical Committee of NCUTCD.

Appendix B

AMPLIFYING QUESTIONS

The following topics and questions identify the key issues of interest to the scan team. They are intended to serve as a general guide to the host agencies in determining which technologies, devices, and systems to demonstrate to the team. Since the team members are not aware of all aspects of traffic control in the host agencies, the host agencies may want to identify other devices and technologies that the team might be interested in. These should be coordinated through the liaison contacts.

I. TRAFFIC CONTROL DEVICE SYSTEMS

A. There are some basic philosophical differences between European and U.S. approaches to highway transportation and traffic control. The team is aware of many of these differences, but would like the host agencies to summarize the basic objectives of their traffic control device systems, particularly as they relate to innovative traffic control devices and technologies.

B. Please provide team members with the key document(s) that establish the basic principles for communicating information to drivers, if such documents exist.

1. The major document(s) of interest is the one that establishes the basic principles for traffic control devices. (In the United States, this document is the Manual on Uniform Traffic Control Devices.)

2. Other documents that establish basic principles for specific applications (such as changeable message signs or in-vehicle signing) are also of interest.

3. It may also be helpful to see documents or brochures that are used to educate or inform drivers of new applications of innovative traffic control devices or technologies.

4. If any countries have performed evaluations of sign sheeting and/or pavement marking materials, it would be helpful to get copies of the reports so that they can be compared to our test results.

C. Have you implemented innovative technologies that are improvements to the traditional types of traffic control devices (signs, markings, and signals)?

D. How are innovative traffic control devices and technologies being used to integrate traffic control information on all modes of transportation (passenger cars, transit vehicles, trucks, trains, bicycles, and pedestrians)?

E. What provisions have European national and state transportation agencies taken to ensure/improve uniformity between innovative traffic control devices and technologies used in different agencies?

1. How do you promote uniformity between jurisdictions in the operational aspects of the systems?

2. How do you tie together applications of innovative traffic control technologies to form a coordinated system for presenting information to the driver?

3. How do you coordinate the presentation of information to drivers so that they have a seamless system (consistent presentation format) as they travel from one jurisdiction to another?

4. How do you address the language differences between countries as it relates to the presentation of information to drivers?

5. How do local agency applications of innovative traffic control relate to national applications?

II. REAL-TIME TRAFFIC CONTROL

A. Does your agency utilize real-time traffic control devices to convey information to drivers about any of the following conditions?

1. Work zones or construction affecting traffic flow.

2. Weather (fog, rain, snow, ice, or other).

3. Traffic congestion and recommendations for alternate routing.

4. Driver alerts to prevent run-off-road accidents.

5. Availability of parking at specific locations.

6. Travel time for specific segments of a roadway.

B. In providing real-time information, how does your agency perform the following?

1. Collect the information.

2. Determine the most effective means for presenting the information.

3. Communicate the information from the point of origin to point of presentation.

4. Coordinate the information from various transportation modes.

C. What technologies have you found to provide the most effective means of presenting the information to drivers?

D. How have transportation agencies responded to the increasing use of personal communication technologies (such as cellular telephones, pagers, and in-vehicle navigation systems)?

E. Have you implemented any in-vehicle technologies for providing real-time traffic control information?

1. What steps have you taken to ensure/improve uniformity between in-vehicle communication devices and roadside traffic control devices?

2. What inter-connecting systems do you use to tie traffic management centers to in-vehicle communication systems?

F. How is the private sector involved in communicating real-time information to drivers?

III. SAFETY ASPECTS

A. What innovative traffic control devices and technologies have been implemented with the specific intent of improving safety (reducing the frequency and/or severity of accidents)?

B. How do you assess the effectiveness of these applications?

C. How do you provide for driver education, driver familiarization, and driver utilization of innovative traffic control devices and technologies?

D. Are you using photo-enforcement to improve driver compliance with traffic control devices?

1. If you are, what has been the public acceptance of this type of enforcement?

IV. VERY HIGH SPEEDS

A. What provisions or accommodations do you make when implementing traffic control devices on highways with very high speeds (100 km/h and higher)?

B. How have you utilized innovative traffic control devices or technologies to improve the effectiveness of traffic control devices on very high speed roadways?

C. Does your agency use dynamic speed limits on any of its roadways?

1. How do you determine and establish dynamic speed limits?

2. How is this information presented to drivers?

3. Is it regulatory or warning information?

D. What special provisions, if any, do you make for the design and operation of traffic signals on very high speed roadways?

V. VISIBILITY AND LIGHTING

A. Please describe technologies and practices you have implemented to improve the visibility and legibility of traffic signs and changeable message signs.

