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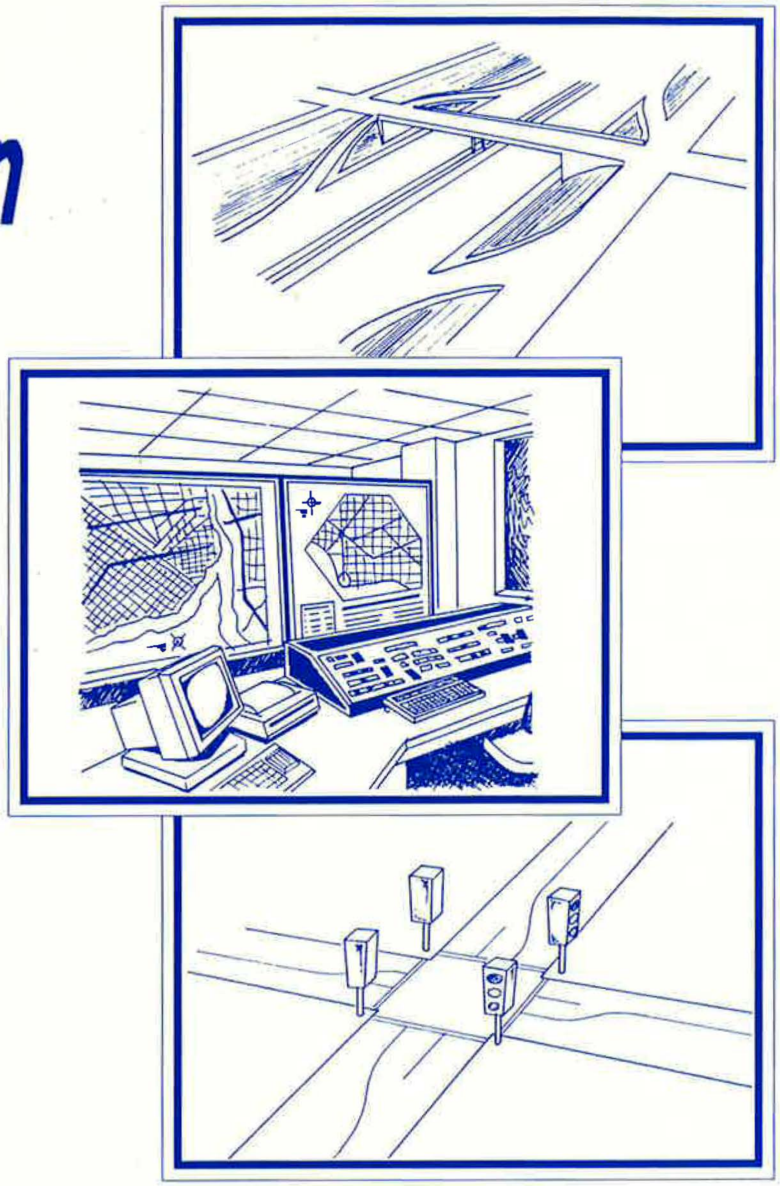
Symposium on Integrated Traffic Management Systems



June 24 - 26, 1992
Arnold and Mabel Beckman Center
Irvine, California

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SYMPOSIUM PROCEEDINGS

Symposium on Integrated Traffic Management Systems

June 24–26, 1992
Arnold and Mabel Beckman Center
Irvine, California

Presented by
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Federal Highway Administration

Symposium Proceedings

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Foreword

In most urban areas, the responsibility for operating and monitoring the overall transportation system is distributed among multiple agencies at the local, regional, and state levels. The operating policies and practices of these different jurisdictions are often determined independently, with little active coordination among the responsible agencies. However, the potential benefits of improved coordination are becoming apparent to transportation professionals concerned with maximizing the efficient use of the existing transportation system.

Transportation agencies within several urban areas have made significant progress toward coordinating activities related to facility implementation, system operations and maintenance, data collection, and incident management. More recently, those efforts have evolved into the development of integrated traffic management systems (ITMS). Integrated traffic management systems utilize advanced technologies to enhance the communication of information among multiple agencies, allowing for coordinated decision-making that maximizes the efficiency and effectiveness of the overall transportation system.

Planning, designing, and operating integrated traffic management systems is a complex undertaking involving multiple agencies and jurisdictions. In order to better understand the issues associated with implementing and operating these systems, the Transportation Research Board Freeway Operations Committee and Traffic Signal Systems Committee—in cooperation with the Federal Highway Administration—sponsored the *Symposium on Integrated Traffic Management Systems*. The symposium was held at the Beckman Center in Irvine, California on June 24-26, 1992. Its function was to bring together transportation professionals from the public and private sectors to discuss techniques and approaches for developing and operating integrated traffic management systems.

A diverse collection of issues were presented and discussed during the symposium. These proceedings contain the complete text of the keynote presentations and summaries of the symposium workshop sessions. Material is included on planning, designing, and operating integrated traffic management systems, as well as the use of advanced technologies, funding, and institutional issues. Innovative approaches being used by some agencies to address these and other issues are presented.

These proceedings represent a valuable resource for transportation professionals and others interested in the planning, design, and operation of integrated traffic management systems. Furthermore, it serves as a valuable source of information about the experiences of many current ITMS projects and plans for future activities to enhance the efficiency and effectiveness of urban transportation systems.

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J. Robert Doughty, consultant — presiding

Welcome Address

Irv Pickler
Anaheim City Council
Orange County Transportation Authority

I would like to take this opportunity to welcome you to Orange County, California. When I first came to California in 1945, we had no smog and no traffic jams. You are all aware of the problems that have developed in this area since that time with the rapid growth we have experienced. When I moved to the Anaheim area 37 years ago, we had a population of about 25,000. Today we have a population of some 280,000.

I think Orange County is one of the most dynamic areas in this country today. It is home to 2.5 million people. We currently face many problems that threaten the standard of living we have come to expect. Today, I would like to address one of those challenges: transportation. This is the area you have come to discuss over the next 2 days.

The street and freeway systems in Orange County provide the basic mobility for area residents and visitors. Although the traffic situation in Southern California is often the focus of numerous jokes, I want you to know we approach transportation in anything but a light-hearted manner. In fact, our attention to transportation has led us to be one of the most innovative areas in the nation.

I hold the unique position of viewing traffic problems from two vantage points. I am both a member of the Orange County Transportation Authority and the Anaheim City Council. As a member of the Orange County Transportation Authority, I can safely say that the passage of *Measure M* in November of 1990 has had a significant impact on the area. This countywide initiative added a half-cent sales tax to the county transportation funds for 20 years. This will raise more than $3 billion for a variety of transportation projects.

Forty percent of these funds have been allocated to freeway improvements, including the widening of the I-5 freeway and the addition of carpool lanes on other facilities. In addition, $350 million has been committed to the enhancement of the regional road network. This includes the creation of 21 super streets, covering 220 miles of the county's busiest roadways. Further, $650 million has been earmarked for local street and road programs that will address a variety of local road repairs and improvements. The remaining 20 percent of the *Measure M* funds will be used to develop and enhance a mass transit system. This mass transit system will include intercity and commuter train services between Orange and surrounding counties.

Recently, the Orange County Transportation Commission adopted a $710 million budget, the largest budget ever adopted by the agency. This level of funding is directly attributable to *Measure M*. Approximately 73 percent of the budget was comprised of *Measure M* funds. In this era when the popular cry is "no new taxes," the voters of Orange County are to be commended for the foresight and vision of approving *Measure M*.

I would also like to note that 3 years of negotiations recently culminated in the agreement by six Southern California counties to purchase 340 miles of existing railroad lines to use for a comprehensive commuter rail project. This $500 million acquisition has put Southern California on the fast track to develop mass transit rail service in a fraction of the time it would take to develop a project of this type from scratch. In fact, by 1993, we expect thousands of commuters to make the switch from driving alone to using the rail system. This will help relieve congestion on our freeways.

These are exciting times for transit projects in Orange County. We are tackling the challenges head on, with ample resources to solve many of the chronic problems that have plagued us for years. These are also exciting times at the local level. As a member of the Anaheim City Council, I have also had the opportunity to participate in the city's creative approaches to traffic problems. We need people like the transportation professionals gathered here today to help us solve these problems.

I believe the jewel of our efforts is the Anaheim Traffic Management Center. Don Dey was one of the key people that helped put the management system in place. This state-of-the-art system keeps millions of tourists, baseball and football fans, and local residents moving efficiently throughout the streets of Anaheim. From a single control center in central Anaheim, we are able to direct the flow of traffic at major intersections throughout the city with the use of real-time video cameras and sophisticated signal switching equipment.

For example, we can now empty a capacity crowd at Anaheim Stadium, which holds approximately 70,000 people, in about 45 minutes. Before the system was developed it took twice that long. The Traffic Management Center also includes a link to Caltrans and the University of California-Irvine. These links provide for the monitoring of regional traffic conditions.

These features have provided a good start to addressing our traffic problems. We continue to explore new technology to enhance our capabilities at the Traffic Management Center. In combination with other innovative projects, the Traffic Management Center has made Anaheim a leader in solving regional traffic problems.

It is fair to say that traffic problems will be with us for many years to come. With the continued cooperation between agencies and the growing use of advanced technology systems, we will meet these challenges today, tomorrow, and well into the twenty-first century. Thank you and enjoy your symposium.

Federal Highway Administration Perspective

Dennis C. Judycki
Federal Highway Administration

It is a pleasure to be here on my first visit to the Beckman Center. I was pleased to be asked about a year ago to participate in this symposium. I think the topic of traffic management is very timely. Certainly, the Federal Highway Administration (FHWA) is interested in promoting and encouraging integrated traffic management systems (ITMS). I would like to share with you some views of where we have been and where we are going in the future with traffic management systems. I very much look forward to learning from the other panelists who will address the state, city, and user views of ITMS.

The first question often asked is, What is an integrated traffic management system? This will

be discussed more fully this morning, but I think it is appropriate to note that the working definition often used is that it is an integrated system representing the organized management of arterial and surface-street traffic management systems and freeway operations and management systems. Although this may be viewed as a more traditional definition, it certainly includes both institutional and functional integration.

My view of the concept of what an integrated traffic management system should be has changed over time, in keeping with the changes we have seen in the transportation system and advances in technology. I think the context within which we view ITMS is much broader now and includes interface with such elements as advanced traveler information systems (ATIS). Certainly, the institutional issues influencing ITMS have evolved to include expanded public/private roles and partnerships.

The benefits of ITMS have been proven at the technical level. However, I think formal documentation of these benefits has sometimes been missing. The TRB Freeway Operations Committee has done a good job of documenting traffic management system projects and completing an inventory for North America. This is an important step in evaluating national experience and gaining insight into lessons that have been learned in different metropolitan areas.

Examples of the benefits of ITMS can be found in many areas around the country. The Long Island INFORM project reports delay savings in the order of 300,000 vehicle-hours a year and a 5 percent reduction in accidents on the Long Island Expressway, while a similar roadway had an increase of 13 percent. The Smart Corridor Project in Los Angeles has demonstrated the benefits when jurisdictional, institutional, and technical issues are addressed through ITMS. The expected return from this system is in the range of $24–32 million in user benefits.

Coalitions are being formed at the local and regional levels to provide a bridge for management and coordination between various levels of government. One good example of this is the National Incident Management Coalition. This group was formed in response to an understanding at the national level that technically and institutionally we know how to deal with managing incidents, but it was not receiving adequate attention from decision makers. The National Incident Management Coalition was structured to reach out and accomplish deployment activities at the national, state, and local level. Many other cities, including Chicago, Minneapolis-St. Paul, Seattle, and Anaheim, have also developed extensive integrated systems.

Even with these examples, however, we still need to do more evaluations, documentation of project benefits, and more demonstrations of the effectiveness of these systems. The results of these need to be made available to technical groups and to decision-makers. It is important to put a priority on operational issues. There are obviously barriers to doing this. These include institutional and financial barriers, as well as technical barriers. Many of these will be discussed during the symposium, and, I hope, new approaches will be identified.

The institutional issues have been discussed on many different occasions and the relationships between local, state, and federal agencies continue to be important. The formation of regional coalitions has been used as one approach in many areas. The new Intermodal Surface Transportation Efficiency Act (ISTEA) provides a much broader and enhanced role for metropolitan planning organizations (MPOs) in this area. The importance of MPOs as a partner in operational activities in metropolitan areas is now greater. Thus, we are experiencing changes in the institutional framework within which traffic management systems are planned, developed, and implemented. System integration must also be addressed, giving full consideration to the increased involvement of the private sector. In April, FHWA sponsored a symposium dealing with the public/private sector institutional issues associated with deploying intelligent vehicle-highway systems (IVHS). You will note that this is the first mention I have made of IVHS. Although what we will be discussing at this symposium is part of implementing IVHS; ITMS is an important subject on its own merits.

A number of conclusions emerged from the April FHWA symposium on public/private sector roles in deployment. One was the need for widely based education programs to provide a better understanding of the programs and opportunities for ITMS deployment. Another was the need for a "corporate" cultural change involving many public agencies. It was felt that the transportation community should help promote innovative approaches, especially in areas such as procurement procedures.

It was further suggested that the public sector needs to better understand the motivation of the private sector in IVHS development and deployment, and that we need to do a better job of identifying the costs and benefits to assure that a priority is placed on deployment. Public agencies need to establish relationships with IVHS technology industries. A number of financial barriers have also been identified, along with technical issues which should not be overlooked. All of these will be discussed at your workshop sessions over the next couple of days.

I would like to note a few recent FHWA activities in these areas related to ITMS. In 1990, FHWA examined the operation and maintenance of traffic control systems around the country. A total of 24 systems in 7 states were examined. The results of this study indicated that many systems were not being operated or maintained at the level of sophistication that they should be. This was not unexpected, but raised a significant level of concern. An internal panel at FHWA developed a series of recommendations to address the concerns resulting from this study. In addition, a panel of experts, some of whom are in this room, was formed to make recommendations from outside of FHWA. Ed Rowe chaired that panel and did an exceptional job, for which we thank him.

The recommendations from this group, which are documented in a final report, included developing minimum standards and skills for operations and maintenance staff, establishing procedures to fund long term operations and maintenance of the systems, developing staffing guidelines for the operations and maintenance of the systems, developing operations and maintenance guidelines and model plans, developing operations and maintenance guidelines for traffic control systems planning and design, the development of a new National Highway Institute course for operators, establishing a FHWA clearinghouse to distribute technical information on ITMS, the development of a task force to update FHWA procurement regulations, and facilitating the formation of regional traffic management committees. All of the recommendations and follow-up actions are included in a program plan that will be available soon for external review.

From a national perspective, ISTEA recognizes the importance of integrated traffic management systems. A number of new elements are included in this legislation. These include the increased funding levels and the philosophy that integrated operations should be an integral part of managing the transportation system. For the National Highway System, the ability exists to pay for operational activities associated with traffic control centers, incident management systems, and integrated systems for up to a 2-year period. Under the Surface Transportation Program (STP), operational activities are eligible, with no time limits or specific definitions for the operational programs. This is new eligibility and something you should be examining for possible application in your area.

Certainly, the IVHS program becomes important to eventual system deployment. IVHS funds are currently being utilized in three principle areas: research and development, operational tests, and, on a limited basis, deployment. The research and development program accounts for approximately $24 million of $234 million available from FHWA for IVHS this fiscal year. Most of the funds focus on operational tests. The criteria to be used in evaluating potential operational tests was issued in the *Federal Register* on May 8. The strategic plan developed by IVHS America includes further goals for the program and will serve as the point of departure for future areas of emphasis. We will annually solicit for operational test partnership initiatives. Early deployment funding at a level of approximately $5 million a year is also being provided to metropolitan areas which demonstrate a capability and interest in advancing projects such as integrated traffic management systems. As with operational tests, we will annually solicit for these deployment programs.

In closing, I would like to suggest that our challenge is to deploy integrated traffic management systems that are operationally seamless to our customer—the transportation user. The development, operation, and maintenance of these systems must be a priority. To this end, the symposium should help advance this challenge. It will, hopefully, instill fresh ideas and enthusiasm within each of us. FHWA looks forward to working with you to demonstrate the resolve of our profession to take advantage of the opportunities to deploy integrated systems. Thank you and good luck.

State Perspective

Ann Hansen
California Department of Transportation

I have been asked to provide a state perspective on ITMS. I would like to start by placing ITMS in the context of the mission described in the 1972 legislation creating the California Department of Transportation (Caltrans). This legislation stated that the mission of the department is to "provide transportation facilities and services which move people and goods at a reasonable cost and in an adequate, safe, and efficient manner."

By way of background, it is important to note that California has spent billions of dollars in building one of the best transportation systems in the world. In the San Francisco Bay Area alone, Caltrans now has a $20 billion investment in its freeway system. The investment in heavy rail systems like Caltrain and the Bay Area Rapid Transit System (BART) is $7 billion. Light rail systems—San Francisco's MUNI Metro and Santa Clara County Transit light rail transit—add another $2.3 billion. Major bus

systems—MUNI, Golden Gate, AC, SamTrans, and Santa Clara County Transit—account for an additional $5.5 billion. Add $200 million for ferries, and you have $35 billion invested in the transportation system to serve the needs of the 6.3 million people in the metropolitan area. This figure is substantially below the total cost of the system because it does not include all the money that has been spent on local streets and roads and some 20 smaller transit systems. Operating and maintenance expenses are also not included.

Unfortunately, the amount of funding available has fallen significantly behind what would be necessary to expand the system at the same rate as the growth in travel demand. In addition to the financial constraints, the social and environmental laws and concerns, primarily air quality in urban areas, will continue to limit construction of new freeways and highways severely and even the widening or improvement of existing freeways. Accordingly, the hours of delay experienced in urban areas are rising rapidly. In some areas, delay has gone up by as much as 25 percent in a 1-year period. Even with the tremendous construction program in the state, we have not been able to keep up with the demand in many areas. Continued maintenance of safety is in jeopardy. These problems exist on both local streets and roads, as well as on state highways, and some transit systems.

Although the primary responsibility of the California Department of Transportation focuses on the freeway and highway system, we are responsible to the citizens of the state to protect the investments in the existing system, maximize the carrying capacity and efficiency of the system, improve safety, reduce congestion, and improve air quality.

One of the most promising solutions for protecting this substantial public investment is through the development and operation of an integrated traffic management system. This can only be accomplished through a partnership of federal, state, regional, and local agencies along with many other groups.

One of the first things that the transportation and planning professionals have done is to establish a whole new vocabulary of acronyms which identify the traffic management system and its components. I am sure you all are familiar with many of the older acronyms like MPO, TIP, STIP, RTP, and AQMP. Some of the newer ones you will be hearing at the symposium include: TMS (traffic management system) or TOS (traffic operations system), ITMS (integrated traffic management system), IVHS (intelligent vehicle-highway system), CMP (congestion management plan), CCTV (closed-circuit television), HAR (highway advisory radio), CMS or VMS (changeable or variable message sign), EMS (extinguishable message sign), TMT (traffic management team), FSP (freeway service patrol), STP (surface transportation program), CMAQ (congestion mitigation air quality program), and TIP (federal transportation improvement program). Of course everyone is looking toward the ISTEA for funding to install ITMS and hoping it will help satisfy the requirements of the CAAA (Clean Air Act Amendments).

Earlier, I mentioned the importance of partnerships. ISTEA and recent California legislation are changing the process for planning, developing, and operating our transportation system. The planning and budgeting process is really a bottoms up rather than a tops down process, beginning with local agencies, called Congestion Management Agencies in California. These agencies are required to develop CMPs which consider the existing street and highway systems in their counties, the current levels of service, the desired levels of service, current and future land uses and their impact on the levels of service, and proposals for mitigating growth while maintaining or improving the levels of service. All projects which are to be proposed for inclusion in the regional TIP must be included in these county CMPs. The partnerships I mentioned earlier are needed to promote the cooperation and understanding necessary to develop these plans. Without this, there will not be a TMS because the necessary elements and projects will not be in the plan and ultimately may not be funded.

I believe the institutional problems associated with establishing ITMS are far greater than the technical problems. There are almost 100 cities in the San Francisco Bay Area and 9 counties. Some of these cities may have only a short freeway segment or one interchange within their city limits; but, if they want to block any portion of a TMS for parochial reasons, you are probably in trouble. You and your attorneys may think you have the authority to take an action affecting the state system, but there is always a judge or a legislator who says you don't. This can leave a lot of holes in any system, and a transportation management system with holes will not do a lot of the things we said it ought to do very well.

Metering is the most vulnerable to this thinking. Each city and county believes that the meter should be on the freeway so that the trip that originated in another jurisdiction has to wait in congestion, so that the local trip can get on the freeway without delay. The meter may take any form, either metering lights at the county or city limits or a geometric meter or bottleneck. Too few lanes to handle the demand will also do. Diverting trips off the freeway and onto local streets can also be controversial, even if it is just for a short distance or is done in response to an incident.

The equity issue is frequently raised with ITMS. Engineers can calculate how to operate the system to reduce overall delay and congestion, increase the capacity of the system, improve air quality, and identify improvements to mitigate impacts on local streets, but equity, like beauty, is in the eye of the beholder and doesn't yet fit into a computer model well. Hopefully, as people see how well ITMS can serve everyone, resistance will diminish and support will grow.

Caltrans has not accepted the reluctance of a few areas to recognize the benefits of ITMS and is proceeding ahead rapidly to upgrade and expand the systems in the Los Angeles and Orange County areas. Caltrans is also undertaking a $200-300 million series of projects in the San Francisco Bay Area, and is making major commitments in the other urbanized areas. Fortunately, many cities are realizing that it is important not only to keep the freeway system operating well, but also to make the local systems more efficient too. Thus, many are installing their own traffic management systems. Los Angeles and Anaheim have well-developed systems which are being expanded to increase the coordination and sharing of information with the Caltrans system. San Jose has initiated a TOS and is working cooperatively with Caltrans. Santa Ana has also requested funding for a traffic management system. Caltrans' districts are integrating their systems into regional systems and sharing information and TMTs, erasing district boundaries in traffic management.

The partnerships I mentioned previously are only a few of the many partnerships necessary to maximize the usefulness of ITMS. The coordination between different groups will be needed in many additional areas. For example, closer coordination between Caltrans and the California Highway Patrol (CHP) is being pursued. The state's traffic operations centers (TOCs) have always been staffed jointly by Caltrans and CHP. In some districts, offices which are separate from both the CHP and Caltrans main offices are being planned to be staffed by people from both organizations.

The information on highway conditions and incidents available in the TOCs is furnished directly to the media for broadcast to the public. The media also provides timely information to the TOCs. Smaller cities which are installing their own HARs are working with Caltrans to provide timely traffic information in their areas, utilizing EMSs to communicate with motorists to tune into a given radio frequency when incidents occur. Transit agencies are also expressing an interest in having a direct connection to the TOC's information system so they can adjust schedules and routes when necessary, and provide instructions to their drivers. In turn, transit vehicles can be used as probes and as a source of information on traffic conditions.

The motorist is now providing a significant amount of information to the TOCs in the form of 911 calls from cellular phones and call boxes along the highways. In California, the CHP answers all these calls, and the information is fed immediately into the information system for the TOC.

Caltrans, the CHP, and the Metropolitan Transportation Commission in the San Francisco Bay Area and the Los Angeles County Transportation Commission, are jointly responsible for the freeway service patrols providing help to stranded motorists on the freeway system.

Caltrans has provided considerable funding to the University of California for research in IVHS as a part of the Partners for Advanced Transit and Highways Program (PATH). The research program involves work by several universities, Caltrans districts and the Office of New Technology, regional and local agencies, and the private sector. Universities which are currently involved are UC-Berkeley, UC-Irvine, UC-Davis, Cal Poly San Luis Obispo, University of Southern California, and Stanford. The private sector involvement includes professional consultants, major development and manufacturing companies, and small entrepreneurs. Some of the areas being studied or scheduled to be studied are computer simulation, methods for detecting incidents, closed-circuit television, on-board navigation systems, automated vehicle control, automated vehicle identification and location systems, information and communication systems, common and uniform data base for mapping, public policy, and organizational structure. There are tests beds in both northern and southern California.

Clearly, the state is developing an integrated traffic management system. It is investing a large amount of money in this system and expects to see the benefits to the general population both economically and environmentally. The system will be dynamic and flexible, expanding to accommodate new technology as it is developed and tested. The degree of success will depend on how well all the existing partners continue to work together cooperatively and the active participation by new partners.

Local Perspective

S. Edwin Rowe
Los Angeles Department of Transportation

Over the last year we have had a number of conferences on IVHS, traffic management, and integrated traffic management systems. The number of representatives from cities attending these conferences has been low. This has been a concern to many of us who realize the important role cities must play in ITMS. I am pleased to see a number of representatives from city departments in attendance today.

I would like to discuss what I see as some of the major issues associated with ITMS from the perspective of local jurisdictions. My opinions on many of these issues are based on experience with managing transportation during the 1984 Olympics in Los Angeles. This provided the opportunity to bring together all of the relevant operating agencies to develop and implement a full scale transportation management plan. Although we did not have many of the high technology tools that are available today, the program was very successful.

I have also been involved in the development and deployment of the automated traffic surveillance and control system (ATSAC) in Los Angeles over the last 10 years. Many of the features of this system represent the elements that will be needed in ITMS in the future. We have also been working with Caltrans, the California Highway Patrol, and other operating agencies on the Smart Corridor demonstration project. This will be the first project to apply all of these advanced technologies in an integrated traffic management system.

From a city perspective, I think the major issues related to ITMS include the organization of the various agencies, the system architecture, traffic monitoring requirements, development of the appropriate strategies, the increased levels of automation needed to operate the systems, the increased use of different media for traveler information, and the responsibilities of operation and maintenance personnel. I would like to discuss each of these briefly.

The major organizational question is who is in charge. In the case of the Olympics in Los Angeles, we decided to manage the transportation process by consensus. The jurisdictional responsibilities remained the same, but different activities were managed through the use of policy and technical committees that met on a regular basis. This organizational form worked very well and is also being used on the Smart Corridor demonstration project. A similar structure could be used with ITMS.

System architecture represents a technical issue. For the Olympics we started with a top down approach, focusing on a multi-jurisdictional traffic management center. Linked to this center we had the single jurisdiction operating centers and their field command post units. During the Olympics, most of the decisions were made at the field command post levels, with few decisions actually made at the top level. Thus, I think it is important to look at the costs and benefits of developing a traffic management center that attempts to include all agencies. It may be more appropriate and cost effective to link the existing operations centers, rather than design a whole new center. However, it is critical that all the people in the different operating centers see the same traffic picture based on the same information.

To accomplish this in the Smart Corridor demonstration, a centralized data base has been established that provides the same information to all participating agencies. All of the information collected through the detectors and other networks flows into the respective operating centers and then into the centralized data base. What is important about this data base is that it fuses all available information from all the participating agencies to provide one composite picture of traffic conditions. This information is then made available to all participating agencies. It doesn't really matter where the central data base is located, as long as the communication links are there.

One of the deficiencies in many local areas is the lack of ability to monitor local traffic. Freeway monitoring has been in existence in a number of areas for many years. In an integrated traffic management system it is critical that information on the status of traffic conditions on local streets be available, since traffic may be diverted to—or encouraged to use—surface streets. Thus, there needs to be a better balance between the capabilities of the surface street system and the freeway system.

One scarce resource in many communities is the traffic engineers and technicians that will be needed to operate and maintain these systems. The increased responsibilities that come with ITMS will necessitate greater use of automated systems and special training for the personnel needed to operate and maintain these systems. It will also be important to look at the development of expert systems for unusual events. We need to look beyond recurring congestion, respond automatically to these to unusual events, and provide a decision support mechanism for the operators. These may include very complex situations, which will need to be supported by some type of expert system.

Adequate benefit analyses of ITMS are also lacking in most jurisdictions. Evaluations of ITMS often do not go beyond simple before-and-after studies. The costs and labor required to prepare these analyses are commonly mentioned as limiting factors. This is one area where we need to do a better job in the future. The levels of automation included in ITMS should help with these evaluations. These evaluations will be needed to assist in considering future alternatives and responding to questions from decision makers.

An important function I would like to mention is providing priority to transit vehicles. This has not been given full consideration in many metropolitan areas around the country because of the adverse impacts on cross-street traffic. Through the use of traffic-adaptive control techniques, however, we should be able to enhance the operation of transit without hurting other traffic.

Traveler information represents an area that has not been exploited fully. Many areas use changeable message signs and the radio and TV media to provide information to travelers. With ATMS and ATIS, there are many new opportunities to make information available to the traveling public for pre-trip planning and in-route decisions. This is critical to really achieve the potential of ITMS.

The development and agreement among the different agencies on the traffic management strategies to be pursued is a critical step. Development of specific strategies involves resolving a number of sensitive issues relating to traffic diversion, ramp metering, incident response, accident and enforcement policies, and traveler information. Reaching an agreement on these difficult issues is critical to the development of a successful ITMS program. A traffic management matrix can be used to document these plans. Maintaining flexibility to respond to rapidly changing highway conditions during incidents is essential.

The concern about operations and maintenance has already been mentioned. This is indeed a nationwide concern. If operating and maintaining our existing systems is a problem, just think of the problems we will face with much more complex systems in the future. The recommendations made by the FHWA panel address a number of issues in this area. These include the need for specialized ongoing training for local agency staff, additional personnel with expertise in new areas, organizational changes, and additional funding.

In conclusion, it is my view from a city perspective that we can integrate local systems with those of other agencies at the regional and state levels and still maintain adequate local control over the system. In doing this we will have to provide a greater emphasis on traffic monitoring, reach agreement among agencies on traffic management policies and approaches, implement greater automation of all needed functions, and reexamine a broader range of techniques to communicate with the traveling public. If we can do this, the pay-off will be the more efficient utilization of our roadway system at a time when we can not afford to add new highways in many metropolitan areas.

User Perspective

A. Keith Gilbert
Automobile Club of Southern California

I have been asked to discuss the benefits of ITMS from the users' standpoint, the institutional issues that will need to be addressed, and how the general public and groups like the Auto Club can better interact with state and local governments. In order to do this, I would like to start by providing you with an idea of how ITMS is viewed from the users' perspective.

Often the highway users' perspective is being stuck in traffic behind a truck without being able to see the highway signs or anything else. Further, the users' perspective in Los Angeles is often dominated by construction activities. I was pleased to note in the white papers that construction traffic management is one of the elements of ITMS. I think that Cal-

trans has done a good job in utilizing some very effective traffic management programs. I think these are more important from a users' perspective than a few seconds saved at a traffic signal or some other program.

Ramp metering is also an element of ITMS. I have not heard many complaints from users about ramp metering in the Los Angeles area. This may be because people are starting to get used to the meters. This also holds true for the use of HOV ramp by-pass lanes and HOV facilities, although we do hear a few more complaints about these types of facilities. I think users appreciate the benefits of spacing traffic and improving the flow of traffic that these types of facilities provide. I think the user perspective also focuses on busy intersections in our urban areas.

I think safety is a very important issue for users of our roadway systems. I think we can all be proud of the progress that has been made in the area of highway safety. For example, although the annual number of fatal accidents occurring in California between 1981 and 1990 has remained relatively constant, fatalities per 100 MVMT has dropped from 3.2 to 2.0. There are a number of reasons for this, including more extensive use of seat belts, DWI programs, safer vehicles, and safer highways.

The question is, How much better can we get? I have been looking toward IVHS as one way to keep the accident rate from increasing in the future. I think it is important to look at the safety aspects of ITMS. For example, if we divert motorists away from congested freeways to avoid an incident, are we taking them from one kind of safety environment to another?

Operations and maintenance is another major issue area that users are concerned about. There is a session that will focus on this topic tomorrow. Given its importance, it may have been appropriate to have scheduled this as one of the first workshops. The Auto Club is very concerned about traffic signal operations and maintenance because it relates to both benefits and operational issues. The user bears the brunt of poor signal management and operation. The Auto Club has printed a booklet on this problem because it is such an important issue.

I would like to suggest that careful thought is warranted as we approach many of the "whiz-bang" ideas associated with IVHS and ITMS. This is especially important at a time when maintenance of any kind is coming under the gun due to limited budgets. If the loops don't work, it doesn't matter how well integrated your signal controllers are. The user is the ultimate loser in this.

Another concern I have is how we will measure the benefits of IVHS and ITMS. This is not a new issue. It has been raised regarding TDM, congestion pricing, IVHS, and other programs. The user may not comprehend what a term like "experimental design" means, and may not care. It is the user who is paying the bill for these systems, however. Thus, the user deserves some assurance that these systems and programs are providing their money's worth—that they will indeed see benefits.

I fear that many of our grand schemes are littered with speculative and unproven benefits. These are often promised without informing the users that these will be achieved only if accompanied by radical changes in travel behavior. Thus, many of these programs may be based on unrealistic expectations, because we have not shown that we can truly deliver the projected benefits. As we move forward with ITMS projects, it is important that we focus on presenting a realistic picture of the benefits of ITMS. We also need to distinguish between demonstrations, where we are simply trying to show that we can develop and operate system elements, and field experiments, where the impacts and benefits are being measured and evaluated.

I think the institutional issue that concerns me the most relates to the "B" word—bureaucracy. It is no secret that we are in an era of mistrust in government. This has been evident here in Orange County and in other parts of the country. So far, however, I think we have been fairly successful in the transportation field at keeping transportation in a good light in the public eye. For example, we have been successful in California in getting increased funding for transportation projects approved at the state and local levels. There are a number of reasons for this. The agencies that are receiving these funds are viewed as performing well. Caltrans continues to set new records in getting projects out for contracting and here in Orange County the development of the Route 55 carpool lanes was done in record time.

As new projects come on line, however, we have to be aware of numerous new issues and requirements. Both ISTEA and the Clean Air Act Amendments are spawning new programs, new regulations, new fees, new permits, and new required approvals. As we move forward with ITMS we should be careful to streamline, to coordinate, and to consolidate, rather than build weighty new governmental structures.

Over the course of the symposium, I think you will hear a number of good examples of solutions to the institutional issues associated with ITMS. These include the Smart Corridor project, the Anaheim Traffic Management Center, and the Los Angeles Freeway Service Patrol.

There are number of other points I would like to cover relating to the need to look beyond just smart corridors to focusing on whole smart systems, the short-term tools for managing congestion offered by ITMS, and the somewhat disappointing results to date for many voluntary ridesharing and TDM programs. However, let me close by offering one final observation. Although it is important to understand the federal, state, and local perspectives, it is really the user that is the client we need to focus on. We need to pay attention to the needs and wants of the customer and how they are willing to behave. The most successful businesses are those who know their customers and meet the needs of these customers. I think ITMS has the potential to be the ultimate public/private partnership with the public providing the systems in response to the needs of the private users.

Session Two
Presentation of ITMS White Papers

Leslie N. Jacobson, Washington State Department of Transportation — presiding

What is ITMS?

Herman E. Haenel
Advanced Traffic Engineering

I would like to thank Les Jacobson for his assistance as a co-author of this paper. The ISTEA and the Clean Air Act Amendments have provided needs and challenges for close cooperation between governmental agencies within urban metropolitan areas. Further, the predictions for increasing congestion support this need for cooperation between city, county, state, and federal agencies. Studies have shown that if nothing is done to relieve congestion, delay on freeways will increase by approximately 430 percent within 20 years and delay on city streets will increase by approximately 240 percent.

During the 1970s and early 1980s, TSM projects improved traffic operations considerably, even though many were provided only on a piecemeal basis. During the 1980s, however, congestion began to increase significantly. Today's traffic and transportation requirements challenge agencies to view the transportation network as one system and to begin integrating many aspects of the urban transportation system. It is necessary to view the transportation network as one system and to bring together and coordinate as many aspects of transportation management as possible.

Further, the opportunity to develop integrated traffic management systems is with us at present. Many systems developed under the federally-funded TOPICS program for improving traffic operations are becoming obsolete. Also, developments in automating traffic management for public transportation have increased significantly, providing further opportunities to bring transit within an integrated system. Communication capabilities and systems have improved. Telecommuting, through the use of satellite offices, makes it easier to route traffic over short distances. All of these elements, and others, make this an opportune time to develop ITMS.

ITMS brings together all aspects of transportation management within a community. We often think of ITMS as coordinating hardware with software elements, traffic signal systems with freeway management systems, and motorist information systems. These are all parts of ITMS. However, they are not the only elements of ITMS. In order to carry out ITMS as a coordinated operating system, it is necessary to bring together all aspects of traffic management. These include the following four elements: an integrated approach to transportation management, resource integration, sharing information, and integrating hardware and software systems.

The way in which we view the transportation system is one of the critical elements of the ITMS concept. Everyone involved must believe that the entire metropolitan network will function as a single system. This includes administrators, managers, planners, traffic and transportation engineers, and the operators of these systems. All of these people and their agencies must work together, cooperate, and support each other for a successful program. Institutional issues between these groups must be addressed and overcome.

The integrated approach to transportation management draws together all efforts to create a balanced system. For example, when congestion is severe, the demand can not be accommodated with only modified control strategies. Motorists must be encouraged to change routes, change modes of travel, or change travel times. Assistance must also be provided to motorists when incidents occur and accurate information must be provided to other motorists on the facility. Further, if motorists are informed, they must be able to change routes and have adjustments made to traffic signals and freeway traffic controls for rapid movement to their destination.

Research also represents an important part of the integrated approach to transportation management. Research will become even more important as we move forward with the development and operation of ITMS. Research is needed in all phases of ITMS and will play an important role in solving problems that will emerge as we move forward with development. Research feeds design and implementation. Design and development in turn provide input for future research.

Training is another important area to be addressed in implementing ITMS. Training is needed to ensure that the results of research studies are properly implemented and that systems are properly designed, operated, and maintained. Ongoing training will be needed to keep pace with changing technologies.

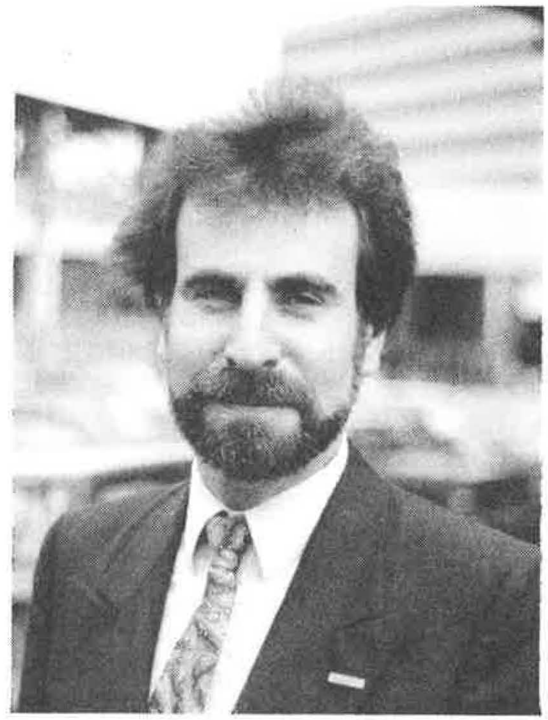
The second area is resource integration. Resource integration involves the integration of facilities, personnel, and financing. These resources apply to combined planning, development, and use of HOV lanes, integrated communications, and traffic control centers. Resource integration will reduce the lifetime costs for all systems and provide optimum pay back.

The coordination of the transportation system in Houston provides one example of resource integration. A regional freeway corridor traffic management system has been designed for the Houston/Galveston metropolitan area. Each freeway corridor is designed for the use of one fiber optic cable as a "backbone" for a communications system which will serve the HOV and freeway general purpose traffic lanes along with the frontage roads and freeway corridor street network. The concept has also been designed for one traffic management center which can house the city, county, state, and public transportation personnel. Also, the financing of the project is being coordinated to provide reduced costs to the taxpayer.

The third area is information exchange. It is imperative that agencies share information. We must develop and maintain communication, cooperation, and coordination between all agencies. This can be carried out through periodic meetings, and the utilization of management teams to permit engineers, planners, enforcement personnel, and other groups to share information and jointly solve problems. Further, historic traffic and accident data must be shared to develop an ongoing traffic data base for making system improvements, and real-time information must be shared to permit rapid response during incidents, recurring congestion, and changes in traffic patterns.

The fourth area is the traffic management system. Traffic management systems must be designed to ensure that traffic leaving one traffic control system can be accommodated by the adjacent system. Also, motorists must be given accurate travel information so that they can make proper decisions. This can be done through the integration of the freeway, HOV, arterial street, travel information, incident management, and IVHS systems. ITMS systems need to be capable of adding new emerging advanced technologies. Thus, we need to design our systems today with the future in mind.

In closing, I think the integration of traffic management systems is a must today. ITMS will be increasingly important in the future. Communication, cooperation, and coordination will be required to accomplish this. All agencies must focus on developing and operating these integrated systems in a coordinated and comprehensive manner. These agencies and their personnel must think of ITMS as one system. A balanced system must focus on the four elements I have discussed: integrated transportation management, resource integration, information sharing, and integrated traffic management systems. We must begin today to develop ITMS to reduce congestion, emissions, fuel consumption, and accidents.



Institutional Issues of ITMS

Matthew Edelman
TRANSCOM

I would like to introduce the co-author of this white paper, Sergeant Paul Einreinhofer from the Bergen County, New Jersey Police. I think the fact that Paul is a co-author shows that local agencies can think in a regional perspective when dealing with ITMS. To twist around a much quoted quote, he acts locally and thinks regionally.

I would like to use TRANSCOM and the New York/New Jersey area to give you an example of why we need to think regionally in the development and operation of ITMS. I will use the example of a trip from Rockland County in northern suburban New York to Queens in NYC to show this.

To make this trip you would first use the New York State Thruway, owned by the New York State Thruway Authority, with incident response provided by the New York State Police, and pay a \$.40 toll at the Spring Valley toll barrier. Second, you would use the Garden State Parkway owned by the New Jersey Highway Authority, with incident response provided by the New Jersey State Police and pay a \$.35 toll at the Hillsdale toll barrier. Third, you would get on Interstate 80, owned by New Jersey DOT, where incident response is provided by the New Jersey State Police. Fourth, you would use the New Jersey Turnpike Authority's Eastern Spur, paying a \$.45 toll at Interchange 17W. You would then get on Route 495 East, a New Jersey DOT facility, where incident response is provided by a combination of local police. At the Lincoln Tunnel, operated by the Port Authority of New York and New Jersey, you would pay a toll of \$4.00 (round-trip) and enter into NYC. Once in Manhattan, you are on streets under the jurisdiction of the New York City Department of Transportation. Once you cross Manhattan, you go through the Queens Midtown Tunnel, which is run by the Triborough Bridge and Tunnel Authority, and pay a \$2.50 toll. This provides access to the Queens Midtown Viaduct and Long Island Expressway, where incident response is provided by NYCDOT and the New York City Police Department, and the highway is owned by the New York State DOT.

Obviously, as we move into ITMS, new institutional solutions are going to be required to address the issues of multiple players I just outlined. In the case of the New York metropolitan area, it goes without saying that we will not see the legislatures of New York, New Jersey, and Connecticut meeting jointly and merging their three states for the benefit of traffic management. Thus, we must deal with the world the way it is. An organization like TRANSCOM, which recognizes the autonomy of these different agencies, serving to coordinate their activities, represents one approach. We often call ourselves the United Nations of traffic and transportation. We do not say this in a frivolous way. Like the U.N., we have a good deal of responsibility, but we also have no authority to carry out our work. Thus, our approach is all based on cooperation.

TRANSCOM has 14 member agencies, which includes the major police departments, toll authorities, DOTs, and transit agencies in the region. We will soon be increasing to 15, with the addition of the Connecticut DOT at the end of the year. The functions provided by TRANSCOM include incident notification, construction coordination, and incident management planning, all implemented by an operations information center (OIC) that is open 24 hours a day. The OIC links major highway facilities, transit agencies, state and local police agencies, and the broadcast media services. These agencies are linked by alpha-numeric pager, telephone and fax. The information is sent selectively, each agency receives an alpha-numeric page only when there is an incident that affects them.

TRANSCOM is governed, staffed, and funded by its member agencies. The current chairman is the Executive Director of the New York State Thruway Authority. From managing a regional consortium, I have learned that it is critical to have not only the support and involvement of the CEOs of the various agencies, but also the operating staff. The people at the operating level need to believe in the importance of sharing information and alerting others when an incident occurs on their facility. When an agency calls in an incident to TRANSCOM, knowing that TRANSCOM in turn will give them back important information on other agencies' facilities, they realize that acting in one's self interest and the regional interest are not mutually exclusive.

In terms of motivation, we have also learned that enforcement agencies may be more resistant initially to thinking in a regional perspective than their engineering colleagues. We have found that once they realize the benefits of taking a regional approach, though, police become the most enthusiastic supporters.

We also have put together a complete working inventory of the variable message signs and highway advisory radio systems of all the participating agencies. These currently represent a wide mix of types and capabilities. The key is to get all of the organizations to work together in providing needed information and respond in a regional manner.

The white paper includes a discussion of construction coordination. I think this reflects an important aspect of team-building for ITMS. Organizing interagency scheduling and coordination during construction and reconstruction can be difficult because each agency is charged with getting their projects done on time and in budget. The trust that develops when agencies realize the operational and political benefits of construction coordination can carry over into the implementation of ITMS as well.

The administrative people in the different agencies—human resources, accounting, MIS, purchasing, auditors, and legal—are another group of people you need to reach out to in developing new institutional arrangements for ITMS. We have found that these groups are very important in making sure the programs operate smoothly within and between organizations. Because these groups are detached from ITMS operations and planning, they often are less aware that implementing an ITMS takes far more interagency involvement than other projects. With this involvement comes a need to be more flexible about procedures. By probability, there will be some mutual exclusiveness among the regulations of the agencies involved. One of the best approaches is to ensure that you have a good contracts attorney. We have a great one and it really helps set the tone for flexibility by all parties involved.