B. How have you used innovative traffic control devices and technologies to improve the visibility of work zone traffic control?

C. How have headlight technologies affected the use of innovative traffic control devices and technologies?

VI. ADMINISTRATIVE ISSUES (information for managers and policy makers)

A. How have you addressed the following aspects of implementation of innovative traffic control devices and technologies?

1. What have you done to encourage public use of the various innovative traffic control devices and technology applications?
2. How do you assess the effectiveness of innovative traffic control devices and technologies both before and after implementation?
3. How do you address the issue of providing effective systems using low-bid equipment?
4. What problems have been associated with the implementation of innovative traffic control devices and technologies?

B. How does your agency prioritize innovative traffic control devices and technologies projects for competing needs?

1. What problems has your agency encountered with the training and retention of the qualified staff needed to implement and operate innovative traffic control devices and technologies?

C. How has the private sector been involved in the development and implementation of innovative traffic control devices and technologies?

1. Are systems financed by means other than by the government agencies?
2. How are the auto manufacturers involved in the use of in-vehicle communication systems?
3. What role has the private sector played in the deployment of the roadside infrastructure for major European implementation.

D. Have any particularly successful methods been used to educate elected officials and policymakers on the importance of traffic control devices and the need for priority in funding operation and maintenance of these devices?

E. What experience have you had with implementing innovative traffic control device systems over large and significant segments of highway?

Appendix C

CONTACTS IN HOST COUNTRIES

The following pages list the names of the individuals that the team met with during the trip. The team members wish to express their sincere gratitude to these individuals for their time and the valuable information they provided to the team. The listings are presented in alphabetical order.

ENGLAND

Highways Agency
- Bob Bannon
- Ian H. Beck
- Joe Burns
- Robert Castleman
- Richard Eastman
- Brian Harbord
- Ian Harrison
- Ken Hewitt
- John A. Kerman
- Hugh Maxwell
- B.S. Moore
- David J. Pike
- John Robinson
- Terry Sullivan
- Bill Wadrup
- Andrew Wilson

City of Birmingham
- Paul Welsh

FRANCE

COFIROUTE
- Jean-Pierre Boudin
- Guy Frémont
- Philippe Garnier
- Olivier Grillot
- Claude Humblot

Mairie de Paris (City of Paris)
- Gérard Briet
- Murièle le Marquand

Service dEtudes Techniques des Routes et Autoroutes (S.E.T.R.A.)
- Anne-Marie Barc
- Gilbert Batac
- Jocelyne Le Boudec
- Claude Caubet
- Francois Perret
- Joëlle Villanneau-Hamel

GERMANY

Bundesministerium für Verkehr (Federal Ministry of Transport)
- Jürgen Behrendt
- Stefan Drause
- Elvira Kretschmer-Bäumel
- Walter Kretschmann
- Hans Mundry

Bundesanstalt für Straßenwesen (BASt)
- Fritz Bolte
- Peter Krieg
- Hans-hubert mesebert
- Sylvia Piszczek
- Wolfgang Schulte
- Roland Weber

Hessisches Landesamt für Straßen- und Verkehrswesen (Hessen)
- Rolf Andree
- Gerd Riegelhuth

Tegaron
- Wolfgang Behnck
- Roman Eiber

WDR (West Duetsche Rundfunk - Radio Station)
- Uwe Platzek

SWEDEN

Enator
- Lars Jernbäcker

Institutet för Transportforsknig (Transport Research Institute)
- Jan Arfwidsson

Mobiplan
- Hans-Åke Pettersson

Vägverket (Swedish National Road Administration)
- Torbjörn Bidding
- Fredrik Davidsson
- Stefan Eglinger
- Philip Gustafsson
- Susanne Planath
- Bengt Anders Wiklund

City of Gothenburg
- Kjell-Arne Hellden
- Anders Kåbjörn
- Hans-Ake Pettersson
- Claes Westberg

Electroswede Co.
- Henrik Lewerntz

PEEK
- Michael Severs

Appendix D

PROBLEM STATEMENTS

The following pages contain problem statements developed by team members. These problem statements address some of the most significant recommendations contained in this report. Team members are willing to assist individuals in developing other problem statements that relate to issues described in this report or in modifying the problem statements in this appendix to meet the needs of an agency.