Funding ITMS

Alan Clelland
JHK & Associates

The white paper focuses on the funding approach that has been used in Orange County. However, I would like to take a more practical approach this morning and provide an overview of how an agency can prepare for coordinating funding for an ITMS program, using Orange County as an example.

Orange County is networked by a series of freeways which reflects the tremendous growth experienced in the 1980s. In order to better address this growth, Caltrans split the Los Angeles/Orange County area and established an Orange County district, District 12. However, the new district remained dependent upon District 7 for their traffic management system.

Recently, the district has been making significant steps to establish its own Traffic Operations Center (TOC). Currently, there is also a movement toward the use of toll roads which introduces and adds to other opportunities for funding of the District 12 TOC and Traffic Operations System (TOS).

A number of agencies are involved in traffic management in the Orange County area. This includes agencies and organizations that were involved in Mobility 2000, are active members of IVHS America, and pioneered the use of various traffic management and motorist information systems. The regional agency, the Orange County Transportation Authority (OCTA), is also very supportive of the local agencies. For many years, the OCTA has convened a regional signal round table where traffic engineers from the various local agencies can get together on an *ad hoc* basis and discuss relevant concerns. This combination of progressive regional and local agencies has provided a good basis for many of the activities currently underway.

The current traffic management systems in the area include freeway surveillance, changeable message signs, the use of highway advisory radio, motorist information systems, and the information links between Caltrans District 12 and traffic management centers in key cities and the county. So, you can see the multi-agency nature of the program in Orange County.

As a result of Orange County's growth, there is demand for communication links throughout the county for surveillance and motorist information. One of the key elements of the Orange County Operations Study was the need for an action plan for the development and deployment of ITMS. This is especially important to bring together all the different agencies and to make sure they are all working in a coordinated way. The action plan should be the foundation for the multi-agency coordination. A different form of cooperation is needed at this stage than the cooperation needed during the operating phase just described by the previous speaker. You need to ensure that all agencies are moving forward on the same schedule and implementing each part in a coordinated fashion. The action plan should address this interdependency of components, identify costs, and clearly identify the responsibilities of the different agencies.

I would like to briefly review the action plan that was developed for the Orange County study to give you an idea of the major components. ITMS by its very nature is a complex system. The key to implementing ITMS is a phased approach. You should not try to take everything on at one time. This helps reduce the complexity of the program and provides realistic goals. This approach also reduces the risks of deploying IVHS—both technical and political. If the project is not a success initially, you may find additional political barriers and issues to address. The implementation plan must address the interdependency of the different elements, but identify ways that each can be implemented individually. Finally, everyone likes success. It is important to identify early winners, as this will make it easier to move to the next step.

The Orange County study identified each step, the responsibilities of each agency, and the schedule. These were incorporated into a summary to show how each of the individual elements could be scheduled for deployment. This helped each individual agency understand what elements it was responsible for and the time line for implementation.

The questions associated with costs and funding were then addressed for each of the system elements. These were shown on an annual basis to provide a clear picture of the funding required from each agency. This helps focus on potential funding sources. The regional agencies have been instrumental in assisting with identifying potential funding sources. Having identified possible funding sources, the next step is to examine the selection criteria. This is especially important with the competition for funds under ISTEA and other programs. Cities and agencies are competing against each other to secure funding that is becoming available. It is important to know and understand the criteria, so that you increase your chances of funding. If you have any questions or concerns, be sure you check with the funding source. Personal contact can help solve a number of problems.

One of the sessions tomorrow focuses on funding, so I won't spend a great deal of time discussing the different sources. The key element in funding is to understand how one source may impact another source and how you can leverage your funding to obtain the maximum benefit for your project. Often a small amount of local funding can be combined with regional or state funds to leverage federal funds. Local sources may include fees on new development, trust funds, toll revenues, sales taxes, and local motor vehicle registration fees. At the state level, potential funding sources include gasoline taxes, independent IVHS research funds, motor vehicle registration fees, and the Petroleum Violation Escrow Account. Sources at the federal level include ISTEA, specifically those programs associated with the National Highway System, the Surface Transportation Program, and IVHS research.

The next step is to match the different funding programs with the appropriate system elements. Given the dynamic nature of the funding programs, it is important to continue to monitor these programs and make changes as needed. The main source of funds for the Orange County ITMS has been the state TSM program. This program has been very successful in funding a variety of components of ITMS.

In closing, I think there are a number of lessons that can be learned from the work being done in Orange County. These include establishing a good working relationship between the local, regional, and state agencies, developing a comprehensive implementation plan, and identifying a realistic funding program.

Session Three
National ITMS Case Studies

Frank L. Dolan, Monroe County, New York — presiding

Houston Traffic Management System

Stephen Albert
Metropolitan Transit Authority of Harris County

Implementing, operating, maintaining, and funding traffic management systems in the Houston area—with 560 square miles, 5 transportation agencies, and 13 municipalities—represents a real challenge from the standpoint of communication, cooperation, and coordination. Although the Houston area may not present as great a challenge as that described by Matt Edelman, it is a significant challenge. I would like to provide a brief history of the development of the traffic management systems in Houston, and the lessons that have been learned.

Traffic management systems really began back in the 1960s on the Gulf Freeway (I-45 South) with the implementation of a variety of traffic management elements, including closed-circuit television and isolated ramp metering devices along a 6 mile stretch. These systems were supplemented with call boxes, which were located along sections that were not covered by closed-circuit television cameras.

Although many of these projects may have been conceptually successful, operationally they were unsuccessful. The call boxes in the Houston area implemented in the 1960s were unsuccessful because at that time a police officer had to be present when you removed your vehicle from the freeway after an incident. If you tried to get a tow truck with one of the call boxes, a police officer had to come out first and confirm that there was a need for a tow truck before they would dispatch one. The call boxes were not located where the closed-circuit television cameras could be used to verify the need.

Accident investigation sites were also implemented along the Gulf Freeway. The accident investigation sites were located under freeway overpasses, at shopping centers, and at other similar locations. They were well lighted, signed, and provided motorists with public pay telephones from which tow trucks, police, or family assistance could be obtained. The accident investigation sites were well-utilized initially because the Houston Police Department provided good public information and education on their use. As the public information effort diminished, however, utilization of the accident investigation sites declined.

Most of these projects were removed as part of the freeway reconstruction efforts, and were not relocated until some years later. Work is still underway on the Gulf Freeway today.

In the 1970s, as travel demand started to exceed the capacity of the roadway system, congestion became a major concern for local officials. In 1979, an experiment with an HOV contraflow lane on I-45 North was implemented. This system proved so successful—it moved more people in fewer vehicles, thereby increasing the person movement capacity of the corridor and stabilizing the congestion—that an extensive system of HOV lanes has been planned, designed, and implemented. Right now approximately 47 miles of the planned 100 mile system have been completed.

Although the recession in the mid-1980s slowed growth somewhat, the demand is starting to exceed the capacity of the roadway system once again. Average daily traffic is increasing at about 3 percent a year. This has forced all agencies in the Houston area to continue looking at a variety of strategies for managing traffic. Traffic management systems represent one of those approaches.

In Houston, a regionwide approach is being taken to implement the traffic management system. This involves coordinating the activities of the Metropolitan Transit Authority of Harris County (METRO), the Texas Department of Transportation (TxDOT), the city of Houston, and Harris County. Each of these agencies have different concerns, and therefore different interests in traffic management elements. Traffic management teams have been used successfully in Houston to help coordinate the efforts of these different agencies and ensure a coordinated traffic management system. You will hear more about the use of these teams in one of the workshops tomorrow.

The first element of the system to be implemented is the freeway traffic management system. This is primarily a TxDOT and METRO project focusing on freeway corridors. A freeway corridor is defined as the freeway, HOV lane, frontage roads, and selected arterial streets. These systems are planned to include traditional surveillance, communication, and control techniques using inductive loops that detect traffic, closed-circuit television cameras to verify any problems, and changeable message signs that inform the public of travel conditions or incidents ahead.

One question that has been addressed in the development of these systems is the appropriate use of changeable message signs. Recently the use of changeable message signs for general messages and ridesharing information was discontinued in Houston. Now they are being used only to provide information about incidents, thereby increasing their target value. Ramp metering devices are also in use on selected freeways, as are lane control signals for the HOV lanes. These confirm the proper direction of travel by advising motorists with a red "X" if they are going in the wrong direction. This is important because the Houston transitways are barrier-separated reversible facilities.

METRO, in cooperation with the city of Houston, is implementing an approximately $120 million regional computerized traffic signal system that will update and modernize the region's current system. One might ask why METRO, a transit agency, is actively involved in traffic management systems. METRO is a very atypical transit authority. In addition to the traditional bus and ridesharing responsibilities, METRO has a general mobility program that provides approximately $1.4 billion per year for repaving streets, adding capacity to streets, TSM measures, modernizing traffic signals, and other similar projects. These are not the typical activities performed by a transit agency. METRO is viewed more as a transportation agency that is concerned about mobility in general.

The selection of an A&E consultant to design the central control center is currently underway. The center, which will be operated by all the agencies, is being designed by METRO and will be constructed by TxDOT. The design includes a large video display like the one at Caltrans, as well as the applications for controlling intersections like the Anaheim system.

These elements all focus on the future of the traffic management system in Houston. Currently, only a computerized traffic management system on about 6 miles of the Katy Freeway HOV lane is operational. Thus, it was decided a few years ago that short-term strategies for reducing congestion needed to be developed and implemented.

Non-recurrent congestion caused by both major and minor incidents was one area targeted for these strategies. The first element implemented to address this problem was a motorist assistance program or service patrol. This program costs approximately $1.2 million per year, of which METRO contributes about $750,000. The program consists of nine vans operated 16 hours a day by the sheriff's department. The vehicles, which are provided by the Houston Automobile Dealers Association and dispatched by TxDOT, assist motorists along the most congested freeway corridors.

Non-recurrent congestion caused by traffic to and from special events was the second area addressed. By pre-planning for the events, it was believed that the resulting congestion could be reduced. Strategies such as motorist information systems, detouring traffic to utilize the available capacity of arterial streets, and operating special park-and-ride service from shopping centers have all been used successfully to help manage traffic during special events.

It also was realized that a good deal of information already exists that could be used to better manage recurrent and non-recurrent congestion. Cooperative efforts with other government agencies and their dispatch centers were explored. Essentially, this involved the collection and dissemination of information through TxDOT's interim communications center. That effort did not prove to be very successful, however, because each of the participants had their own objectives, which were primarily to manage their own fleets.

An InfoBank system, which provides information about reconstruction efforts on a major freeway facility, has been implemented in Greenway Plaza, a major suburban employment center. Monitors were installed to provide current information on incidents and recurrent congestion on the freeway. This program has been quite successful, and there are plans to expand it to the central business district and other major activity centers.

Another project underway in the Houston area focuses on the use of traffic probes on the freeways to collect information. This demonstration project, which is being conducted by TxDOT and the Texas Transportation Institute (TTI), uses motorists with cellular telephones as traffic probes. When these motorists pass specified roadside markers they enter a code into their phones, which is used by a central computer to provide real-time traffic information. This has provided valuable information prior to the completion of the computerized traffic management system. Currently, 200–300 probe vehicles are operating in the test corridor, primarily during the peak periods.

These short-term strategies for reducing congestion are viewed as the initial stages of a fully developed IVHS program in Houston. To focus those efforts, an overall program called the Houston Intelligent Transportation System (HITS) is being developed with the assistance of TTI. This will help in coordinating the IVHS efforts in the region. The result will be a single document that represents a master plan for moving forward and applying for the necessary funding.

The Houston *Smart Commuter* IVHS demonstration project also represents a major IVHS program in the Houston area. The *Smart Commuter* project has two parts. The first focuses on encouraging the use of the HOV lane for suburb to downtown trips on the north side of town, by providing real-time traffic and transit information to approximately 700 homes. The goal of this element is to encourage commuters to use the park-and-ride lots, bus service, and the HOV lane for their trip downtown. The second part of the *Smart Commuter* project concentrates on the use of HOV lanes for suburb-to-suburb trips. This will involve a computerized, single-trip carpool matching system to assist motorists in taking advantage of the HOV lane.

These efforts will represent the initial stages of a comprehensive IVHS program in Houston. A plan for the Congested Corridors Program has been submitted to FHWA. This program encompasses a large area and includes a number of transportation improvements. These include advanced traffic management systems, advanced public transportation systems, and the use of advanced traveler information systems.

TxDOT is also examining the use of automatic vehicle identification (AVI) to supplement the computerized transportation management system that is being developed. The technology could be used on both the freeways and the HOV lanes to collect current traffic information.

These IVHS efforts are not just targeted at motorists. Commercial users will also benefit through the improved movement of goods and services in the Houston area.

One of the lessons we have learned in the Houston area is that communication, coordination, and cooperation are very important. Yet, in my opinion there also needs to be a master plan that identifies what the goals are, what is trying to be achieved, what funding is available, and what the responsibilities of each agency are. Although each agency has their own goals, it is important that a cooperative approach be taken that involves all agencies and organizations. Developing an overall plan will help in this effort.

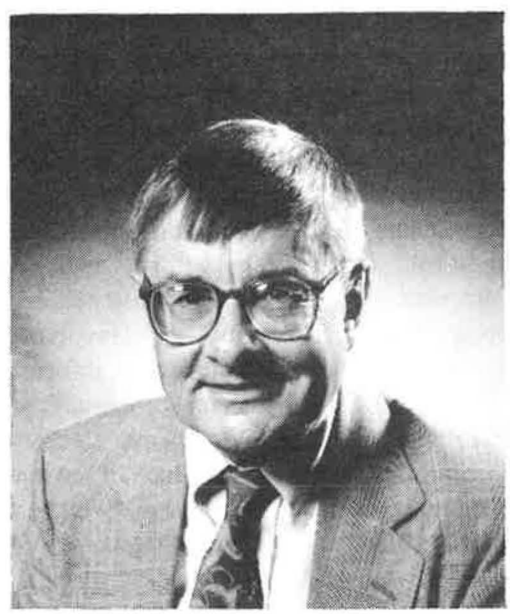
In conclusion, the complete implementation and operation of these traffic management systems is still well in the future for the Houston area. It takes a long time to design and implement these systems. Thus it is important to start using the resources currently available to initiate elements of the program, such as the provision of real-time traffic information. This will provide the public with early benefits from the system and help build public support.

INFORM

David C. Powell
New York State
Department of Transportation

INFORM is a traffic information system for Long Island drivers. You may be wondering what a Long Island driver is. Although we don't tell them, anyone that drives on Long Island is a Long Island driver. INFORM grew out of an earlier public information effort known as IMIS (Integrated Motorist Information System). Because it took so long to implement the project, IMIS had developed a tarnished image. A public relations firm was hired and, working with some local people, developed the name INFORM. It is a nice name and has gotten very good press.

The INFORM corridor on Long Island is 40 miles long and about 5 miles wide. It goes from Queens in New York City, through Nassau County, and out into Suffolk County. At the far end is Hauppauge, where the control center is located. One of the things we have learned from the project is that the best location for the control center is not at the end of the corridor. In



the future, we will consider developing a system for the Southern State Parkway that could be integrated with INFORM.

I would like to provide you with a brief overview of the key system elements. Also, I want to summarize some of the major points from an evaluation of the system done by JHK & Associates. It was an independent evaluation funded by FHWA. Local staff members were not involved, other than for interviews and providing some information. I think the evaluation was very objective and well done, and provides some valuable insights that I would like to share with you.

The system covers 128 centerline miles. The backbone of the system is the Long Island Expressway, I-495. I think that one of the reasons it was selected many years ago for an operations demonstration project is its nearness to, and opportunity for diversion with, the Northern State Parkway, the Grand Central Parkway, the Jericho Turnpike, and the Veterans' Highway. The system also includes a number of north/south routes, and it keeps growing, which is a positive sign.

The operations center in Hauppauge has three minicomputers. There are 2,400 roadway loop detectors, and at last count we had 80 variable message signs. This number continues to grow. We are implementing the first HOV lane on the system and there will be a number of variable message signs associated with that facility. There are 75 ramp meter locations. We are also installing some stand-alone ramp metering to the east of Hauppauge. There are CB monitors, 160 miles of coax cable, and 25 closed-circuit TV cameras, with 9 planned. We seem to be having some bid savings here in New York State: contractors are cutting corners and bidding about 25 percent less than normal engineering estimates. This has allowed us to develop the system more that originally anticipated. We have 14 VTIP subscribers, which I will describe in a moment, and 126 arterial traffic signals. That's the system as it stands now, but it is constantly growing.

VTIP stands for Visual Traffic Improvement Program. It uses the 2,400 loop detectors to collect speed information, which is then transferred from the mainframe computer to PCs. Subscribers pay $200 for the software, but we will provide it to public agencies free. The system displays the speeds on the network, updated every minute. We are also hoping to start a limited scale demonstration that uses voice synthesis to broadcast this real-time information over the radio.

Before the INFORM system was implemented, we noticed that there were times when the Long Island Expressway was very congested and the parallel Northern State Parkway had very little traffic. Without the variable message signs and ramp metering, the motorists were unaware of the better conditions on the alternate route. Thus, the benefits of the system have been demonstrated to the public.

I would like to give you a brief idea of the cost of the system. The initial cost of the project was about $35 million, although it is probably closer to $40 million right now with all of the expansions and improvements made to the system. An interesting point is that the communications elements make up about 40 percent of the total cost. We are certainly looking for ways to save on this significant part of our costs for future projects. The system is mostly coaxial cable, which is not the state-of-the-art today, and there are some problems with it.

One of the largest headaches has been the annual operating costs of the system. A consultant operates the system for us and a maintenance contractor is used as well. The total cost is about $5 million per year, which is close to 10 percent of the construction costs. Ten percent has been used as a rule of thumb for the cost of operating a system like INFORM. Since this was our first big job in the state, our fiscal people did not realize it was going to cost this much. Every year we wonder what the funding will be like, and there are times that our operating consultant and maintenance contractor don't get their paychecks.

Last spring some people at the state level thought the new ISTEA legislation provided operations money from the federal government, so they took our allocation out of the state budget. When the new fiscal year started in April, we had no money to operate INFORM. People were working and not getting paid. To resolve this problem, we first met with the local FHWA representatives and worked out an agreement to fund a part of the operations costs, but not the maintenance expenses. The next step was to meet with the Region 10 office staff in Hauppauge and present our case to the MPO, where it was included on the TIP. We are very fortunate now that we are getting federal funding on an 80/20 formula basis. To me this is really a commitment from the MPO and the community, and I think MPOs have to become more involved. It isn't just $5 million for 1 year. If you look at it as a 5-year program, that's $25 million of blacktop that is not going to be put down.

Next I would like to describe the staff of the INFORM system. New York State DOT has 8 full-time people assigned to the project, 6 engineers and 2 clerical workers. The consultant has 18 full-time and 5 part-time people, and the system is operated 24 hours a day.

We are delighted with the recent evaluation report on the INFORM system. At the time construction was finishing up, it was decided that our department should evaluate INFORM. Then FHWA decided to do an independent evaluation of the project. I had confidence that our system would look good in the report, but if it hadn't, we probably would have turned it off.

With our variable message signs we generate 14,000 messages per year, 500 a day, and 50 during the busiest hours. Approximately half are manually generated. Incident related delay savings are 300,000 hours per year, about 1900 hours per incident. There are other benefits as well. In particular, we use the variable message signs during construction and maintenance activities and for major events in New York City.

One thing that the evaluation report noted was that the effective use and value of the variable message signs are highly dependent on the diversion potential of the corridor. This seems obvious: if there is no alternate route, you can't tell motorists to divert. Another main point was the importance of accurate information on the signs. It does not take long for motorists to disregard the signs if the messages are not believed to be accurate, so credibility is probably one of the most important things.

The results of the project provide a simple formula for diversion rules: the percent diversion increases as the directness of the alternate routes increases, and the percent diversion increases with the increased excess capacity on alternate routes. If you put those two together it makes sense. Of course, this assumes that the quality and accuracy of the information is sufficient.

The absence of traffic responsive capabilities on parallel arterials is the most significant detriment to the potential overall effectiveness of the diversion strategies. In other words: if there is no facility to divert to, they aren't going to help you out much.

At INFORM, operation of the variable message signs consumes about 80 percent of the operators' staff time. Between 5 and 10 percent of mainline traffic can be diverted when a variable message sign is in passive message. Passive message is when the sign is simply telling you that there are delays ahead, not where to go to avoid it. A rule of thumb is that if you give a diversion message, that percentage would double. So up to 20 percent can be diverted by giving a positive message.

During the design of an integrated traffic management system, the variable message sign locations should be associated with special route diversion opportunities. You need to think through where there is going to be an incident and where you would put the sign. When you place the sign, put it far enough in advance of the exit so the message doesn't get to the driver too late.

Maintenance of the quality of information on the variable message signs must be a top priority of the system operator. Our studies have found out that an automated sign control with human monitoring and refinement is the most effective way to do it. You just can't do it with a human control alone, and you can't do it by automation alone, so it is a combination of the two. That means you need to have people in the control center.

We found out that bracketing congestion areas—for example "delays from exit 34 to exit 37"—is more effective than identifying the length of the congestion—"delays next 3 miles ahead." If you had delays between these two exits, you could go back maybe four or five variable message signs and start giving the message ahead of time. We use exit numbers because some of the cross expressways or parkways have very long names that might not fit on a variable message sign.

We have come to the conclusion that all on and off ramps should be detectorized to properly evaluate the effect of variable message sign operations and provide feedback to the operators, even if it is not a ramp meter location.

During the implementation of the system, the variable message signs were installed by the contractor long before we were ready to turn them on. The result was a lot of motorists who thought the signs were not working, which is an image problem. Because of that experience, we have decided that it is better to continuously display messages on the variable message signs, even if there are normal traffic conditions ahead. If there is no message, the drivers may again start to think that the sign broken.

Another thing we do with the variable message signs that creates some problems is run public service announcements, like promoting seat-belt use or discouraging drunk driving. We have a committee set up to review requests for these messages. The problem is that they are not like traffic control signs where you have to get FHWA approval. This may be an area where research is needed to develop some standards. We may be getting ourselves in trouble because this is a very sensitive area, and there is a lot of pressure from groups to put their messages up, even ones that are not traffic-related.

As I mentioned earlier, one important thing is to minimize the time between installing the sign and turning it on. Another important element is to incorporate on-line testing and operator training with the software.

Several sources for inaccuracies in variable message sign information were identified in the report. First, information can only be bracketed to the nearest interchange, which are probably less than 2 miles apart. Second, there is a time gap for the motorist between encountering a sign and arriving at the incident location, so you might warn of delays ahead and when the motorist arrives it is already cleared out. Third, detector spacing is about a half mile apart, so you can be no closer in accuracy that half a mile. Finally, there could be failed detector stations, but I think our loop detectors are working very well out there, or at least I haven't heard of any problems. Of course there are also errors made by the system operators.