PROPOSED RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Review of Temporary and Long-Term Pavement Markings Practices

II. RESEARCH PROBLEM STATEMENT

One of the most notable differences in traffic control devices between the United States and Europe is how pavement markings are used. Recent scanning team members observed marking applications in all four countries and found numerous differences, especially in the use of color, work zones, horizontal messages, center line and edge line use, symbols, merging, diverging, intersection control, and pedestrian warning. The lack of yellow centerline median edge line pavement markings in Europe was very obvious. Differences in stripe/gap ratios were also observed between center lines and lane lines. Team members were impressed by many other pavement marking applications that are not extensively used the U. S. roadways. Examples include highway numbers(s) in the lane(s) in advance to the indicated highway; STOP and Yield markings at intersections and roundabouts; markings that indicate parking prohibitions; lane marking carried through the intersections; and multilane entrance ramp marking.

III. RESEARCH OBJECTIVES

Conductive an in-depth review of the pavement marking practices used in the U.S. and Europe for both long-term and temporary applications. This review shall seek research supporting information on their effectiveness in controlling and managing traffic, how easily they are understood by drivers, and the overall effect they have on driver behavior.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

18-months; $150,000

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

The FHWA Office of Highway Safety is in the process of rewriting the Manual on Uniform Traffic Control Devices (MUTCD) to propose changes that will enhance the mobility and safety of all road users, promote uniformity of traffic control application, and incorporate technology advances in innovative traffic control. The data gathered from this NCHRP study will provide a basis for including MUTCD standards for the use of pavement markings. The urgency of this study is also recognized because of the environmental issues associated with the use of certain types of pavement marking materials.

VI. PERSONS DEVELOPING THE PROBLEM STATEMENT

Linda L. Brown, FHWA Office of Highway Safety

PROPOSED RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Variable Speed Limit and Dynamic Lane-Use Control Signs

II. RESEARCH PROBLEM STATEMENT

Vehicle travel is increasing throughout the world, particularly in large urban areas. Accommodating the increased travel demand has led transportation officials to utilize a variety of innovative traffic control practices. Today's information age and technology advancements have raised the level of expectation of our road users and created much more savvy drivers. Road users have come to expect more and more from the highway system: more information, more options, and more quality of service. The challenge for transportation officials is to provide more real-time information to the road users. Providing real-time information through dynamic/ variable message signs has the potential benefit of making our highways safer and more user-friendly, and warrants consideration.

In May of 1998 a team of U.S. transportation officials visited four European countries (Sweden, Germany, France, and England) to explore and identify traffic control practices that may have current or future value to transportation agencies in the United States. Dynamic variable speed limit signs were extensively used in Germany and England to control traffic flow and improve safety. The speed limits are based on real-time traffic speed and flow data provided by loop sensors used to detect forming queues and slow moving vehicles occurring from incidents ahead. The speed limits are changed to provide the road user with real-time information regarding the prevailing traffic speed. This advance information provides the road user with more decision and reaction time. In addition, the installation of the variable speed limit signs over the travel lanes appears to improve the visibility of these signs from greater distances than the static speed limit signs found along the side of the road. When there is not an incident ahead, the variable speed signs are set at the normal advisory or regulatory speed and serve as reinforcement messages to remind drivers of the safe travel speed.

In addition to recommending an evaluation study for variable speed signs, dynamic lane-use control signs are also recommended for inclusion in this study. Overhead lane-use control signs help inform road users of the traffic conditions downstream. A red X designates lane closure situations, a yellow or white diagonal arrow designates lane merge situations, and a green down arrow designates open lanes.

III. RESEARCH OBJECTIVES

1. To determine what factors drivers use to determine the appropriate speed.

2. To determine if variable speed limits and lane-use signs smooth traffic flow and reduce rear-end collisions.

3. To determine if providing this type of real-time information helps improve driving tasks such as lane changing, sudden stops, and other erratic maneuvers.

4. To determine if the design and location of these signs improves sign visibility.

5. To study the merits of photo enforcement cameras used in conjunction with variable speed limit signs.

Tasks:

1. Review and critique available literature pertaining to variable speed limit signs and dynamic lane-use control signs used for providing real-time information to road users.

2. Convene a panel of experts including representatives from traffic engineering, law enforcement, judiciary, MPOs, DMVs, and human factors.

3. Develop comprehensive work plans and measures of effectiveness to determine the potential benefits.

4. Conduct controlled field studies to determine the impact and reactions of drivers, particularly older and younger drivers.

5. Prepare a public awareness effort to inform road users of the potential benefits, and promote the innovative technology.

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

The estimated funding for this project is $750,000. The research is expected to take 36 months to complete.