The ramp metering was also evaluated, but the process got kind of fuzzy. The original plan was to conduct a 5 week before and 5 week after study, but no one anticipated how long it would actually take to turn the ramp meters on. We were very concerned politically and wanted to be right there as each one was turned on. It took so long that they decided to measure the speeds once all the meters were on in March 1990, then they turned them off and measured the speeds again. There was an 8 percent increase over the non-metered case, but when the metered case was compared to 3 years earlier, the improvement in speed was 13 percent. One possible explanation for this is that INFORM has helped commuters plan their trips better; the variable message signs were not in operation in 1987, but they were in 1990. The p.m. peak wasn't quite as good during the 1990 comparison. The meter-on and meter-off speeds were essentially unchanged, but when compared to 1987 there was a 13 percent increase in speed.

To summarize, I think a true test for the project is the vehicle-miles traveled. During the 1990 analysis there was a 1 percent increase in VMT, and from 1987 to 1990 there was a 5 percent increase. That clearly shows that the ramp meters are working. There was a 7 percent maximum increase in the throughput at bottlenecks due to ramp metering. The average increase was 2 to 3 percent, and some locations were unchanged.

There have been some publications of congestion index numbers, although I think they were printed in a way that gave the wrong indication. The congestion index is based on the number of speeds less than or equal to 30 miles per hour. In the March 1990 comparison there was a 25 percent decrease in the index, but the number that was published was 50 percent. I guess you could say it was up to 50 percent from 1987 to 1990.

The phased turn-on of the ramp metering worked well. It allowed the necessary traffic engineering attention. Instead of turning several on at the same time, a traffic engineer evaluated and worked with them one at a time. Some of the ramp volumes doubled in the time between the feasibility study and the actual turn-on. I do not think anyone can be faulted for that problem—it just happened, and it is something to be aware of.

One of the biggest problems is the inability to manage queues that back-up on the cross streets from a ramp meter. I think the best approach is the use of 2-lane ramp meters. It is certainly a very efficient solution, and I believe we are beginning to use it for INFORM.

The public relations consultant that was hired for INFORM also conducted a study. It is interesting because what we as traffic and transportation engineers think is one thing, but this was an opportunity to find out what our customers think.

The first result relates to the perceived accuracy of the information. Seven percent indicated that they think the information is always accurate. I would not expect any more than that, but I think it's delightful that the "usually accurate" response got 56 percent, and when you add that to 7 you're up around 60 percent. The usefulness of the information on the variable message signs was the next question. It surprised me that "very useful" got 29 percent and "moderately useful" got 48 percent. When you add the two together you get 77 percent. Only 3 percent responded "never useful." I expect that in a normal sample you would get more than 3, so that looked pretty good. For the travel time comparison, 43 percent agreed exactly and 35 percent differed by only one interchange, which was pretty good. Another significant response was to a question about route changes. Forty-six percent indicated that they "sometimes" divert. I think that is very good for a system like INFORM where the drivers are not forced to divert.

Here are some of the things that were listed as threats to the evaluation. First is the occurrence of incidents. They should be screened out because they will create problems with the data. During the winter in northern climates there is no construction activity, but there is inclement weather. As soon as the weather breaks, road construction begins. This gives a bias to the evaluation. There were also time-related factors because the implementation took so long. The evaluation went on for 2 or 3 years, and is not as accurate as 5 weeks before and 5 weeks after would have been. Furthermore, there were seasonal factors, like daylight savings time and inclement weather, which added to the complexity and difficulty of an evaluation like this.

One issue that may not be that big of a problem is designing easy access to variable message signs. You don't want to have to block traffic lanes for the maintenance contractor to get in there.

One thing that is important is the construction phasing of high visibility devices like ramp metering and variable message signs. As I mentioned previously, they should not be installed and just sit there for 2 years before being turned on.

In any high volume corridor there are always going to be construction projects, which is both an opportunity and a threat. I think the people that run our system have been able to use those projects as opportunities to upgrade and improve the system, adding closed-circuit TVs and other elements.

Our department elected to hire a design consultant that helps integrate other corridor construction projects with INFORM. For example, if we have someone designing an interchange, we do not have that particular consultant design the INFORM features. Rather, we use one that works directly for our traffic people. They learn how to do it and they are very skillful at it. I think this has been a very positive element.

One of the problems that I think is a criticism of the consultant, and probably us for not catching it, has to do with replacement parts. The problem is when you design a project and there is no supplier 3 years down the road when you run out of parts. This is something that needs to be addressed.

The location of the control center probably, we now think, should not be at the east end of the job but towards the middle. I think we are going to be looking at the issue of moving the control center in the not too distant future. This might come out of some IVHS funding we are looking at in the Long Island area.

One of the big things that we did had to do with the communications cable. We had to cut costs when we let the job originally and could not afford to put conduits in, so direct burial was used. The first year of operation there were 200 cuts by our own contractors and maintenance people. We should have put it in conduit, I think that is a must.

In conclusion, I think that the bottom line is to look at the benefit and costs of the system. The benefit/cost for the March 1990 comparison was 1.82. When comparing 1990 to 1987 the benefit/cost was 8.27. Those estimates were made using $8 an hour delay time. The regional planning people in the Long Island area thought that the value should have been about $14 an hour, so I think the benefit/costs are even higher. Regardless, it is pretty obvious that the project is a success.

Gardiner-Lake Shore Corridor Traffic Management System

W. Leslie Kelman
Municipality of Metropolitan Toronto
Transportation Department

The Gardiner-Lake Shore Corridor consists of an urban freeway (the F.G. Gardiner Expressway) and a parallel signalized arterial (Lake Shore Boulevard), which together form a major access route into downtown Toronto. Corridor traffic management systems have traditionally focused on freeway and arterial traffic operations, employing subsystems such as loop detectors, closed-circuit television cameras, changeable message signs, low power highway advisory radio, and ramp metering. However, the Municipality of Metropolitan Toronto Transportation Department recognizes that it is important to integrate other concurrently operating traffic management systems which are related functionally and geographically.

There are many good reasons for integrating traffic management systems. Foremost, integration serves to consolidate systems which would otherwise be isolated. Integration thereby allows for the coordination of activities and enables each system to take into account the operations, strategies, and capabilities of the other systems. Motorists, perceiving the road network as a seamless continuum, benefit from an integrated system which presents a unified package of information to assist them in making decisions such as route choice and departure time. Integrating several systems with similar functions enables operational efficiencies within the overall system. Interactions with external agencies are simplified and improved by providing a single point of contact with each source/user agency. Finally, by facilitating intensive cross-communication and cross-support among the linked traffic management systems, integration promotes synergy.

The Metro Toronto Transportation Department is currently in the process of implementing several projects to improve traffic flow within the municipality. I will be discussing four of these traffic management projects today. Not only will the projects be integrated operationally, but they will be controlled from one central location—the Integrated Traffic Control Centre (ITCC).

The first project is a freeway and arterial traffic operations system. As a major commuter route into downtown Toronto, the Gardiner-Lake Shore corridor accommodates directional peak volumes of 8,800 vehicles per hour, with an average daily two-way traffic volume in excess of 200,000 vehicles. Over 200 major special events take place annually at sites adjacent to the corridor, including the Canadian National Exhibition, Toronto Blue Jays baseball games and an Indy car race. The corridor currently experiences about 7 hours of congestion each weekday, divided about equally between morning and evening peak periods. High volume weaving sections, short merges, poor vertical alignment, and extensive rehabilitation and maintenance activities on the elevated portion of the Gardiner Expressway add to the congestion problems and are contributing factors to an accident rate of 6.6 accidents per million vehicle miles, almost five times the provincial freeway average.

Since capacity expansion is expensive and subject to major physical constraints, corridor traffic management through freeway and arterial traffic operations offers an opportunity to make more efficient use of available roadway capacity now and in the future. Freeway and arterial traffic operations are being implemented in three phases.

The first implementation phase, which will be completed in mid-1993, is the detection system. Loop detectors are being installed on both the Gardiner Expressway and Lake Shore Boulevard for the purposes of incident detection and congestion monitoring. Closed-circuit television cameras, offering virtually 100 percent coverage of both roadways, will also be in place. Detection and surveillance subsystems will be linked via a fiber optic trunk to the ITCC. Real-time detection will enable prompt emergency response through external interfaces.

The next implementation phase will be an advisory system in mid-1994. Changeable message signs, located upstream of key decision points on both the freeway and the arterial, will advise motorists of lane blockages, construction activities, and congested conditions ahead. Queue monitoring and automatic queue length estimation will be important features of the advisory system. More detail on events and traffic status will be provided by highway advisory radio and enhanced external interfaces with the media.

The final implementation phase, planned for late 1994, will be diversion strategies. Arterial advisory signs, changeable message signs, highway advisory radio, and external agency communications will provide diversion messages to motorists. Diversion will be based on travel time differences between the freeway and the arterial. Queue length data will be incorporated in travel time calculations for more precise estimates. Automatic traffic signal timing/phasing changes and ramp metering will support diversion strategies.

The second traffic management project will be a demonstration of SCOOT. SCOOT—which stands for Split, Cycle, and Offset Optimization Technique—is a computerized traffic signal control system that provides real-time traffic adaptive control on a signal cycle by signal cycle basis. The system incorporates a traffic model which predicts delays and stops caused by specific signal settings, based on actual traffic data detected and processed in the real-time model.

The Metro Toronto SCOOT demonstration project encompasses 75 intersections within three distinctly different operational control areas. One control area includes 42 intersections within a grid network of the central business district.

Another control area includes 13 intersections along a major suburban arterial. The third control area includes 20 intersections along Lake Shore Boulevard, within the Gardiner-Lake Shore Corridor. The control areas were chosen in order to evaluate the benefits of SCOOT under various types of operating and road environment conditions. The demonstration project is scheduled to be commissioned by September 1992, with subsequent before/after survey studies to be conducted and documented by the end of 1992.

In the future, SCOOT will function as the traffic signal interface to the Gardiner-Lake Shore Corridor Traffic Management System (CTMS). CTMS will provide input to SCOOT on suggested diversions from the freeway to the arterial, on-going freeway congestion, and the onset of freeway congestion. It is intended that a proactive response, through additional green time required to clear traffic diverted to the arterial, will be supplied by SCOOT, if the demonstration project is successful.

The third traffic management project will focus on the reconstruction of the Humber Bridges. The project involves rebuilding six bridges over a 6-year period, beginning in May 1993. The bridges span the Humber River, located at the west end of the Gardiner-Lake Shore Corridor. The rerouting of traffic and the unavailability of certain ramp movements throughout the reconstruction is expected to have a major impact on traffic along this heavily traveled portion of the corridor. Therefore, a local traffic management project in the Humber Bridges area is being initiated for the duration of the reconstruction.

Since the initialization of the first phase of the Gardiner-Lake Shore CTMS coincides with the start-up of Humber Bridges reconstruction, there is an opportunity to integrate the two projects. Humber Bridges traffic management will proceed on the basis that inputs from a number of sources—including overview cameras, Autoscope video incident detection, and on-site crews—will be sent to the ITCC for processing and response initiation. The responses will include emergency agency assistance at incidents, the use of accident investigation sites, and low-infrastructure advisory techniques, such as portable changeable message signs. External interface communications for the Humber Bridges reconstruction project will also serve as a pilot demonstration of the Traffic Situation Room, which I will be describing in a few minutes.

A number of components will continue to be used by the Gardiner-Lake Shore CTMS after the Humber Bridges relocation has been completed, including the overview cameras and accident investigation sites. The Humber Bridges project also provides an excellent test bed for new products, such as Autoscope. The results of Autoscope tests on traffic monitoring and video incident detection capabilities will be applied to other situations where imminent construction makes loop detectors impractical.

The final project is the Traffic Situation Room (TSR). The concept of the TSR is currently being planned and developed by the Metro Toronto Transportation Department. The purpose of the TSR is to act as a communications and coordination center among transportation, media, and other agencies to improve the overall efficiency and operation of the transportation system in the greater metropolitan Toronto area. Input from the Gardiner Lake-Shore CTMS and the urban Traffic Signal Control System (including SCOOT) will be combined with other traffic and road information to coordinate response to traffic events, and to provide user agencies with data on overall traffic status. An important role of the TSR will be as a central command site for major emergencies, drawing on the communications infrastructure that would already be in place.

Good interfaces with motorists, and with third party agencies that make it their mandate to redistribute traffic and road information to motorists, will ensure the areawide dissemination of travel information. Freeway and arterial traffic operations subsystems alone, such as changeable message signs and low power highway advisory radio, are not capable of reaching the wide audience accessible through external interfaces.

Given the number of potential external interfaces to the TSR, the potential diversity of two-way information flows, and the requirement for information that is timely, accurate and consistent, a central computer data base would be used for the entry, storage, processing, and retrieval of traffic and road information. A variety of dissemination technologies would accommodate the diverse requirements of different external agencies under different circumstances, and would maximize audience exposure to the information.

Linking all these projects together will be the Integrated Traffic Control Centre (ITCC), which currently is being developed by the Municipality of Metropolitan Toronto. A contract for major building renovations was awarded in December 1991, and occupancy is targeted for February 1993. It is expected that the consolidation of various traffic functions will improve the overall management and effectiveness of the transportation network throughout metropolitan Toronto. Among the shared-use areas in the building will be a control room, a computer/ communications room, and a room that combines the functions of a TSR command post, a visitors' viewing room, and an operator training facility.

The ITCC will enable new possibilities for information exchange, direct and immediate communications, efficiencies in computer and communications systems, and design flexibility, yielding benefits to all participating user groups. The major user groups in the ITCC include the Gardiner-Lake Shore Corridor Traffic Management System, the Traffic Signal Control System, the Traffic Situation Room, and other sections, such as the Traffic Data Centre. The building in which the ITCC is located is shared by the Communications Branch of the Metro Toronto Police Department, which includes the 911 emergency response center.

In conclusion, the benefits of disaggregate traffic management systems are typically too localized to be of great value to motorists. In addition, motorists typically do not recognize the boundaries of traffic management systems, but instead perceive the road network as being continuous. True areawide benefits of traffic management systems can be achieved only through integration. The Municipality of Metropolitan Toronto is applying this approach to several traffic management initiatives, to optimize the benefits of the combined system. Central control from the Integrated Traffic Control Centre further supports integration by facilitating interaction among the systems.

Session Four
Planning for ITMS: LA Smart Corridor Case Study
A. Keith Gilbert, Automobile Club of Southern California — presiding

Smart Corridor Introduction

Jack L. Kay
JHK & Associates

Mr. Kay began the panel discussion with a general introduction to the Los Angeles Smart Corridor project. The major points he made during his presentation are summarized below.

- The purpose of the Smart Corridor project was not to dream up new technological toys and then find ways to apply them. Rather, the needs in the corridor were examined first and then appropriate technologies were identified. The goal of the project was to test technologically advanced methods for improving regional mobility.

- There were three primary objectives or functions of the Smart Corridor project: to operate the freeways and surface streets at their highest level of efficiency, to balance the flow of traffic between the freeway and surface street systems, and to concentrate on the use of motorist information as a control option.

- A series of premises were established for the Smart Corridor project. They were to: build upon on-going activities, recognize agency charters, coordinate the agency responses, recognize that it is a demonstration project, adapt to on-going research, make it part of a regional plan, and work on advance agreements among the agencies.

- The Smart Corridor project focuses on the Santa Monica Freeway, which is one of the busiest freeways in the country. The corridor also encompasses 5 parallel and 15 perpendicular arterial streets. There are several agencies that have been integrated or linked together through the project, including: Caltrans, the Los Angeles Department of Transportation, the California Highway Patrol, the Los Angeles Police Department, and the Southern California Rapid Transit District.

- The Smart Corridor is really not a control system itself. It is more accurately described as a central data base for collecting and redistributing corridor information. The real control goes back out to the various agencies and their own systems. An important point is that each participating agency in the Smart Corridor project retains its traditional role.

- System elements to maximize the efficiency of the freeway and surface streets are: freeway ramp metering, computer traffic signal control, freeway incident detection, incident response teams, and freeway service patrols.

- The project planners did not envision a significant amount of diversion from the freeway to the surface streets. Rather, they wanted to be able to alert motorists of unusual conditions before they entered the freeway, when they might be convinced to use an alternate entrance or route. The system elements to balance the flow of traffic between the freeway and the arterial surface streets are surface street changeable message signs and site specific highway advisory radio.

- System elements to gather and manage information include: inductive loop detectors, closed-circuit television, changeable message signs, highway advisory radio, in-vehicle navigation systems, call-in services, media communications, digital broadcasting and teletext.

- There are a few features that will be used to provide operational support for the combined decisions made by the various agencies in real-time. They will include: a combined information data base, shared data among agencies (including video images), decision support mechanisms, strategies to influence route choice, and adaption of the network to conditions in real-time.

- Despite its apparent size and complexity, the Smart Corridor system configuration is rather simple. Basically, it is a network of workstations and high-end PCs; there is no large single computer at the center of the Smart Corridor project. One important aspect to operating this distributed system effectively will be to have established standard operating procedures and agreements among the participants.

Mr. Kay concluded his presentation by discussing the use of expert systems for decision support in the Smart Corridor. Some examples of potential expert system uses include arterial incident detection, incident correlation, and incident response support.

Project Development

S. Edwin Rowe
Los Angeles Department of Transportation

Following the general introduction to the Smart Corridor project, Mr. Rowe focused on the evolution of the project concept and the implementation process. He described the following major steps in the process.

- The process began in 1987 with the development of a vision for the Smart Corridor concept. At that time, the traffic conditions were getting noticeably worse in Los Angeles County and continued growth in the demand was expected. With very little new capacity being constructed, it became obvious that the existing facilities would need to be used much more efficiently. That situation led to the vision of a network of corridor integrated traffic management systems in the county. That concept, which came to be known as the Smart Corridor, drew heavily from the experiences of the 1984 Summer Olympic Games. The idea received initial approval from the Los Angeles County Transportation Commission (LACTC).

- After obtaining initial approval and preliminary funding, the project moved forward into a concept design study during 1989. That process involved detailed studies of over 40 separate functional elements that were being considered for the project. The results of those studies were summarized in a concept report that was essentially a recommendation for the system. It had a system definition, an idca of the costs, and a project plan. The report also contained the results of some parallel research conducted by several universities. The LACTC approved the project, which then went into detailed design.

- A systems manager approach was used during the detailed design of the overall program, which began in mid-1990. Much of the work and detailed design was done by the operating agencies, like Caltrans and the Los Angeles DOT. JHK & Associates, the project consultant, was responsible for the development of the computer systems and software. They were also responsible for the integration and advising of the various agencies. It was very important that all of the elements being developed worked together as an organized system.

- The project is now being implemented, and should be completely in place by the summer of 1993. At that point, the Smart Corridor will go into full operation and a year of intense evaluation. Some topics for evaluation will include the various motorist information elements, the expert systems, and the relationships and coordination among the operating agencies. In addition, there will be an overall performance evaluation of the impact on the corridor in terms of moving traffic, increasing throughput, and increasing travel time reliability. Based on the results of that evaluation, a decision will be made to move forward with an expansion of the Smart Corridor concept into other parts of the county.

Mr. Rowe ended his discussion by describing how the coordination of traffic signals operated by different cities in the Smart Corridor was being handled. The number of participating agencies has been kept as low as possible, but there are several municipalities involved. The city of Los Angeles has a majority of the intersections in the project, but Beverly Hills and Culver City each have a string of intersections that are included in the Smart Corridor.

After looking at how to coordinate the signals operated by the different cities, it was decided that Beverly Hills and Culver City would upgrade their systems to an ATSAC-type of system. Rather than having each city develop their own control center, the actual control of the signals will take place in the Los Angeles ATSAC control center. This situation required the negotiation of operating protocols and agreements with the other cities that may provide a model for future use in other areas.

Implementation Issues

David Roper
Roper & Associates

The final panelist was Dave Roper. Mr. Roper discussed Caltrans' role in the area of traffic management, the capabilities it could contribute, and its attitude toward participating in a joint project like the Smart Corridor. The key elements of his discussion are outlined below.

- Many traffic management ideas have been tested on the Santa Monica Freeway over the years. It provides an ideal laboratory because it has the severe problems and necessary facilities for testing traffic management systems. Some of those previous Caltrans efforts on the Santa Monica Freeway included: ramp metering, changeable message signs, closed-circuit television, a traffic operations center, standard operating procedures, and incident management teams. In general, a good traffic management system existed for the freeway before the Smart Corridor project was initiated, but it was not as effective as it could have been.

- Diversion is a very sensitive issue in integrated traffic management. Caltrans and other agencies have almost always relied upon voluntary diversion, but it does not seem to work as planned. Some motorist surveys have been conducted to help understand why voluntary diversion is not very effective, and the results are very revealing. Many reasons were given for not diverting, including getting lost, concerns about personal security off the freeway, and the whole issue of credibility. As an agency, Caltrans was also hesitant about the idea of forcing diversion because there was very little information about the conditions on the surface streets, or even about its own freeways.

- It is imperative to develop staff expertise within the operating agencies for traffic management systems. Over a period of time, particularly during and since the 1984 Olympics, both Caltrans and the Los Angeles DOT developed the necessary staff for operating and maintaining the systems. In addition, a very important factor is the strong commitments made by both state and local agencies to these systems. Too often, systems are implemented without enough commitment given to their operation.

- One of the most important aspects of a system like the Smart Corridor is interagency trust. There was a history of trust between key staff members from Caltrans and the city of Los Angeles, but it had to be taken a step further. Each organization had to be willing to trust the other, because they were being asked to share information to effectively operate the corridor. Essentially, Caltrans had to give up something in the interest of the surface streets, and the city had to give up something in the operation of the freeway. That is a major hurdle that must be overcome for a project like this.

- Caltrans had some specific needs from the project. First, it was essential to maintain control of their portion of the system. No agency would be willing to give up the responsibility or authority over its portion of the transportation system. Indeed, most agencies have enough problems of their own without taking on the responsibility for operating someone else's facilities. At the same time, it did see the need to share or coordinate its control for the benefit of the corridor. Caltrans also had the need to build on what it had already accomplished in the corridor.

Mr. Roper concluded by emphasizing the value of cooperation in projects like the Smart Corridor. The history of cooperation between Caltrans and the city of Los Angeles has been helpful when problems arise. It is essential for the success of integrated traffic management systems to develop cooperative attitudes and trust at all organizational levels.

Session Five
ITMS Technology

Raj Ghaman, Federal Highway Administration — presiding

ITMS Technology

Gary E. Euler
Federal Highway Administration

Using a series of viewgraphs, Mr. Euler provided a framework for thinking about ITMS technology. He stressed the need to think of the technology aspects of ITMS in a broad and comprehensive manner. Mr. Euler covered the following major elements during his presentation.

- Surveillance and monitoring provides the basis for the development of ITMS. The four elements of a comprehensive surveillance system include point detection, area detection, probes, and AVI/AVL. All of these are needed for a comprehensive system. Each provides different information that is needed in the system.

- The information provided through the different elements needs to be processed or fused, which is a term coined from the military. Data fusion is a term applied to the decision process utilized with the information provided by a variety of sources. IVHS provides the opportunity to rethink the approach to incident detection and develop new techniques and approaches that may be more effective in the long run.

- The processed data can be used for a number of purposes. For example, providing this information to individuals in the home and workplace can help improve the travel decision-making process. The focus of many IVHS programs to date has been on providing in-vehicle information. However, a number of recent projects are focusing on obtaining a better understanding of the different travel markets and the types of information travelers desire. It is important to remember that the information provided by these systems must be accurate, reliable, and based on what people want.

- The information provided through ITMS is also used in the control and management of the transportation system elements. These include the broad areas of traffic controllers, speed advisories, incident management, routing, and pricing.

- There are a number of software challenges that will need to be addressed in the development of ITMS and IVHS. These include dynamic assignment, traffic condition prediction, and combining ITMS and ATIS.

- A number of issues are associated with the communication functions of ITMS. These focus on how much information is available, how frequently it should be provided, and the costs of the different methods of dissemination. The involvement of the private sector will be needed in this area and creative approaches will be necessary to facilitate this involvement.

- IVHS system architecture is also another important area. This will establish the basic framework for IVHS. It will identify the functions to be included and will define how the system will be designed. It will define the type and nature of the infrastructure needed to support the desired functions and will outline the components of the system for manufacturers and the private sector. In essence, it will define what functions are to be accomplished and how they will be accomplished.

- The IVHS America System Architecture Committee has recommended to the U.S. Department of Transportation that a substantial amount of funding be made available to support different teams working in parallel to sketch out IVHS architecture. The number of teams would be narrowed the second year to focus on designing those system that appear most feasible and to identify the benefits and costs of these. At the same time, the committee recommended a consensus building process that would involve all the major stakeholders. This consensus building process would reach out to all groups and organizations to ensure that they understand the issues, process, and have an opportunity to participate in the development of the system architecture.

INFORM System Hardware and Software

Daniel H. Baxter
Parsons DeLeuw, Inc.

Mr. Baxter presented on overview of the INFORM system architecture. He covered the operational objectives of the system, the development of the system architecture, and the process for adoption. Major points covered included:

- The first step to understanding the complex system architecture needed in any ITMS project is to understand what the system is trying to accomplish. Once the objectives, which are often relatively simple, are outlined, the system can be designed and developed to meet these.

- The INFORM system was built around the integrated motorist information system (IMIS). The system has built on this with functions and enhancements added over time. The operational goal of IMIS, which was more a control and information system, was to marry a freeway traffic management system with an arterial street traffic management system.

- The INFORM corridor includes more than one longitudinal freeway, which made it an ideal setting for the demonstration. Initially, the project focused on balancing the utilization of capacity between those freeways and the major arterials in the corridor.

- The selected architecture for the system was to implement the freeway controls for all the facilities using one rule-based system architecture. A rule-based architecture basically means that a set of rules is developed and adopted that apply to each of the freeway management segments. The simplest rules, which might address failed equipment, will apply to a large number of problems that the system has to process. Other sets of rules are then developed for other issues. A table or matrix format is used to illustrate these, so that each type of problem or occurrence has a rule to cover the appropriate response.

- The integration of the freeway traffic management system and the urban traffic control system was accomplished through the use of shared memory. This approach was a relatively simple process, but at the time it represented a new technique. It allowed for the coordination of strategies for freeway-to-freeway diversions, freeway-to-arterial coordination, and the interface of ramp metering and freeway and arterial operations.

- Other elements, such as the master controller for the 75 variable message signs, were added to the system. Automated message generation, capacity balancing through traffic diversion, and surface-street sensitive ramp metering are three areas the INFORM system focused on.

- Although the hardware is now outdated, the basic approach and concepts utilized in the development of the INFORM system do provide a good model for other areas.

TravTek

Robert Rupert
Federal Highway Administration

Mr. Rupert provided an overview of the basic elements of the TravTek project in Orlando, Florida. He noted that many of the presentations at the symposium have mentioned the use of in-vehicle information and guidance systems. TravTek represents the most advanced in-vehicle information and guidance system under operational testing today. Mr. Rupert covered the following topics relating to the TravTek project.

- TravTek is a public-private partnership among General Motors (GM), the American Automobile Association (AAA), the Florida Department of Transportation (FDOT), the city of Orlando, and the Federal Highway Administration (FHWA). Other major participants include: Avis Rent-a-Car, who is working with the AAA and renting the TravTek cars at the Orlando International Airport; Motorola, Inc., who is supplying the radio system used to transmit data between the Traffic Management Center (TMC) and the TravTek cars; and Magnavox, who is supplying the global positioning system (GPS) devices in the cars.

- There are three major subsystems included in TravTek. The first is the TravTek cars, which are 1992 Oldsmobile Toronados supplied by GM. Second is the TravTek information and services center (TISC), which is operated by the AAA. The third element is the TMC, which was designed under a FHWA contract and is operated by the city. The TISC serves as the "help desk" for TravTek users, with free cellular calls provided from TravTek cars. The TMC collects traffic information concerning the TravTek network, processes it to produce travel times, and transmits these times to the TravTek cars.

- The in-vehicle TravTek subsystem includes two 386-based microprocessors, each with a removable 20-megabyte hard disk. A radio system operating in the 800 megahertz range provides communication between the cars and the TMC. The cars use a system of dead-reckoning and map-matching to keep track of their location. GPS receivers are added to provide a means of correcting the cars' locations. A cellular telephone is built into each Toronado and integrated with the TravTek equipment. Buttons on the steering wheel and the visual information center (VIC) in the dashboard are the chief ways that the TravTek system interfaces with the driver. The VIC is an available option on the Toronado and houses the radio and climate controls.

- A variety of screens can be displayed on the VIC by the TravTek system. The first screen provides a "Main Menu." Options are available for viewing a map of the car's vicinity, calling for emergency services, specifying a destination, or viewing a listing of services and attractions. The user may also choose to make one of the services or attractions a destination.

- Once a destination has been selected, the user has a choice of three routing methods. The user may ask for the fastest route, regardless of road type; a route may be determined that avoids expressways; or a routing avoiding tollways may be selected. When the TravTek computers determine the routing, it is displayed to the user as a purple line overlaid on a map of the local area.

- A computer-synthesized voice also informs the driver of what the next maneuver is. All of these selections are only available while the car's transmission is in park. Once the car is taken out of park, simple screens with arrows indicating the next turn are displayed. Mileage and travel time estimates to the destination are shown, as are the distance to the turning street and its name.

- The only functions available to the driver while the car is in motion are those selectable from the steering wheel. These functions include "Traffic Report," "Where am I," and "Swap Map," the last of which lets the driver switch between guidance arrow displays and a map display of the car's vicinity. If the driver misses a turn or travels off the designated route, a voice informs the driver that the car appears to be off the route and asks if a new route should be calculated. If a new route is desired, the driver would press the "OK New Route" button, and the TravTek computers will determine a new route to the destination. The "OK New Route" button would also be used if something were to occur along the planned route to significantly affect the travel time. The voice would suggest that a better route may be available, and the driver would press the "OK New Route" to see the new route.

- In addition to receiving data, the cars transmit their locations and travel times to the TMC every minute. This information is combined with information from the city's traffic signal system, FDOT's freeway system along I-4, and sources such as media traffic reporters, police and emergency agencies, and delivery companies. Travel times for segments of the roadway network, called traffic links, are processed from this information. These real-time travel times are transmitted to the TravTek cars every minute and are used by the TravTek computers in the vehicles to determine the fastest routes, locations of congestion, and major incidents. At the TMC, the TravTek operator workstation can display maps of the TravTek area. Sections of the roadways are displayed in different colors, depending upon their calculated travel times and congestion levels. The TMC operator can also display the locations of the TravTek cars and enter accidents or other incidents that impact the traffic network on the operator workstation.

In closing, Mr. Rupert noted that a fleet of 100 cars driven primarily by out-of-town visitors may not result in a great deal of quantifiable information from a traffic management point of view. However, the establishment of a TMC as a central information collection point is an invaluable resource for areawide traffic management. The city of Orlando and the metropolitan planning organization for eastern central Florida view TravTek as an element in an overall traffic management plan. Regardless of whether there are "smart" cars with which to communicate, the TMC is planned to continue operations as a cornerstone for integrated traffic management.

Transit Applications of ITMS

Ronald J. Fisher
Federal Transit Administration

Mr. Fisher discussed the need to take a broad view of ITMS development. He believes that the development should not just be limited to traffic concerns, but also should include transit and other modes. During his presentation, Mr. Fisher made the following points.

- Transportation professionals face the challenge of providing good choices for improved mobility to a broad group of travelers or users of transportation services. While by far the greatest number of these travelers are behind the wheel of an automobile, the policy directions contained in ISTEA, clean air, and energy legislation strongly support developing alternatives to single-occupant vehicle travel.

- Taking a broader view of the responsibilities of transportation professionals is not new. In the 1970s the Highway Research Board became the Transportation Research Board, and in the 1980s the Institute of Traffic Engineers changed to the Institute of Transportation Engineers. Although actual practice in the field often lags behind these surface changes, transportation will continue to evolve in the 1990s to meet increasing demands and responsibilities.

- Traffic management and ITMS should encompass a broad focus. The term transportation management, rather than traffic management, may more accurately reflect the goals and objectives of these programs.

- This broader view should include the provision of information to travelers in their homes and places of work. Effective alternatives to the single-occupant vehicle will be found when all the modes are considered. This means looking at all travel options that could serve the mobility needs of urban areas. The challenge is to broaden the meaning of the "T" in ITMS: it is not just traffic, but transportation. Travelers need information to help them make educated decisions on what time to travel, what mode to use, and/or what route to take.

In closing, Mr. Fisher noted that he would be providing additional comments on many of these ideas at the closing session of the symposium. He challenged the members of the audience to reflect on the traditional mind set of the transportation profession. Mr. Fisher recalled that when he started to practice as a transportation engineer in the late 1950s there was no community involvement in the highway location decision process. This has changed significantly, with community involvement playing a key role today. Environmental, energy, and social concerns are the driving forces that will impact how the profession and decision-makers address mobility for travelers in the 1990s.

Session Six
Financing: Leveraging Funds for ITMS

Mark R. Norman, Institute of Transportation Engineers — presiding

Federal Funding

Sheldon G. Strickland
Federal Highway Administration

Mr. Strickland provided a summary of the various sources of federal funding available for ITMS. These sources focused on the Intermodal Surface Transportation Efficiency Act (ISTEA) and other related legislation. Mr. Strickland made the following major points in his presentation relating to the provisions of ISTEA addressing ITMS, the funding available through these programs, the requirements to obtain these funds, and the procedures to be followed.

- ITMS, IVHS, and other related advanced technology programs are clearly needed to deal with current traffic congestion and air quality problems. Although it is not easy to design, fund, implement, and operate these systems, it is clearly worth the effort to pursue these projects.

- ISTEA is supportive of ITMS. The provisions of ISTEA clearly endorse the notion that traffic operational improvements and the operating costs for these systems are eligible for federal funds. This represents a change from the old policies. Previously, capital costs were eligible, but not operating or start-up costs. ISTEA clearly includes "integrated traffic control systems" in the definition of operational improvements. Start-up costs for a 2-year time period and integrated traffic control systems are both specifically referenced.

- The three primary sources of federal funds within the ISTEA are the National Highway System (NHS - $2.8 billion FY 92), the Surface Transportation Program (STP - $3.2 billion FY 92), and the Congestion Mitigation and Air Quality Improvement Program (CMAQ - $826 million FY 92). The start-up costs available through NHS funds are only eligible for a 2-year period. The STP and CMAQ programs, however, can fund both start-up and long-term operating costs. To apply for CMAQ funding, the project must be listed in the state implementation plan (SIP) and the project must clearly make a contribution to improving air quality in the area. STP funds are determined primarily by the MPO, in consultation with the state. CMAQ funds should supplement or augment, rather than replace, existing operating funds. It may be possible to qualify for up to 100 percent federal funding under the NHS, STP, and CMAQ programs.

- Before operating a system, however, planning and design work must be conducted. Federal funding sources that can be used for planning activities associated with ITMS include the two historically available programs, Highway Planning and Research (HPR - $278 million FY 92) and Metropolitan Planning (PL - $116 million FY 92), and the new IVHS Planning and Deployment Assistance program ($7 million FY 92). Funds in this program are targeted for the 75 largest cities in the country. Areas must apply for these funds, which can be used for IVHS planning. FHWA division offices should be contacted for more information on this program.

- A longer-shot source of funding might be the Congestion Pricing Demonstration Program (Section 1012 - $25 million FY 92). Congress provided this funding to demonstrate congestion pricing strategies, which might include some ITMS activities.

- In terms of obtaining funding, the ISTEA makes it clear that the state DOTs and the MPOs are the critical links in the decision-making process. There are four major activities within ISTEA that provide support to market IVHS and ITMS to decision makers. These include the requirements contained in the Congestion Management System (Section 1034), the Clean Air Act and SIP, Metropolitan Planning and TIP (Section 1024), and Statewide Planning and TIP (Section 1025). The common elements of all these are that congestion must be reduced and/or prevented, and the project must contribute to clean air and air quality improvements.

- The recommended steps for deployment include:

  - Develop an areawide Traffic Management Plan using IVHS or HPR funds.
  - Incorporate these into the Congestion Management Plan through the MPO and state planning process.
  - Obtain endorsement by the MPO as part of the Long Range Plan and SIP.
  - Include the project in the Transportation Improvement Program (TIP).
  - The project is then eligible for NHS, STP, and CMAQ funding.

State Programs

David W. Brewer
California Department of Transportation

Mr. Brewer provided an overview of the funding programs available in California and the approaches that have been used in the state to implement ITMS. Mr. Brewer covered the following major topics in his presentation.

- In 1989, new state legislation altered the approach used in California to fund ITMS and other related projects. This legislation, called the Transportation Program for the 21st Century, anticipated many of the changes made at the federal level in the ISTEA. Three different programming documents were required as the focus of the program. These included the Highway Systems Operations and Protection Plan, the State Highway Improvement Program, and the Traffic Systems Management (TSM) Program. This last program is the one most relevant to IVHS and ITMS. The TSM program established a 10-year funding target of $1 billion for traffic management systems, required Caltrans to annually establish a priority listing of projects for funding, and called for the development of congestion management programs in the urbanized counties. The intent of the TSM program was to provide for effective traffic management systems in major urbanized areas of the state.

- Most of the projects funded through the TSM program fall within three categories: traffic operations centers and related surveillance and information systems, freeway ramp metering systems and HOV bypass lanes, and traffic flow improvements on conventional streets and roads. It was determined that eligibility would be limited to retro-fitting existing projects. It was also determined that this program should focus on the high-priority congested corridors. The annual priority listing is developed by Caltrans, based on criteria established by the state Transportation Commission. This list must be presented to the commission by December 1 each year. Funding is then allocated to projects during the year, up to the limit of the dollars available.

- The state expects the ISTEA and related programs to provide significant funding for ITMS and IVHS programs. It is a challenging time for Caltrans, the MPOs, and others to work out ways to coordinate the funding and operation of these programs.

- State legislation that would allow for the implementation of the ISTEA programs in California is still pending. As a result of a conference in February, there is general agreement between the state, MPOs, transit agencies, and local jurisdictions on how the programs should be implemented. Elements of this approach include distributing the formula funds from STP and the air quality and congestion mitigation program to the

MPOs for programming, broadening the definition of TSM to include HOV lanes and traffic control measures, and coordinating the federal and state programs. Further, it is anticipated that the state TSM program will be a major source of local match for the federal program.

- It is also anticipated that, although annual TIPs will still be required, Caltrans will need to make funding commitments several years in advance. Thus, the goal in California is to maximize and leverage all funding sources for the development of ITMS and IVHS.

Local Programs

Donald W. Dey
City of Menlo Park, California

Mr. Dey provided a local perspective on the development of ITMS and IVHS and the use of local funding sources. Mr. Dey covered the following major points in his presentation.

- The definition of ITMS needs to be very broad. Many elements of the local transportation system—including transit, police, and emergency services—should to be included. Further, the link to neighboring systems and the regional network is critical. In terms of management, both the human and technical aspects of the system must be coordinated.

- The first step in leveraging local funds is to identify a problem and the project you want to implement to address the issue. Having defined the project, you need to identify appropriate federal or state funding sources and develop the appropriate applications and supporting documentation. It is important to be aggressive in pursuing these programs. Keep in touch with agency representatives and the requirements of the different funding programs. Maintaining flexibility is also important. This will allow you to take advantage of changes and new opportunities at the state and federal levels. Also, be sure you can show results for your efforts. Federal and state officials are just like local officials in that they want to see results and benefits from their funding. Thus, you must be able to produce and show results.

- Governmental units, especially at the local level, must learn how to package, sell, and market their proposals. Don't get discouraged if a proposal is turned down. Follow up with the funding source and find out what the weaknesses of your proposal were. Use this feedback to improve your next effort.

- One key element to attracting federal funding is that the project must have the potential for technology transfer, or sharing the knowledge in other areas.

- In terms of local projects in California, a number of funding sources may be available. Potential sources include Caltrans, FHWA, regional and local programs, and special programs such as the fuel overcharge fund. Although each of these alone may not be enough for an entire project, when combined, they provide adequate funding for most projects. Thus, it is important to leverage a variety of funds.

Private Sector Participation

Alan Clelland
JHK & Associates

Mr. Clelland provided the private sector perspective on the implementation of ITMS and IVHS. He focused on the issues associated with deployment of these systems and the funding implications of design/build contracts. Mr. Clelland covered the following major topics.

- The best leverage for obtaining funding is a successful program. If you look at the funding for the early stages of the IVHS program you will see a correlation between the successful projects and where the early funds are being deployed. Thus, it is important to develop successful projects and then build on this success.

- ATMS and ATIS are critical elements of IVHS. Many of the other IVHS programs, such as APTS and CVO, build off of many of the elements included in ATMS and ATIS.

- The current responsibility for developing ITMS rests with the public sector. The typical deployment approach includes preliminary and final design, advertising and contract award, construction/technical services, system integration, and operational support.

- Three different deployment approaches are often used. These include engineer/contractor, program manager, and design/build. In the classic engineer/contractor approach, an engineering or design firm carries out the PS&E work. Once this is completed, the public agency issues an RFP and goes through the selection process. Typically, the contract goes to the lowest bidder. There are drawbacks to using this approach with ITMS and IVHS. Most of these focus on the fact that ITMS and IVHS projects include a number of advanced technologies that many firms may not have expertise in. Thus, the agency must maintain active involvement in monitoring these projects.

- The program manager approach turns over the responsibility for the total implementation to a program manager. The program manger could be an individual within the public agency, but typically the agency contracts with a private firm for this function. The program manager is responsible for preparing the design and the bid specifications and monitoring the other elements of the process. Typically, the selection of a program manager is negotiated, rather than a low bid process.

- In the design/build approach, a single entity performs all the work. At the beginning of the process, a relationship is established between the agency and the design/build firm. The firm will design the system to meet the clients needs, will take the preliminary design through to about the 30 percent completion stage, and at this point will negotiate the fee for the remainder of the contract. The design/build firm then has the responsibility to make sure that all the elements are completed on time.

- Each of these approaches has advantages and disadvantages in terms of the time to complete the project, risk, total program costs, and agency resources. The major attributes of the engineer/contractor approach are that it matches the current practice, agencies are familiar with it, it initially guarantees a low bid, and there is only one construction contract to monitor. Major disadvantages with this approach include the lengthy time to implement, the risk of selecting the wrong contractor, potential for difficulty in making changes, and a high agency staff commitment.

- Attributes of the program manager approach include well defined technical responsibilities, qualification-based selection, ease of modification, the potential for significant cost savings, faster deployment, and reduced agency staff time. This approach is being used in some areas. Disadvantages of the program manager alternative include the length of time to implement and unfamiliarity with the technique among many agencies.

- The key feature of the design/build approach is a faster implementation time and the reduction of agency staff demands. The single point responsibility is very clear and cost savings can be realized through the procurement process. The disadvantages of the design/build approach are very difficult to overcome. The political and institutional issues associated with this approach may be difficult to address. Further, the total cost of the project may not be known until 30 percent of the design has been completed. It is also not as flexible as other approaches and there are significant demands on agency staff resources.

- In summary, there is no one correct deployment strategy. An assessment should be made for each project on what the best approach is. It is important to maintain flexibility with whatever approach is used.

Session Seven
Implementation: Lessons Learned

William C. Kloos, City of Portland, Oregon — presiding

Seattle ITMS

Mark E. Hallenbeck
Washington State Transportation Center

Mr. Hallenbeck is involved in a project that integrates the signal control systems for two independent arterial networks with a real-time freeway ramp metering system in Seattle, Washington. In his presentation, he discussed some of the implementation issues that the Washington State DOT is experiencing with the system. The major points of his discussion are summarized below.

- The project is intended to be a low-cost, simple approach to integrate the control systems for three parallel facilities. It includes the signal systems on two arterial streets, SR-99 and SR-522, and the ramp metering on I-5.

- The configuration of the integrated system is quite simple. Each of the facilities has its own existing control system. The project simply added a central computer that communicates with the three existing systems. That central computer monitors the other systems, and when a problem arises, it proposes appropriate coordinated responses by those systems.

- Many of the implementation problems have not been technical. Rather, they are related to the research nature of the project, which means that no one has a primary responsibility to make the system work. The Washington DOT is very supportive of the project, but the resources are not always available to address problems quickly. The operators of the control systems are responsible for their own operations, and this project is attempting to integrate their efforts. Those operators are willing help when they can, but there are not enough resources to make it a priority.

- The key solution to this implementation problem is the dedication of sufficient resources to the project. ITMS and IVHS need to be given the necessary priority if they are to be implemented and operated successfully. Interested agencies need to decide how ITMS and IVHS will fit with their other responsibilities.

- There are some important questions that need to be addressed before implementing ITMS. First, Which agency will assume the lead role? Next, Do all the agencies involved agree with the project and their role in it? And last, Do all agencies agree with the intended operation of the system? If there is agreement on questions like these, then it is only a technical issue to implement the project. On the other hand, if it is a question of political will, then there may be problems that cannot be overcome.

- Other questions also must be considered. For example, Do the agencies have the technical knowledge to operate and maintain these integrated systems? Also, What control strategies are already in place, and are they being used to their maximum potential? If an agency lacks the staff and resources to effectively operate and manage its current systems, integrated systems may not be an intelligent choice.

- Three suggestions for the implementation of ITMS were outlined. First, providing flexibility in the system design is imperative. Second, the different agencies should be offered different levels of integration and control. And third, it is important to recognize that the desired levels of control may change over time.

Mr. Hallenbeck concluded his presentation with a discussion of three lessons that have been learned in Seattle. First, all agencies must be willing participants with a desire to cooperate on the project. Second, progress is made at the rate of the slowest participant in the system. Finally, you must be willing to dedicate the necessary resources and staff to the project—you need someone whose job it is to make the system work.

Implementation Issues

Philip Tarnoff
Farradyne Systems, Inc.

Mr. Tarnoff has been involved in numerous control system projects during his career. During his presentation, he discussed some of the implementation lessons learned from those projects.