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

The FHWA Office of Highway Safety is in the process of rewriting the Manual on Uniform Traffic Control Devices (MUTCD) to propose changes that will enhance the mobility and safety of all road users, promote uniformity of traffic control application, and incorporate technology advances in innovative traffic control. The data gathered from this NCHRP study will provide a basis for including MUTCD standards for the use of dynamic message signs, particularly in the area of speed and lane-use control. The anticipated date for publishing the next edition of the MUTCD is September 2000.

VI. PERSONS DEVELOPING THE PROBLEM STATEMENT

Linda L. Brown, FHWA Office of Highway Safety

PROPOSED RESEARCH PROBLEM STATEMENT

I. PROBLEM TITLE

Software to Reduce Dilemma Zone at Signalized Intersections

II. RESEARCH PROBLEM STATEMENT

In a recent FHWA Scanning trip to Europe, the team was briefed in Sweden on a system they had developed to improve intersection safety. The system was based on a sophisticated system of detection and traffic signal controller logic which enables the change in right-of-way between opposing traffic movements to be based on assessing and minimizing the safety risks for traffic on the approaches which will be stopped. It is a dilemma zone enhancement which translates stopping risks and cross street queue development to a cost algorithm. Safety is a specific consideration in the control logic process. The objective is to reduce rear-end collisions by finding the perfect gap for the signal phase to terminate. This may be a useful application at high-speed U.S. intersections

III. RESEARCH OBJECTIVES

The objective of this effort is to assess the technical feasibility of using this type of intersection control to improve intersection safety, estimate the cost/benefit potential of the application, estimate how many U.S. accidents and fatalities could be prevented with this application, and determine if a field operational study should be initiated (under a separate effort).

IV. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

The estimated funding for this project is $100,000. The research is expected to take 18 months to complete.

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

VI. PERSONS DEVELOPING THE PROBLEM STATEMENT

Sam Tignor, FHWA Office of Safety and Traffic Operations R&D

FHWA INTERNATIONALTECHNOLOGY EXCHANGE REPORTS

Highway Information Management

National Travel Surveys (September 1994)
Traffic Monitoring (June 1996)
National Personal Transportation Studies (October 1993)
Acquiring Highway Transportation Information from Abroad—Handbook (1994)
Acquiring Highway Transportation Information from Abroad—Final Report (1994)

Intermodal Transportation

European Intermodal Programs: Planning, Policy and Technology (September 1994)

Pavement

Highway/Commercial Vehicle Interaction (1996)
South African Pavement and Other Highway Technologies (May 1997)
European Asphalt (1990)
European Concrete Highways (1992)

Policy

International Contract Administration Techniques for Quality Enhancement—
CATQEST (June 1994)

Safety

Pedestrian and Bicycle Safety in England, Germany and the Netherlands (October 1994)
Bicycling and Walking in the Nineties and Beyond (1994)
Highway Safety Management Practices in Japan, Australia, and New Zealand (June 1995)
Speed Management and Enforcement Technology (February 1996)
Road Safety Audits—Final Report (October 1996)
Road Safety Audits—Case Studies (October 1996)

Structures

Geotechnology—Soil Nailing (June 1993)
European Bridge Structures (1996)
Northumberland Strait Crossing Project (July 1996)
Bridge Maintenance Coatings (January 1997)
Advanced Composites in Bridges in Europe and Japan (October 1996)
Geotechnical Engineering Practices in Canada and Europe (March 1999)

Research and Development

Scanning Report on Advanced Transportation Technology (December 1994)
Snowbreak Forest Book: Highway Snowstorm Countermeasure Manual
(Translated from Japanese)

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FHWA COTR: Donald W. Symmes , Office of International Programs

16. Abstract

This summary report describes a May 1998 transportation technology scanning tour of four European countries. The tour was co-sponsored by FHWA, AASHTO, and TRB. The tour team consisted of 10 traffic engineers who visited England, France, Germany, and Sweden to observe traffic control devices and methodology and to determine if any European practices should and could be recommended for use in the United States. Team members included representatives from FHWA, TRB, Texas Transportation Institute, Montgomery County, MD, and the Departments of Transportation of the States of Oregon, Utah, Virginia, and Wisconsin. This report is organized into five key chapters: Traffic Control Devices, Freeway Control, Operational Practices, Information Management, and Administrative Practices. The material within chapters falls within two categories: Primary Findings and Other Observations.

The team noted a number of traffic control practices, from signing to speed control to information management that were being effectively used by the Europeans. Team members believe that many of these innovations could and should be introduced on U.S. streets and highways. Among the devices and practices recommended for further study for U.S. adoption are specific freeway pavement markings, variable speed control, lane control signals, intelligent speed adaptation, innovative intersection control, and variable message signs that incorporate pictograms. The report includes statements for proposed research problems.

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