- Previous experience with integrated systems suggests that the non-technical issues are invariably bigger problems than the technical ones. Those problems include such things as project administration, staffing, institutional issues, and funding. The technical problems and issues are typically more interesting, but they can usually be resolved with a competent staff.

- There are several lessons to be learned from the area of traffic signal systems, and they may be equally relevant to freeway systems. The signal system market is more mature in some respects, and as the freeway market continues to grow, many of the same opportunities and problems will arise.

- There are currently a number of standard signal systems available. Many cities conduct detailed surveys of the those systems for their own projects. Often, the conclusion is that a particular package meets their needs. Acquiring that package presents a problem when there is a policy for low-bid procurement. It generally means writing a proprietary specification that is blatantly obvious and may cause trouble. Even worse, a city may conclude that none of the systems exactly meet their needs, and produce a specification that includes the best features of all the systems, but no one can meet.

- Another problem for both signal and freeway systems is interfacing with various manufacturers' equipment. Agencies are often forced to deal with a single manufacturer of proprietary systems, or to hire consultants to develop specialized interface software. There is a real need for improved standardization of equipment. Other industries have demonstrated that standardization can be successful, and many of the arguments against it do not materialize.

- A third concern is the desirability of standardized software. It is hard to believe that every agency's problems are so unique that they require a completely customized system. There seems to be little appreciation for the costs of including long lists of unique features into an RFP. The costs are rarely traded-off against the benefits of those features.

- Finally, on most projects the design and implementation consultant cannot be responsible for the procurement of the equipment. Instead, the agency is responsible for procuring the equipment for the consultant. This is called systems management, and it is one way to avoid the problem of picking certain packages and then having to specify the sole source. The important point is that with agency-supplied equipment, it is necessary to consider the agency's procurement cycle. Otherwise, significant delays could result.

- There are also a few institutional issues with respect to implementation. Some integration projects have suffered because of the number of agencies that were involved. It is true that a project will only proceed as quickly as the slowest agency is willing or able to. In these projects it is critical to get commitments from all the participants. They must receive as much priority as other internal activities at each agency. Unfortunately, that is difficult because no single agency is responsible for the success of a cooperative project.

Mr. Tarnoff concluded by discussing a very common problem for traffic management systems: the lack of adequate internal staff to operate and maintain them. If internal staff is not available, the possibility of contracting out for support staff should be considered. It simply does not make sense to spend millions of dollars on systems that are not going to be properly operated and maintained.

Traffic Management Lessons

Colin A. Rayman
National Engineering Technology Corporation

Mr. Rayman has been involved with traffic management projects in several capacities. In his presentation he shared some perspectives on traffic management from personal experiences in the industry, as a client, and as a consultant. His comments are summarized below.

- One of the most important lessons in traffic management is that we never seem to learn. There are many valuable experiences out there, but we have failed to educate ourselves. That failure may be due to a competitive attitude among agencies, a lack of traffic management education at our universities, or some other reason. Whatever the reason, every time a system is implemented there is a struggle to justify its existence. There is a long history of experiences out there indicating that these systems do work.

- Integration represents a new era in traffic management systems. Because of this, there is a need for constant education and reeducation in traffic management. The program at Texas A&M University is a noteworthy effort to educate our young engineers in traffic management. The reeducation effort must also extend to our decision makers.

- While there are a lot of knowledgeable people in the field, there are also a lot of naive people. That includes agencies who think they want to implement a traffic management system, but don't really know what it involves. It also includes consultants who want to provide services, but are not capable of doing so. And finally, there are suppliers who don't know how their products can be applied effectively in traffic management systems.

- There are also some unrealistic expectations for traffic management systems. This problem exists in expectations about project costs and the implementation schedule. It is important to be very clear about what the expectations are, given the industry's capabilities.

- There is a growing assortment of exotic traffic management products. The potential exists to focus too much on the technology and lose sight of the true objectives of a traffic management system. This is a danger that we need to be aware of.

- As clients, agencies also need to be aware of exactly what they are purchasing, whether it is from a equipment vendor or a consultant. It really is common sense, but the concept of "buyer beware" needs to be emphasized.

- These systems require a champion within the agency for them to succeed. Knowledge of these systems and what they are capable of is not necessarily widespread. In order to implement and operate a system successfully, it takes someone who is willing to defend it continuously.

- It is necessary to think beyond implementation. That stage is often difficult, but one also must think about what is necessary to operate and maintain the system. In addition, there will be advances in the technology, which means continuous upgrades and changes. These projects do not end once they are operational, and that requires a long-term vision for the project.

Mr. Rayman concluded by emphasizing an important point about integrated traffic management systems. He noted that it isn't just systems working together, it is the people who must work together.

Houston ITMS

Alfred H. Kosik
Texas Department of Transportation

Mr. Kosik provided a brief case history of a traffic management project on I-10 West in Houston. He used the project as an example to discuss some of the lessons that have been learned in Texas. The highlights of his presentation are summarized below.

- The project involved the instrumentation of a 6-mile stretch of HOV lane for surveillance, communications, and control. Design work for the system began in 1982. In 1984, the project was let and computer equipment was purchased. Construction was substantially complete in 1985, but the system was not put into operation until 1988.

- The system has an assortment of surveillance and control devices, including closed-circuit television cameras, inductive loop detectors, changeable message signs, lane control signals, and an on-site control center. The system uses a distributed computer architecture, and the communications are by standard coaxial cable.

- One of the biggest problems with the project was the fact that it was designed by a committee. It was a large group that included TxDOT, Houston METRO, the city of Houston, Harris County, the Texas Transportation Institute, the Houston-Galveston Area Council, and consultants and suppliers. Because of the size and diverse nature of that group, resolving detailed design issues was very difficult.

- The project was initiated because TxDOT was planning to reconstruct I-10. However, there was a funding shortage in the department at that time. Houston METRO had funds, and they agreed to help finance the reconstruction, an HOV lane, and the instrumentation.

- A good working relationship was developed between TxDOT, METRO, and the other participants. This was built on the previous relationships between METRO and TxDOT, which were formed during the joint implementation of the HOV lanes in the Houston area.

- Many of the problems that had to be overcome were design differences. Some specific issues that the design committee struggled with were the control system architecture, the joint chairmanship of the committee, and a proposed fast-track construction schedule that had to be coordinated with other construction activities. Developing the specifications was also a major issue.

- Some other problems were more typical of traffic management projects. For example, there was not enough consideration given to the operation and maintenance of the system during its design, the project inspectors were not familiar with either the technology or the contractors, and there were weather-related delays. Also, the contractors should have been given some flexibility to improve some of the designs if possible.

Session Eight
Overcoming Institutional Barriers to ITMS

W. Scott Wainwright, Montgomery County, Maryland — presiding

Coordination of Governments

Leslie N. Jacobson
Washington State
Department of Transportation

Mr. Jacobson presented an overview of the approaches used in the Seattle area to encourage interjurisdictional cooperation on ITMS. Many of his comments focused on the FAME project. Mr. Jacobson highlighted the following points concerning the institutional issues and approaches in the Seattle area.

- The scale and scope of jurisdictions in the Seattle area is not of the same magnitude as in Southern California or many other parts of the country. Thus, with fewer agencies and jurisdictions, the institutional issues associated with ITMS may be more manageable. However, there are still institutional barriers and trust issues between agencies that must be overcome.

- Instilling ownership and building consensus through the different activities is a major focus of the approach taken in the Seattle area. Jurisdictional cooperation needs to be addressed on both the political and technical level. Often the political level may be the more difficult of the two. The technical and institutional issues include both the equipment and technology aspects of the project and the people responsible for planning, designing, and operating the systems.

- Many of the institutional issues are associated with making changes in the traditional roles and responsibilities of the different groups or implementing new approaches. The Seattle approach started with the attempt to understand the needs of the agencies involved and to show that the different objectives of these agencies can be accommodated within an integrated system.

- The problems associated with an integrated approach were identified and different ways of overcoming them were discussed. All groups—traffic engineering agencies, transit agencies, planning agencies, and other organizations—were involved in the process.

- The first step was to meet with staff from all these agencies and discuss their needs and concerns. This started the process of building a consensus for an integrated traffic management system. Six options for integration were developed and presented as part of a research project. The Seattle area was divided into three subareas and the options were presented and discussed in each. The level of interest differed among the areas, and the area expressing the most interest became the focus for the next steps.

- The approach of taking small, incremental steps to develop and implement the integrated system was followed. This included starting with a demonstration project, which focused on the I-5 corridor to the north of downtown Seattle.

- It is important to realize that not all agencies and organizations have to agree on all of the system objectives. Integrated systems can be developed to meet the different needs and objectives of the different agencies. However, it is important that a consensus exists on the general approach and the general objectives of the system.

- Funding is also important. All groups must feel that they are providing an equal and equitable amount of funding. Further, they must feel the benefits they receive are worth their commitment of funds.

Texas Traffic Management Teams

Steven Z. Levine
Texas Department of Transportation

Mr. Levine provided a summary of the use of traffic management teams in the Houston area. These teams have been used successfully over a number of years on a variety of projects. Mr. Levine covered the following points in his presentation.

- The traveling public does not always realize who is responsible for the different transportation facilities, nor do they really care. Their major concern is that the facilities are maintained and operated to serve their needs. To accomplish this, traffic management teams—comprised of representatives from all the different agencies responsible for the system—have been used in many areas.

- The first traffic management team in Houston was formed in March 1981. The initial focus of this group was on the development of the Houston HOV lanes. This effort established the communication links and cooperation between agencies that continues today. The team has been meeting once a month for 11 years and the success of many projects in the Houston area can be traced to this coordination and cooperation.

- The traffic management team has addressed a number of issues. These include coordinating traffic control plans for major construction projects, enforcement of work zone safety and regulations, coordinating truck routings and the movement of hazardous material, developing plans for incident management, and coordinating transportation and special events.

- The team has recently been reorganized to provide for subcommittees to address specific problem areas and projects. Incident management and special events are the two areas currently being examined by the subcommittees. The use of these subcommittees allows a smaller group to focus on a specific issue and helps resolve them in a more timely manner.

- Additional programs have been developed through the cooperative efforts of the traffic management team. An example of this is the successful Motorist Assistance Patrol.

- The team has also helped with public information, especially through participation in the annual Houston Automobile Show. Further, the team has been assisting with a variety of IVHS-related demonstration projects that are being implemented in the Houston area.

- Funding for the traffic management team has been borne by each of the involved agencies. Capital improvements for the different projects and programs are funded by the respective agencies.

- The team has withstood the test of time and is being viewed as an integral part of the activities associated with developing ITMS and IVHS in Houston.

Anaheim's Katella Corridor

Dr. Michael McNally
University of California-Irvine

Dr. McNally provided an overview of the institutional issues associated with the Katella Corridor project. This project is one part of the ITMS program for the city of Anaheim. Dr. McNally summarized the following points concerning the Katella Corridor project.

- The Katella Corridor project focused on interjurisdictional coordination of traffic signal timing. Four cities, Orange County, and Caltrans were all involved in the project. The first question addressed in the project was, Is interjurisdictional cooperation necessary for an coordinated signal system? The second question was, Is such cooperation feasible?

- The need for cooperation at the hardware, signal, and institutional levels were all examined. Key factors at the institutional level included administrative, financial, liability, and engineering issues.

- The initial administrative issues were associated with the staffing, staff training, and funding needed to implement the project. A key staff person is important to lead and move the project along. There is also a need for a commitment from higher levels within the organization. Financial issues focused on the need to obtain funding for the projects. A variety of funds were used in the Katella Corridor.

- Liability and engineering issues were also concerns. The liability associated with timing signals between municipalities had to be addressed through a series of intergovernmental agreements. The engineering issues were fairly conventional. These related to the technical issues associated with linking the different system elements together. One issue that needs to be addressed early in the process is at what level the system should be coordinated.

- Key elements for successful projects include a commitment from all agencies, adequate funding, leadership, and expertise.

Police Perspective

Sergeant Paul A. Einreinhofer
Bergen County, New Jersey
Police Department

Sergeant Einreinhofer provided a perspective from law enforcement agencies in the implementation and operation of integrated traffic management systems. Major points made by Sergeant Einreinhofer included the following.

- Bergen County is home to many corporations, Giants Stadium, and has a population of approximately 850,000. The county is also the western terminus of the George Washington Bridge, which serves Manhattan Island.

- Police and law enforcement agencies are concerned with the actual operation of the transportation system. What looks good on paper may not work in actual practice, and it is the police and highway patrol that must deal with the actual operation of the system.

- It is important to realize that traffic problems may not be the first priority for police departments. This is especially true when traffic problems are compared with life-threatening situations. Police agencies are concerned with how the system functions and are interested in determining their appropriate roles in ITMS. Police departments are also concerned with the transportation of hazardous materials, incident management, and public information.

- Management teams appear to be a good way to address many issues. Representatives from police and law enforcement agencies should be members of these teams. The incident command approach is used in Bergen County to provide one lead group to coordinate responses to major problems.

- Who is in charge and who pays are always major issues. Everyone wants to be in charge, but no one wants to be responsible for the cost of incident management and other activities. Reaching an agreement on these two issues is important.

- More sharing of information and coordination between police and enforcement agencies and the other groups responsible for ITMS is needed. Police and enforcement agencies should be viewed as important elements in implementing ITMS and should be involved in the different activities associated with planning and operating these systems.

Session Nine
Operations and Maintenance: Keeping ITMS Working

Joseph M. McDermott, Illinois Department of Transportation — presiding

Los Angeles Experience

Anson Nordby
Los Angeles Department of Transportation

Mr. Nordby is in charge of the ATSAC Operations Division in the Los Angeles Department of Transportation. He provided an overview of the signal systems maintenance program in Los Angeles, and the significant changes that have been made as a result of the ATSAC system. The major points of his presentation are summarized below.

- Up to the 1970s, the situation in Los Angeles was very similar to most other cities. There was a mixture of different traffic controllers in the system, which required a large inventory of spares and equipment for maintenance. Furthermore, the signal system was interconnected using several types of communications. All of that equipment was maintained by electricians, and they appeared to be fairly successful at keeping the system in operation.

- In 1976, there was an attempt to conduct a TRANSYT study of the downtown signal system. They found that the signal equipment could not be kept operating well enough to perform the study. Each day they would discover new failures that had to be repaired.

- That experience led to a signal reliability study in the late 1970s. Many systems within the city were surveyed, and they discovered that 24 percent of the traffic signals had some sort of failure that was affecting traffic flow continuously. Even after a significant amount of diligence by the maintenance supervisors, the failure rate remained at about 24 percent.

- In the late 1970s, the city also decided to standardize its signal systems with Type 170 controllers. There was an aggressive program to replace the other controllers, which eliminated the need for a large inventory of spare parts for different types of equipment. After a little hesitation, the electricians seemed to accept the standardization with 170s.

- The first installations of the ATSAC system coincided with the 1984 Olympics in Los Angeles. It worked very well, and large-scale implementation of ATSAC was approved. The ATSAC system involved a lot of new technologies that the maintenance personnel had never worked with before, including fiber optics, digital multiplexing, and video surveillance. Many of the older technicians resisted the new technology, which is not an uncommon problem.

- As a result, it was necessary to create a special maintenance group that did nothing but work with the new technologies. These technicians are responsible for the initial turn-on of the systems, they resolve any integration problems that arise, and they do training within each of the regional maintenance groups.

- Once it came on-line, the ATSAC system exposed that constant problem of a 24 percent failure rate in the signals. The automated system is very intolerant of any faults out in the field—whenever a problem was detected, the system operators were alerted immediately. This led to a significant increase in the number of maintenance calls, particularly for intermittent problems that were difficult to detect previously.

- The new system incorporates a significant amount of surveillance, which places an additional burden on the maintenance activities. In particular, there is an entire network of system detectors in addition to the loop detectors at each intersection. This was complicated by another city program to resurface the streets, destroying some of the newly installed detectors.

- All of these problems associated with the new system have forced the department to reexamine its maintenance program from a top-down view. They are attempting to reorganize their maintenance structure by looking at two things: the fundamental maintenance requirements of each piece of hardware, and the skills needed to perform that maintenance. The intention is to compare those needs with the existing maintenance organization, and restructure the organization accordingly. This will also reveal any holes in the future maintenance program that need to be filled.

- They are also addressing the problems associated with the need for special groups of technicians for the new systems. There has been an effort to establish a new class of maintenance personnel, with a pay bonus to compensate for the additional skills that are necessary.

- Because of the serious budget problems in the city, a lot of maintenance work is being contracted out. All of the advanced, technical maintenance is still done by the city personnel, but contracts are being let for other work. One potential solution to the financing problem is the federal funds that may soon be available for operations and maintenance activities.

Mr. Nordby concluded by noting that many automated systems around the country will be facing these same maintenance issues in the coming years. Although the current emphasis seems to be on system implementation, after a short period it will shift to the day-to-day concerns of operations and maintenance.

INFORM Operations and Maintenance

David C. Powell
New York State
Department of Transportation

The New York State Department of Transportation has implemented an integrated traffic management system on Long Island called INFORM. In his presentation, Mr. Powell discussed five important elements needed to keep a system like INFORM operational. His comments about each of those items are summarized below.

- Funding for operations and maintenance is the most important issue. Most transportation agencies are not accustomed to projects that have annual cost for operations and maintenance that equal approximately 10 percent of the constructed cost, particularly in the period immediately after implementation. Funding for capital costs is relatively easy to obtain. On the other hand, operations and maintenance funding is unpredictable and difficult for most agencies to secure.

- Upper-level management support within the agency is another important issue. When the INFORM project was about to go on-line, the department officials were unfamiliar with many of the system components and became concerned about some of the promises being made. They were reassured once they had the opportunity to meet with people involved in other successful systems.

- The state has used a different approach for meeting the staffing needs of the INFORM system. The private sector has been relied upon for a significant amount of the work. This approach is expected to continue. The project involved a collection of entirely new technologies, and the state did not possess the necessary skills to maintain them. Thus, it was always assumed that the maintenance work would be done by a contractor. There is also a consultant for the operation of INFORM. The initial plan was to phase-out the use of an operating consultant, but that has changed because the current arrangement seems to work well.

- The people who work with INFORM are always looking for opportunities to expand, enlarge, and enhance the system. Money has been made available for an IVHS project on Long Island that could be integrated with the INFORM system. There are also plans to expand the system in several directions, add new hardware components, and possibly relocate the control center. The state has also developed a unique relationship with a consulting firm for designing INFORM features into other corridor projects.

The final point that Mr. Powell made was that operations and maintenance efforts should be decentralized to the lowest possible level in the organization. It is very difficult to keep a system like INFORM in operation with a top-down approach from a central office.

ITMS Operations in Seattle

Peter M. Briglia
Washington State
Department of Transportation

Mr. Briglia provided a description of the efforts being made to integrate traffic management systems in the Seattle area. Currently, their systems are primarily freeway-based, but they are moving toward integration in several areas. His comments about those efforts and the operations and maintenance issues are summarized below.

- The existing traffic management system consists of 1,200 loop detectors, 23 metered ramps, 55 closed-circuit television cameras, 22 variable message signs, and 6 highway advisory radio stations. It covers about 30 miles of freeway, and about 7 of those have ramp metering. There are plans to expand the system to about 60 miles of freeway. The system crosses numerous jurisdictions, and the expansion will involve several more. A major effort is underway to convince those municipalities of the benefits of ramp metering, which can be a challenge.

- The department is also working on plans for traffic management systems in the cities of Tacoma and Vancouver, Washington. Typically, there is a lot of discussion about interagency coordination for traffic management, but it is also necessary to think about the integration of different districts within the department. Sometimes that can be as difficult as integrating separate agencies.

- One example of a successful integration effort is a traffic information telephone hot line, *622-CARS*. The objective of this program is to provide a single source of regional traffic information for motorists. In addition to traffic conditions, it provides construction information and road conditions that have been downloaded from city and county agencies.

- There is also a computer-generated graphic of freeway congestion information that is distributed to other agencies. The system is not used very effectively yet, but it does have significant potential in an integrated system for sharing real-time information among agencies.

- The Seattle area has many miles of both freeway and arterial HOV lanes in place or being planned. Like freeways, the HOV lanes cross many jurisdictions as well, and the operation of these facilities needs to be integrated in future systems.

- Currently there are two traffic management teams that meet regularly. One of the teams is working to implement a multi-jurisdictional traffic signal coordination system south of Seattle. A problem with these teams is that they are perceived as DOT controlled, and it has been difficult to get other agencies to participate actively.

- There are some specific problems with respect to the operation and maintenance of integrated systems. The first is that the technology clearly out-paces the skills of the maintenance personnel. Some typical solutions include additional training or contracting the work out. A different approach is to not favor the latest technology, but to select hardware than can be supported with existing capabilities.

- Another issue is equipment compatibility to permit the sharing of data, including video, with other agencies and systems. Sometimes it is difficult for agencies to effectively coordinate their procurement processes to ensure compatibility.

- The department and the State Patrol have a good working relationship that includes direct connections between radio dispatchers. However, there is a definite lack of coordination with the local police agencies in the Seattle area. Most suggestions by the department to establish direct communications with the local police have received little attention.

- A different interpretation of integration is to integrate the skills of the engineers or technicians. Most of the staffing for these projects have backgrounds in civil engineering-related work, but there is a need for expertise in computers and electrical engineering. The perfect employee for these systems would be a civil engineer with a strong interest in electronics and computer programming.

- Steps also have been taken to integrate freeway operations with the other aspects of traffic engineering in the department. The main objective of this effort is to get the signal operations people and freeway operations people to begin working together, which is an essential step in the development of a truly integrated system.

- Finally, some successful efforts have been made to integrate transit into the freeway operations. In particular, the operation of the area HOV lanes is coordinated with the general freeway operations, and there is a direct communication link between the department's operations center and the Seattle Metro dispatchers. Metro is advised immediately of changes in the operation of the HOV lanes, and is consulted about the standard operating procedures of those facilities. The arrangement has worked very well for both Metro and the department.

Session Ten
Getting Started: Southern California Case Studies

Donald W. Dey, City of Menlo Park, California — presiding

District 12 Traffic Operations Center

Joeseph Hecker
California Department of Transportation

The first Caltrans Traffic Operations Center, located in Los Angeles, recently celebrated its 20th year in existence. This center has the capability to monitor 391 miles of freeways, including some in Orange County. Orange County was part of Caltrans District 7 until 1988. In that year, state legislators responded to the citizens' demand for a better transportation system by establishing a new Caltrans district, District 12, in Orange County.

District 12 includes all of Orange County, which currently has a population of approximately 2.4 million. The district has an extensive freeway system of approximately 140 centerline miles and a network of major surface streets. Approximately 220 miles of those surface streets have been identified as super streets, and emphasis is being placed on interjurisdictional cooperation in developing and operating them. Sixty percent of the freeway facilities in the district are congested. Also, the region falls within the South Coast Air Quality Management District and is part of a severe ozone non-attainment area.

Orange County does not have a traditional downtown business center, nor is there any one area that receives a significant majority of the traffic. Rather, there are several business/commercial areas throughout the county, including east Anaheim, the major activity center of Anaheim/Garden Grove/Orange, the civic center area in Santa Ana, the Spectrum area in Santa Ana, and the Spectrum area in Irvine. There are also several tourist areas like Disneyland, Knott's Berry Farm, and Newport Beach. Major event areas include Anaheim Stadium/Arena, Santa Ana Arena, the Orange County Fairgrounds, and the Irvine Meadows Amphitheater. Finally, there are retail centers such as South Coast Plaza, Brea Mall, and Main Place in Santa Ana. In addition, two major universities, a major metropolitan airport, and several military bases are located in Orange County.

A number of innovative approaches to funding transportation improvements are used in the region. The Transportation Corridor Agency was created to build approximately 65 miles of new highways using development fees and tolls. A privatization project has been developed to construct an HOV and toll facility in the median of an existing freeway. The project is to include the most advanced forms of toll collection and HOV monitoring. There is an additional privatization project that proposes to extend Route 57 from the I-5/SR-57/SR-22 interchange to the

I-405/SR-73 interchange. The residents of the county also passed a one-half cent sales tax increase measure to fund transportation improvements. This will generate approximately $3.1 billion in local funds over the next 20-year period.

Orange County's daily recurrent congestion is currently between 30,000 and 40,000 vehicle-hours per day. The average systemwide congestion is actually on the order of 60,000 to 65,000 vehicle-hours per day when congestion from holiday, weekend special event, beach, and incident sources is included. Since Orange County is no longer a bedroom community for Los Angeles, workers commute from Riverside, San Bernardino, Los Angeles, and San Diego Counties to their jobs in Orange County. This is due in part to the cost of housing in Orange County, which is the highest in the state.

Commuter lanes and transitway facilities are currently under development on major freeways in the county. Although drastically needed, these improvements are not expected to eliminate congestion and must be managed to maximize their potential. Also, two of the busiest interchanges in the nation currently are under construction with another three projects to begin this year, all on Interstate 5.

Orange County has designated 21 super streets. Super streets are major arterials that have been selected as candidates for high-flow arterial improvements. When used together, these improvements—including signal coordination, channelizing traffic, removal of street parking, and widening—will provide substantial relief to traffic congestion.

There are 13 major transportation centers throughout Orange County, the largest of which is John Wayne Airport. These centers are an integral link as mode transfer points. Each provides transit services for commuters. All locations, with the exception of the airport, are served by public transit. The airport is served with private taxi and shuttle services. Six locations are served by rail, and two are designated park-and-ride locations. These centers also provide other amenities such as telephones and rest rooms, and some have food service and bicycle facilities.

The Division of New Technology, Materials, and Research, in cooperation with the cities of Irvine and Anaheim, UC-Irvine, and District 12, is developing an advanced traffic management system (ATMS) test bed to demonstrate the latest technology in Orange County.

Currently there are approximately 39,700 vehicle-hours of recurrent a.m. and p.m. congestion on District 12's freeways, and approximately 60 percent of the 242 directional miles experience daily congestion. That total represent daily averages during the winter months; congestion in the summer is roughly 60 to 70 percent of that, or about 25,000 vehicle-hours.

The recurrent congestion is about half the total congestion due to all causes, which includes weekends, holidays, special events, incidents, and planned lane closures. Each month, an average of 60 incidents occur that block at least one lane. Also in a typical month, there are 60 planned lane closures for maintenance on weekdays, and approximately 80 construction lane closures and 10 full freeway closures, generally occurring during the night.

A critical sections study showed that 90 percent of the freeway system in Orange County would experience congestion between 5:00 a.m. and 10:00 p.m. on weekdays if just one lane were closed. Flow rates during most weekday periods are greater that 1700 vphpl. Some sections experience rates of 1800–2200 vphpl almost all day. Computer records show 2–5 mile backups due to stalled cars or minor lane blocking incidents in the middle of the day. On weekends, congestion will occur on approximately 75 percent of the system if lane closures occur between 9:00 a.m. and 2:00 p.m.

Currently, 46.2 percent of the freeways in District 12, or 130.4 directional miles, are under surveillance. There are 232 ramp meters, 10 changeable message signs, 7 closed-circuit television cameras, and 2 highway advisory radio systems installed in the district. In the next year, additional equipment will be installed, including 27 ramp meters, 8 changeable message signs, 19 closed-circuit television cameras, 3 highway advisory radio systems, and communications conduit on 30 directional miles. District 12 has 92.6 directional miles of HOV lanes, and 18 additional miles will be opened in the next year. The full system of 185 miles will be implemented by 2001.

A Traffic Operations Center provides the district with the capability to obtain maximum utilization of the urban highway system. In early 1990, the decision was made to set-up a Traffic Operations Center in the Caltrans District 12 facility. The center is a joint Caltrans and CHP operation, providing traffic engineering, maintenance, and law enforcement expertise. Roles for each agency were established in a joint operational policy statement. Staffing levels, equipment, and training needs were also established as well as targeted activity milestones.

District 12 opened its interim Traffic Operations Center in November 1990. The Traffic Operations Center serves as the focal point for traffic management and information for Orange County freeways, providing a rapid and coordinated response to incidents and up-to-the-minute traffic information to the media and motorists. The center is staffed with law enforcement, engineering, and maintenance personnel. It is in full operation Monday through Friday, from 5 a.m. to 7 p.m. The maintenance dispatch is in operation 24 hours a day, Monday through Friday. Current equipment and activities at the District 12 Traffic Operations Center include:

- Three dispatch areas (maintenance, traffic operations, and service patrols)
- Graphics display showing freeway status
- Modcom computer
- Changeable message sign terminal
- Automatic vehicle detector monitor
- Highway advisory radio recording studio
- Ham radio operator console
- California Highway Information Network (CHIN) system
- Media information officers
- Large screen graphics display
- Thirteen closed-circuit television monitors
- Media information terminals
- Computer workstations
- Two CHP officers per shift
- Two traffic operations engineers per shift, plus a supervisor
- Two maintenance personnel per day shift, one at night

Because of computer integration, District 12 is somewhat dependent on District 7—if the District 7 computers go down, the District 12 system would be inoperable as well. District 12 is in the process of contracting with a consultant to install an interim system that will be independent but still connected to District 7. The plan for the ultimate system is to have District 12's Traffic Operations Center integrated with the others in Southern California, but operated separately.

Sophisticated equipment and computers, the so called "bells and whistles," are important, but the most critical thing in a successful Traffic Operations Center is the cooperative attitudes of the people. The center is a reality because of the partnership with the California Highway Patrol, the maintenance personnel and engineers working together, the work with local agencies such as the cities of Anaheim, Irvine, and Santa Ana, and the support of the Orange County Transit District. As a result, the district can provide better and safer travel in Orange County.

ITMS Experiences in Los Angeles County

Dave Barnhart
Los Angeles County
Transportation Commission

Institutional issues comprise approximately 80 percent of the concerns in implementing ITMS. In comparison, the technical issues usually make up roughly 20 percent. Funding is also a major concern. This afternoon, I would like to focus my comments on the development of a multi-jurisdictional coordinated traffic management system in the Los Angeles area.

This effort has been underway since 1988. I would like to discuss how the process has been organized, some of the issues encountered, and the current status of the different elements. It is important to stress the evolving nature of both the process and the system.

Coordinating the activities of the different jurisdictions and agencies involved in traffic management in the Los Angeles area is not easy. Maintaining ongoing communication among all groups and ensuring that everyone is aware of the current status of the different activities has been an important part of the process. The lack of knowledge and understanding about a project can often lead to unnecessary opposition. Thus, effective communication is critical to building strong coalitions.

The process in Los Angeles County started with the development of a multi-jurisdictional committee, called TRAFFIC, formed by the county Board of Supervisors. This group was responsible for bringing together staff representatives from the different agencies and organizations involved in traffic management. In addition, the committee had two full-time staff people from the county Public Works Department. These individuals have been instrumental in keeping the committee focused on key activities and following up with specific tasks. A consulting firm, JHK & Associates, has also performed specific activities in support of the committee. These have included both technical and institutional issues.

There are a number of examples of coordination on a project-by-project basis in the Los Angeles area. Many of them have been implemented without a great deal of publicity. However, we still need to do more, especially in a formalized manner. Furthermore, that formal approach should be developed through consensus, rather than imposing a solution from above.

Los Angeles County has approximately 9 million residents. It is a large urban county, with some 10,000 traffic signals operated by 88 different cities, Caltrans, and the county. There are also approximately 500 miles of freeways.

This is a relatively small amount given the size and population of the county. As a result, roughly 50 percent of all travel in the county is on the surface streets. The interjurisdictional coordination of traffic signals is a very important element of the overall coordination of the traffic management system. It is important to remember, however, that traffic signal coordination is just one element of ITMS.

The Los Angeles County Transportation Commission (LACTC) is a unique organization in many ways. It was created by the state of California 17 years ago as a programming and planning agency. The need for coordination was another reason for its creation. The commission programs over $2.5 billion annually in highway, rail, and bus funding. LACTC also has its own sales tax authority. Legislation was passed this year that will merge the LACTC and the Southern California Rapid Transit District (SCRTD). The resulting agency will have responsibility for planning, programming, constructing, and operating the different modes of surface transportation in Los Angeles County.

TRAFFIC, which stands for Traffic Reduction and Free Flow Interagency Committee, is comprised of individuals from many different jurisdictions and agencies. It includes not only engineers, but also representatives from enforcement agencies, trucking associations, and automobile clubs. TRAFFIC was formed in 1988, and was organized around the three "Es:" Enforcement, Engineering, and Education. The initial focus of the committee was on coordinating low cost approaches to traffic management.

Much of TRAFFIC's work is carried out through the use of subcommittees. For example, the Engineering Subcommittee was responsible for the countywide traffic signal synchronization, operations, and maintenance program. The goal of this project was to establish the system and institutional arrangements for operating and maintaining a coordinated traffic signal system within the county. The first two elements of the program focused on consensus building and developing an implementation program. The third phase, which includes a pilot program, is just being initiated.

During the consensus building it became clear that one central approach for all 88 cities would probably not work. Therefore, the county was divided into smaller sub-regions that provide the focus for the project. There are currently 11 sub-regions in the county. A Signal Support Group was established to help with coordination and implementation. The emphasis was placed on the peak-period operation of the system. Several focus groups were held in the sub-regions as one technique for identifying and discussing issues and solutions.

One of the main issues in the second phase was determining where the Signal Support Group should be housed. The alternatives considered included both using an existing agency or creating a new agency. Other issues were the definition of the Signal Support Group and development of model interagency agreements for timing, operations, and maintenance of signal systems. Informational brochures, special meetings, and presentations were used during this phase to reconfirm the consensus. The final decision on the Signal Support Group was that it should be a permanent staff located at the LACTC offices. LACTC was perceived as a neutral location for the Signal Support Group and the commission represents all of the agencies. The staff for this group will be hired soon.

The pilot project for phase three, which focuses on nine cities in the San Gabriel Valley, has been initiated. $1 million in "fast start" ISTEA funding has been earmarked for this project. Now the task of the Signal Support Group is to finalize the needed interagency agreements. This pilot project is expected to provide a model for future programs.

IVHS Test Bed in Orange County

Dr. Wil Recker
University of California-Irvine

I would like to focus most of my comments on the institutional issues associated with the Orange County project. To do this, however, I would like to first provide a brief overview of the major elements of the Orange County IVHS Test Bed. This project has evolved over a 2-year period from a relatively well-defined, specific, and compact project to a larger, more diverse effort.

The program can be traced back to a Caltrans ATMS and ATIS initiative started a few years ago. The mission of this initiative was to expedite deployment of full-function advanced transportation management systems, including advanced traveler information systems, in California. A number of more specific goals were outlined in the initiative. It is important to briefly discuss these, as they influence the institutional issues associated with the Orange County project.

The first goal was to provide Traffic Operation Center (TOC) and Traffic Operations System (TOS) designers and operators with state-of-the-possible ATMS evaluations based on actual field trials. The two key parts of this goals are the use of state-of-the-possible technology and the evaluation of these based on actual field trials. The use of the term state-of-the-possible clearly made it a research, rather than an operations, mission. However, the field trial portion of the goal identified the need to not only conduct the research, but also to actually implement a test.

The second goal was to enlist technological capabilities of private industries in California, especially those associated with aerospace and communications. This charge clearly established the need to bring high technology private businesses into the demonstration. The third goal related to forwarding the California IVHS agenda. The fourth goal was to help satisfy the implementation of the district's TOC. The fifth goal was to foster cooperation among private and public practitioners and researchers. This supported the second goal and clearly identified the need to involve both public and private sector groups in the demonstration. The final goal, which was to test new ways of doing business with the private sector, especially the aerospace industry, further encouraged this cooperation.

These goals were identified by Caltrans at the outset of the process. The California Test Bed, which is basically a research and development program, was designed in response to these. The partners in the Test Bed currently include academic institutions—primarily the University of California-Irvine, Cal Poly San Luis Obispo, and the whole University of California System through the PATH Program, Caltrans districts, local cities, and private sector businesses. The scope of the program is really two-fold. The first is to develop a very aggressive integrated research and development program. The aim of this program is to provide the capability for real-time computer assisted traffic management and communication. The second element of the program, which has evolved over time, is the development of a statewide facility to support IVHS research and development applications. This focuses on building and equipping a laboratory for IVHS research and testing.

The physical boundaries of the Test Bed currently focus on the area around Disneyland in the city of Anaheim. We anticipate implementing research addressing network-wide application within this area first. A second Test Bed focuses on the Golden Triangle area in the city of Irvine. Research in this Test Bed will focus more on corridor type applications.

There are three basic dimensions to the Test Bed. The first addresses TOC decision support. This includes developing real-time computer assisted capability to help operators make traffic operations decisions. The second is to develop strategies or venues from which operators will be able to choose appropriate treatments for the different problems. The last addresses the development of management and integration capabilities for all forms of data that will be needed to help solve these problems.

Specific research components focus on further refining each of these dimensions. The development of real-time knowledge-based expert systems represents a major focus of the TOC decision support component. Other elements include AI-type applications for incident detection. Strategies being examined include research to develop real-time capabilities on ramps and arterials, real-time provision of traveler information, prediction of individual responses to real-time traveler information, and on-line response authorization. Strategies relating to data base management and communication focus on data fusion needs, real-time acquisition and transmission capabilities, and risk, reliability, and security.

The best way to highlight the institutional issues and opportunities associated with the California Test Bed is to review the major elements in chronological order. Caltrans initiated the first discussions on the project almost 2 years ago. These informal discussions included representatives from the district offices, academic institutions, and private industry. Given these early meetings, it is difficult to separate the roles of the various participants, particularly in advancing the original initiative. However, Caltrans had been working with the University of

California on a regular basis since 1947, and decided to use the academic institutions as the lead organizations in this effort.

In September 1990, Caltrans issued a formal RFP for ATMS conceptual research proposals. Prior to issuing the RFP, Caltrans significantly increased their advanced technology budget. This may have been done in anticipation of the ISTEA programs and funding for IVHS. The RFP indicated that two to seven test packages would be funded for the fiscal year, ranging from simple TOCs to more complex integrated system elements. It was anticipated that there would be between $18 and $30 million available for these projects over a 3-year period.

In response to the RFP, the initial Advanced Test Bed Partnership was formed. This included UC-Irvine, Caltrans District 12, the city of Anaheim, and two private sector businesses—a transportation consulting firm and a major aerospace firm. This represents a real mixture of groups, with different approaches and working styles. A number of steps were taken to make this group a full functioning consortium. The first step was to establish a partnership between the universities and the operating agencies. This was done by building on existing agreements. The city of Anaheim and UC-Irvine were working on an FHWA-funded demonstration project that had already addressed many of the legal and administrative issues. Further, a master agreement exists between Caltrans and the University of California System. Under the agreement, Caltrans can quickly and easily contract with universities. This agreement was used to make UC-Irvine the lead agency. The burden of subcontracting was then with UC-Irvine rather than Caltrans.

Coordinating operations between Caltrans and local jurisdictions was also a significant issue. Again, historical cooperation, coordinated relationships, and existing agreements were used to develop the new arrangements. The final issue concerned bringing in the private sector and establishing the link between research and the technology providers. Again, existing agreements were used to develop this link. The city of Anaheim had a longstanding agreement with a particular transportation consulting firm. This firm, in turn, had an existing agreement with a major aerospace firm. Thus, a basic research program was established, tied to a research implementation program that built on the strengths of the private sector partners. This provides for an interconnected and coordinated program.

This approach provided a number of benefits for Caltrans. These included the ease of contracting, a rich history of a good working relationship with the university, the ability to sole-source subconsulting contracts, and enhanced credibility for the program. The city of Anaheim brought a state-of-the-art TMC, the start of a Test Bed, and aggressive leadership. Caltrans District 12 was a new district and the project represented a first for them. In addition, the district had aggressive young leadership who were interested in developing new and innovative projects. The private sector groups brought unique skills and the needed advanced technologies. The city of Irvine was added later as a partner using the same approach.

This group developed a conceptual proposal for Caltrans' consideration. The proposal was for a 3-year, $12.5 million program with the Institute of Transportation Studies at UC-Irvine as the lead agency. The basic research element was focused at the university and the research implementation program was delegated to the agencies and private sector partners. A formal link connected the two elements. In April 1991, a revised 3-year proposal for $9 million was resubmitted to Caltrans. This included $5.5 million worth of subcontracts to the private sector firms and the operating agencies. At the same time, Cal Poly San Luis Obispo was brought into the group.

Caltrans later split the basic research element and the research implementation program into two contracts. The basic research element moved forward first. Negotiation of this agreement occurred from June to December of 1991. At the same time, a new master agreement was being developed between Caltrans and the University of California System. This created some delay in finalizing the agreement for the Test Bed.

The final contract for the basic research element was signed in December of 1991, however. This 3-year, $2.8 million contract established the basic research program in ATMS for Caltrans at UC-Irvine, and established a statewide Test Bed facility. From January to June of this year we have been establishing the Test Bed and negotiating the research implementation program contract. Different approaches for private sector involvement are being examined and the consortium has been expanded to include Caltrans District 7 and the city of Los Angeles.

Session Eleven
Closing Session: Looking to the Future

J. Robert Doughty, consultant — presiding

Transit and ITMS

Ronald J. Fisher
Federal Transit Administration

I appreciate the privilege of being invited to share some thoughts for the future at the conclusion of this symposium on a subject so close to my heart. I was here in May, as many of you were, for the second Annual Meeting of IVHS America. Perhaps you recall the remarks I made at that meeting on the paradigm shift the IVHS technologies are likely to cause.

I think the best explanation of this paradigm shift is provided in the strategic plan for IVHS in the United States: "IVHS is, in fact, a paradigm shift. The transportation/information infrastructure is a new way of looking at, thinking about, and improving mobility—a sociological as well as a technological revolution."

The best example I've heard for a paradigm shift occurred in the watch industry. The Swiss clearly never expected the microchip to make such a difference. It provided an alternative way to keep and display the time and provide other functions that many of us have found useful. The Swiss were too focused on their old way of doing business. It is important that we do not make the same mistake in traffic management as the use of IVHS technologies develop.

I believe IVHS technologies give us an exciting opportunity for responding in new and improved ways to the constraints now being placed on us. We no longer have the budget or the space to expand transportation facilities to meet growing travel needs. Public policy for energy conservation, clean air, and other societal concerns is forcing a new look at how we do things and the reason for doing them. As a result, new responses will be required.

My remarks today are focused on providing a few examples of how we as transportation professionals can work together to achieve effective new responses. The integration of vehicle management systems and traffic management systems provide rich opportunities to better serve the public in meeting their mobility needs. Perhaps we will come to view this as transportation system management.

As most of you know, the Federal Transit Administration (FTA) has developed an advanced public transportation systems (APTS) program as a component of the national IVHS initiative. The program is designed to assist operational tests and evaluations in the IVHS area. We have identified four important functions that cover our activities. These are vehicle management systems, electronic fare collection, enforcement, and user information.

Each function is highly dependent upon computers to collect, analyze, and interpret large amounts of data that feed into computations to optimize traffic flow and the movement of people. Indeed, the common thread connecting each of these functions is the computer. The computer permits the linking of each function to achieve results that are greater than the sum of their parts. When directed toward public transit operators and consumers, work in each functional area can directly benefit traffic engineers and planners. I first want to describe these areas of related technologies individually, and then discuss how they can work together in an integrated transportation management system.

Vehicle management systems (VMS) consist of several independent technologies that can be combined for general management and control of a large number of vehicles dispersed throughout a wide area. Included within the VMS area are several critical subsystems, including automatic vehicle location (AVL), computer-aided dispatch (CAD), sensor technology, and digital mapping.

Automatic vehicle location permits the tracking and effective command and control of a fleet of vehicles. Command and control is important for the management of fleets and the resulting efficiencies from such control. In transit applications, bus schedules and headways can be controlled to ensure on-time performance, paratransit vehicles can be routed to pick-up and destination points, and bus, paratransit, and rail services can be coordinated.

Transit security is improved as police cars can be dispatched to bus emergencies based on the actual bus location. Further, general public safety is improved as the most appropriate police vehicle can be assigned to a request for aid. Fire and emergency medical vehicles can be dispatched more efficiently and quickly. Indeed, some communities, like Dade County, Florida, are considering the comprehensive use of automatic vehicle location for all these services.

Computer-aided dispatch permits the effective management of a number of vehicles and assigns tasks to each vehicle. Taxi, para-transit, police, and trucking operations are a few examples of fleet operations that can benefit through this improved utilization of resources.

Sensor technologies are being developed that will identify individual and specific classes of vehicles, such as high-occupancy or emergency vehicles, so they can be granted access to reserved facilities. Vehicle identification opens the door to automatic traffic signal preemption for specific vehicles. These sensors will also feed information on traffic conditions to traffic management centers. Sensors on-board the transit vehicle can assist management in quickly learning of potential equipment problems and passenger loads. Signal preemption strategies may then be invoked based on the number of people being benefitted rather than the number of vehicles.

Digital maps provide the capability of storing geographic information on computers for vehicle and traffic management purposes. Because the maps are digitized, they can be easily updated and changed. Traffic engineers use digital maps to display road networks and traffic conditions. Transit and emergency service providers use digital maps to give visual representations to further aid the dispatch activities.

Electronic fare collection is another area that can benefit many user groups. Essentially, the intent is to develop and deploy cashless fare collection systems that will speed up transactions, reduce time lost due to cash handling, and improve cash security. Requiring exact change provides one more barrier to using transit.

There are several techniques that can be employed for electronic fare collection including magnetic stripe cards and Smart Cards. Magnetic stripes are used on credit cards and in a number of transit applications. While universally available today, they have several significant limitations. They are able to handle only a limited amount of information, are subject to tampering and, due to their magnetic properties, can be inadvertently erased.

Smart Cards are plastic cards with a microchip embedded within them. They can be designed to be read through a proximity interface, so they do not have to be inserted into a reader. This will speed up the flow of users, as the cards may be read from a distance of several feet. The speed of these transactions is critical for line-haul transit services. In a toll road situation, these cards could be attached to an automobile just as tags are today.

The widespread application of electronic fare collection will give transportation system managers the capability to price transportation services according to their use. For example, road pricing using this technology becomes a feasible method of allocating charges in line with particular policy objectives. Pricing peak hour and off-peak periods, as well as single-occupancy and high-occupancy vehicle usage, now becomes feasible as a meaningful policy tool to encourage, or discourage, certain uses.

Enforcement functions using IVHS technologies may assist local supervision of the proper use of HOV lanes. For example, using an enforcement system, authorities can determine whether specific automobiles are eligible to use certain facilities. Unauthorized vehicles can be identified, and, local laws permitting, a traffic citation automatically issued.

A number of sensor technologies are available or under development to help accomplish this. Visual surveillance cameras can be used to visually determine whether the vehicle is authorized to use a facility. Infrared sensors may count the number of occupants by their infrared heat image, and determine whether the vehicle is a legitimate user of the facility.

Electronic tags can be issued that identify pre-approved vehicles and authorize their use of certain facilities. These tags may be license plates with an electronic sensor embedded in them. These technologies could be used to verify a person's or vehicle's legitimate use of a facility and minimize enforcement manpower requirements.

These enforcement technologies also have the capability of being used for other traffic monitoring purposes. By knowing the identity of individual vehicles, their individual speed and location, and the traffic signal status, it may be possible to effectively enforce traffic regulations automatically. A vehicle's compliance with various traffic regulations could be automatically determined. If a violation occurs, an enforcement citation could be automatically prepared and sent to the violator.

For example, on the North Dallas Toll Road, license plate numbers of vehicles not paying the toll are captured on a video camera and $200 fines are levied. Why not record someone running a traffic signal, which has potentially more serious consequences? No doubt these approaches to monitoring traffic will raise public policy questions regarding privacy and civil liberties that must be resolved locally.

User information relating to travel needs is a function that helps users make effective mode choice decisions. It is assumed that many people now using single-occupant modes will consider other alternatives if presented with reliable, up-to-date information. This function seeks to develop improved methods of presenting this information to users. Three important technologies are changeable message signs, video displays, and personal communication networks.

Changeable message signs present travelers with relevant messages on road and travel conditions so the they can be apprised of changing situations and take appropriate action. They are placed along highways, or—in the case of transit—on the vehicles or at heavy boarding points.

In-home or office displays present information relating to planned travel prior to departure. Using interactive television or computers, the traveler will be able to call up information regarding his or her transportation alternatives. Transit schedules, dynamic carpool information, road conditions, and transportation alternatives are some of the information that can be presented to consumers to guide intelligent choices among transportation alternatives.

If this information is presented properly, the consumer hopefully will see the advantages of high-occupancy transportation and select an HOV mode. Another important technological development unfolding in urban areas is the personal communication network (PCN). These networks are made up of small cells that allow widespread use of wireless telephones.

The system is similar to cellular telephone systems in the U.S., except it uses much smaller cells. In fact, one vehicle location supplier proposes to use these smaller cells to locate vehicles within 50 feet. Perhaps this will be a "person" location system, as it will locate a person using a wireless telephone even as he walks down a sidewalk. Closely coupled with the deployment of PCN is the development of palm-size telephones and computers. Prices of these devices will certainly drop just as they have for other electronic products.

Now I would like to discuss the opportunities for an integrated approach to ITMS. Thus far, I have described the individual functional areas and related technologies. However, these individual functions can be integrated into a system to aid transportation operations and planning. By combining data from several of these functions, powerful transportation system management tools are created. Equipping transit and other public service vehicles with AVL will empower them to act as probes to help monitor traffic.

Occupancy data for HOVs may even be used for warrants guiding traffic signal timing decisions. Traffic conditions can also be transmitted to buses, carpools, and vanpools so alternative routes can be selected. My concern is that these routes be protected from diversions by SOVs. If an accident or some other event occurs that causes traffic to completely stop, the probes will quickly identify the situation and add first-hand observations to guide responses.

The same equipment that converts a transit bus into a traffic probe will also permit the transit dispatcher to effectively manage the bus fleet. The AVL system will identify the location of a vehicle to a central computer, which can compare the actual location of a bus to its scheduled location. Through an in-vehicle display, the driver can be advised of various corrective actions to get back on schedule. Clearly, it will be helpful if the timing of traffic signals can be adjusted to assist the vehicle in getting back on schedule. This electronically collected data can also be used for schedule planning purposes, at cost levels significantly less than manual data collection.

The same computer-aided dispatch technology that performs taxicab assignments will also assign the optimum police car or ambulance to an emergency request. These technologies can also be directed toward increasing the use of carpools, vanpools, and other high-occupancy vehicles. One interesting possibility is the development of systems to assist dynamic carpooling. Data bases are being developed through projects in the APTS program to link drivers of single-occupant automobiles and people desiring a ride to a common destination in real-time.

Also, cellular telephones are helping to coordinate "connections" between people waiting at fringe parking with vanpools on a nearby freeway. The availability of HOV lanes give drivers further incentives to share trips with those desiring rides.

Information about each carpool formed will aid traffic engineers since they will know the origin, destination, and number of people in each vehicle. This can be used to fine-tune computerized traffic control systems to optimize the flow of people through the metropolitan area. The green time at traffic signals can be extended where appropriate to permit additional high-occupancy vehicles through an intersection.

Personal communication networks (PCNs) will permit people to maintain contact with data banks providing transit schedules and transit options. These close links between people and information will permit even greater possibilities for the development of shared rides.

Further, these networks, which are presently based on cellular technology, can also be adapted to palm-sized telephones and computers. In the future, it can be envisioned that people with small wireless telephones will be able to call for transit information from any location, even walking along the sidewalk. Directions for walking to the closest transit stop may be given or a bus diverted to pick the person up.

Think of the many opportunities to keep people advised of changing travel conditions through the use of this technology. Using a paging system, people could be buzzed when their bus is a few minutes away. We might even buzz them when an incident occurs and when it has cleared.

I have presented a brief vision of how a number of new IVHS technologies can impact our world as transportation management professionals. These new technologies are linked together—and with users—through information systems that permit people to make good decisions based on real-time information.

We are in the information age. The trend toward even greater information interchange is accelerating. As electronic and communication devices become smaller, less expensive, and more reliable, people will avail themselves of the great benefits these devices provide.

Information interchange is becoming easier and quicker. Access to more information that is relevant to people's daily lives will permit them to make better decisions. Our challenge is to design a system that is consistent with developing public policies on clean air and energy.

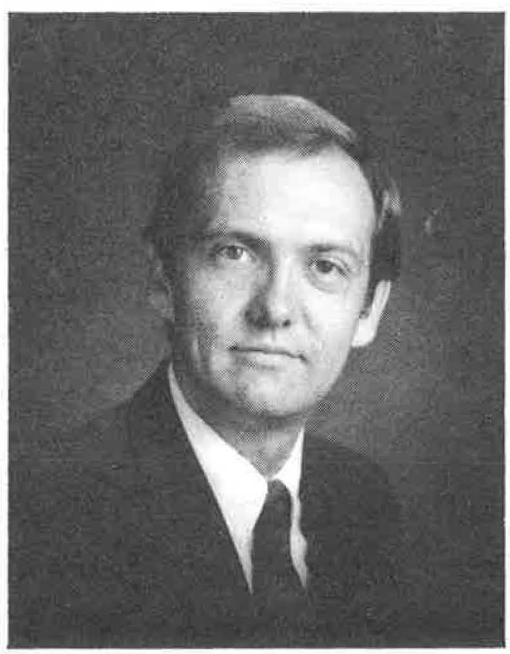
Yes, there is a paradigm shift underway. As we look to the future, there is indeed a new way of looking at, thinking about, and improving mobility.

Congestion Management Systems: Requirements and Opportunities

Jeffrey A. Lindley
Federal Highway Administration

I would like to take a slightly broader perspective and focus my comments on how all the different elements and systems can be coordinated into an overall congestion management system. I want to talk specifically about the congestion management system required in the ISTEA. When the Symposium Planning Committee met for the last time this past January, we thought the symposium would provide a great opportunity to discuss the requirements, issues, and opportunities of the congestion management system contained in the ISTEA. Unfortunately, the regulatory process has not been completed and the requirements have not been issued yet.

Although there are no requirements at this point, there are a number of issues and opportunities that can be discussed. I think the fact that we have a policy legislated by Congress on an issue most transportation professionals felt needed to be addressed presents us with the



opportunity to shape the congestion management systems to meet the needs of individual areas.

FHWA is currently in the middle of a 60-day open comment period and I want to stress that we are interested in your input. This is the first of three comment periods in the regulatory process. I want to briefly highlight the key elements of the legislation with regards to congestion management systems, identify some of the major system characteristics, and discuss the key issues and next steps in the process.

If you have read the legislation, you should be well aware of the strong emphasis on congestion, mobility, and management of the transportation system. Specifically, Section 1034 requires that each state develop six management systems. The six areas to be addressed by these systems are: pavement, bridges, highway safety, traffic congestion, public transportation facilities and equipment, and intermodal transportation facilities and systems. A seventh area, addressing traffic monitoring systems, is also required to provide input data to these six areas. The overall goal of all these systems is to develop an integrated traffic information system to assist in the decision-making process relating to transportation system investments.

The legislation requires that the congestion management system be developed in consultation with the MPOs in urban areas. This further indicates the new importance being placed on MPOs under ISTEA. The legislation also includes a well-defined link to both the metropolitan and the statewide planning process. This builds on the existing process and provides consistency with the current planning process. There is also a very strong link to air quality. The legislation establishes Transportation Management Areas (TMAs) in metropolitan areas with populations over 200,000. No single-occupancy vehicle capacity can be added in these areas with federal funds unless the project is part of a congestion management plan. This is a significant incentive to develop a good congestion management plan.

The legislation requires that the guidelines and requirements for all six management areas be completed by December 18, 1992. It also requires that states certify by January 1, 1995 that they are in the process of implementing all six management systems and the traffic monitoring system. Thus, the first issue to be addressed is what must be completed by this deadline and what will be required in the certification process.

The legislation also provides for funding to support the different activities required by the law. A number of funding sources can be used to support the different management systems. These include the National Highway System, the Surface Transportation Program, Highway Planning and Research, Congestion Mitigation and Air Quality, transit capital programs, and others.

The overall purpose of all the management systems is to provide information for decision-makers to effectively and efficiently manage the surface transportation systems. Thus, it is important to realize that the management systems are not an end product. The purpose of these systems is not to just collect data and generate reports, but to actually help solve congestion problems. The congestion management systems should provide a tool to do this.

I would like to briefly describe some of the issues I see that need to be addressed with the development of congestion management systems. The first one deals with areawide coverage. I think one of the big flaws in many areas with existing congestion management programs, including California, is that plans are prepared on a county basis. For example, each of the nine counties in the San Francisco Bay Area has a plan, and they are not necessarily coordinated. I think that congestion management has to be approached from an areawide perspective.

Second, I think congestion management systems need to be multi-modal. By this, I mean not only the surface or highway modes, but also light, heavy, and commuter rail systems. Rail can play a big part in determining the level of congestion in a corridor. Third, there also needs to be a link to land use. We know the importance of the link between land use and congestion levels and we need to do a better job of coordinating the land use and the transportation decision-making process. I am not sure exactly how this can be accomplished, but it is important that it be addressed. The link to air quality is also important.

The congestion management systems need to address both recurring and non-recurring congestion. Historically, I think we have done a relatively good job of monitoring recurring congestion, but a relatively poor job of monitoring and addressing non-recurring congestion. There also needs to be an implementation focus to these systems, rather than just a data reporting function.

A number of elements are critical to the success of congestion management systems. A data base that includes the roadway and traffic characteristics must be established. Performance measures must be developed and used to determine how the system is functioning. Standards are also needed to identify the desired performance levels. An assessment of baseline conditions is important to establish the current location, severity, and duration of congestion.

A forecasting element is also needed to identify future needs and changes. This should tie into the traffic forecasting process and link with land use planning activities. A needs assessment should also be conducted. In the past, we have not always done a good job of this. This assessment should include an examination of latent demand and both short- and long-term needs. A broad range of potential solutions should be examined. These may include adding new capacity, transit, traffic management programs, IVHS, TDM, and other appropriate strategies. Project and strategy selection should not be limited to a narrow list of alternatives, but should include a broad range of projects. There is no one answer or solution. Finally, a monitoring system needs to be incorporated into the program to provide for ongoing evaluations.

A number of key issues are being examined during the regulatory process. One of these is determining which agencies and groups need to be involved. The legislation gives the states the primary responsibility for implementing congestion management systems. However, it is obvious that MPOs, transit agencies, air quality management agencies, and others must be involved. Another important issue is system coverage. We know that TMAs, or metropolitan areas over 200,000 in population, will be covered as required in the legislation. After these areas, however, it is less clear what areas should be covered and what roadway systems should be included.

Data availability is another concern that has been voiced in many areas. Everyone is concerned that a great deal more data collection will be required. The exact nature of the data requirements have not been determined yet. Performance measures and performance standards are also getting a good deal of attention. The questions here revolve around what measures and standards you should select and how they should be applied.

A relationship also needs to be established with the other management systems. These include the intermodal, transit, and safety management systems. Determining how these links will occur will be important. There is also an issue related to carrots *vs.* sticks, or the use of incentives *vs.* disincentives. The ISTEA focuses more on disincentives. I think it is also important that we build some incentives into the process.

Finally, I would like to point out the next steps in the process. The Notice of Proposed Rule Making has been issued and the 60-day comment period is open until August 3, 1992. I would encourage individuals to provide comments on the proposed rule. A series of public workshops are also being conducted to discuss all of the management systems. There will be two more comment periods before the final regulations are issued.

To summarize, I think there is a tremendous potential to tie all the concepts that have been discussed during the symposium together into a coordinated management system that will help address urban congestion problems. The involvement and input from sources is important in developing the regulations for the congestion management systems, and FHWA is interested in your comments. Thank you.

ITMS to IVHS

Jack L. Kay
JHK & Associates

I would like to focus my comments on the current status of ITMS activities and how we move from ITMS to IVHS. Thus, unlike many speakers at the symposium, I will be addressing IVHS. I would also like to discuss the different approaches that can be used in the development of IVHS and the advantages and disadvantages of these.

Although it may seem obvious, one of the available options is to do nothing to plan the systematic development of ITMS and IVHS. A number of systems have been implemented and other activities are currently underway. Thus, one approach would be to just let these activities occur without any type of coordinated plan. I would suggest, however, that this is not the most appropriate approach. Rather, I would support a more systematic plan that focuses on the key direction and goals we wish to accomplish.

Where are we today? I think the current state-of-the-art is fairly high. There is a good understanding of the elements and capabilities of ITMS and IVHS. However, I would suggest that the state-of-the-practice is not as high. The number of areas and jurisdictions that are using the currently available tools is relatively small. The many examples that have been provided at the symposium represent only a small number of areas. It is important that we move quickly toward state-of-the-art systems in other areas. I would also suggest that most of the current systems are jurisdiction-based advanced traffic management systems. Taking a regionwide approach is needed to fully realize the benefits of ITMS.

Although there are many activities underway that focus on IVHS, it appears that many of these could be characterized as somewhat unorganized and frantic. Many areas are trying to obtain funding for IVHS projects without a well thought out and comprehensive approach. The *IVHS America Strategic Plan* and the activities of FHWA and FTA are helping to bring a little more focus and rationale to this process.

At least three different approaches for moving toward ITMS and IVHS have been suggested. First, some people have suggested that we can just jump from where we are currently to ITMS. I think this may be an unrealistic model. The second approach focuses on taking logical, small steps to develop ITMS. This is an approach that has been used successfully with other programs and provides a realistic technique. However, this approach does take a long time and requires numerous steps. I would like to suggest that the third approach, which focuses on taking small steps, but also taking larger leaps in response to specific opportunities, represents the best alternative. I think opportunities do exist to take larger steps and we need to be in a position to take advantage of these.

I think the first step in the process is to continue to implement regionally-based advanced traffic management systems. These systems can demonstrate the benefits of traffic management systems and provide a basis from which more advanced systems can be developed. From these we can move directly into more cooperative efforts and develop the ties to ATIS and APTS. This will help create the giant step attitude.

A number of models have also been suggested for the ultimate approach to IVHS. One model focuses on networking the five IVHS components: ATMS, ATIS, AVCS, APTS, and CVO. This is the approach being taken in many areas. I would suggest that this is a temporary model, however. The model we should ultimately be looking toward focuses on functions that cut across all of the IVHS areas. A change in thinking about IVHS will be needed to accomplish this approach. Small steps will still be needed to reach the ultimate system, but we will be moving forward focused on an agreed-upon final framework.

Moving toward IVHS will also require changes in the way we do business. Establishing and agreeing on the roles and responsibilities of the different public and private sector groups is an important element of this. The *IVHS America Strategic Plan* identifies a significant role for the private sector. Defining how the different private sector groups will be involved and how they will interact with the public sector will be critical. At the same time, we can not forget about pure research activities. Research and development will be critical to ensuring that we continue to move toward more advanced and sophisticated systems. Establishing links to air quality and mobility efforts is also essential. These are areas that may allow us to take a giant step toward the ultimate system and we should aggressively pursue the opportunities offered by recent legislation.

I think advances in technology will continue to develop more rapidly than the institutional issues involved with IVHS. Further, the advances in technology may help drive resolution of some of the institutional issues. The momentum to move forward and to resolve possible institutional conflicts will be there if we build on our success. I think that regions which cooperate will be more successful in obtaining funding, and other areas will soon follow their lead.

Finally, I think the benefits of ITMS and IVHS are worth the effort. The systems can provide numerous benefits to the users of our roadway networks and transit systems. Further, I think we will continue to see significant levels of funding for these programs over the next 10 to 12 years. As we move forward with these programs we will continue to need the dynamic leadership of the professionals at this symposium and others around the country.

Appendix A:
ITMS White Papers

Integrated Traffic Management Systems

*Herman E. Haenel and Leslie N. Jacobson**

INTRODUCTION

A transportation system of the future was unveiled at the 1939 New York World's Fair. To many people who were used to gravel roads and country lanes it seemed like a dream world. They were amazed to see how traffic would travel along freeways and streets without unnecessary stops. Today, this dream world of a little over 50 years ago is a possibility, thanks to technology.

Today's technology is improving safety and mobility along urban transportation networks. Better mobility reduces vehicle delay, emissions, and fuel consumption, and improves the quality of life by lowering costs for services and goods to everyone within the urban area.

Traffic management systems within the United States are, for the most part, operated and maintained by individual agencies. Freeway control systems are operated by state DOTs, and traffic signal systems in urban areas are operated by cities and counties. Benefits have been obtained from these systems. Additional benefits beyond those obtainable from individual systems can be achieved by integrating them as traffic management systems.

According to Webster's Dictionary (*1*), *integrate* means "to put or bring together into a whole; to unify." Webster also defines *management* as "the act, art or manner of managing, or handling, controlling, directing, etc." Considered together, these two words describe the need to unify systems for the purpose of achieving improved traffic operations within the integrated system.

This is a new area to work in, one that can be uncomfortable at times. But as trained traffic engineering personnel, we can meet the challenge by communicating, cooperating and coordinating with others. Working with other agencies on an organized effort is required to assure improved traffic management.

The following review is intended to show the need for integrated traffic management systems, outline the elements that must be included, and provide guidance in developing such a system. These systems may not provide the dream world of transportation predicted at the 1939 New York World's Fair, but they will bring us closer to eliminating unnecessary stops and achieving optimum mobility.

THE NEED FOR INTEGRATION

From Phoenix to San Francisco to Washington, D.C., citizens are identifying transportation as their number one concern (*2*), outweighing issues such as pollution, overpopulation, unemployment, and crime. Traffic congestion is certainly the primary reason for this concern over transportation issues.

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Several factors have led to the increase in traffic congestion. From 1950 to 1986, population in the United States grew by about 160 percent. This population growth increased the demand for transportation. As evidence of this increased demand, the number of motor vehicles increased even faster than population, by almost 360 percent, from 1950 to 1986 (*3*). In addition, people place more reliance on their automobile as the primary transportation mode. From 1960 to 1980, transit's share of work trips in urban areas dropped from about 13 percent to about 6 percent. In the same time period, work trips in automobiles jumped from 61 to 82 percent (*4*).

The increased reliance on the automobile and the growth in population, jobs, and households, have combined to create severe and alarming levels of congestion in our urban areas. Delay on urban freeways in the United States increased by 57 percent from 1983 to 1985 and is projected to increase at a yearly rate of 8.8 percent through the year 2005. This rate of increase will produce a 435 percent increase in delay from 1985 to 2005. The increased congestion will also affect urban signalized arterials. From 1985 to 2005, projections indicate a 240 percent increase in delay on urban signalized arterials (6.3 percent increase per year) (*5*).

One of the responses to urban traffic congestion has been traffic management efforts. Transportation system management was introduced in the 1970s to improve the efficiency of the existing transportation network. Often, implementation of these efforts was not coordinated within an urban area or even within a single jurisdiction. Through the 1970s and early 1980s, these efforts proved to cost effectively improve system efficiency, even when they were implemented in a piecemeal fashion. However, as noted above, transportation demand and congestion levels continue to grow. It is now necessary to view the transportation network as one system and to integrate as many aspects of transportation management as possible.

System integration is important because it makes maximum use of resources. It can be implemented in a range of ways from personal communication between operating agencies to a sophisticated central computer that supervises individual traffic control systems on arterials and on freeways throughout a given area. Integration allows operating agencies to manage the transportation system better and to more efficiently employ personnel. System integration allows agencies to allocate vehicles and people to the transportation system as efficiently as possible by accounting for the conditions or attributes of all elements within the system.

System integration requires that information be exchanged so that resources can be efficiently allocated. The information sharing can occur among computer systems, operators, or designers, and between the operating agencies and the public. Resources can then be allocated to assure a cost effective program for traffic management.

METHODS OF INTEGRATION

System integration comprises design and operations. Cooperation and communication between agencies are needed for the design and operation of an urban system. Integrated traffic management requires four elements:

1. An integrated approach to transportation management;
2. Resource integration;
3. Manual information exchange; and
4. Integration of control/surveillance systems.

Integrated Approach to Transportation Management

The way in which transportation professionals view the transportation network and management of the network is probably the most critical aspect in the concept of integrated systems. Planners, designers, operators, and managers must believe that the entire network operates as a single system. The management approach must reflect this belief. Agencies and jurisdictions must cooperate. The actions one group takes must be supported by the other groups. Policy issues, incentives, and human factors must be explored to help reduce the demand on the system, in addition to technological ways to increase system efficiency and capacity.

The integrated view of the transportation network includes a framework that meshes all efforts together to create a balanced approach. These elements include physical systems, as well as incentive, policy, and human factors programs. For example, when conditions are severe because of daily peak period congestion, special events, construction, or incidents, the demand cannot be accommodated simply with modified control strategies. Incentives must be offered to encourage people to choose different routes, different modes (i.e., public transportation, car pools), and different times for travel. Furthermore, if traffic management systems do a great job of detecting incidents but the correct information does not reach motorists or assistance is not provided to them, then the detection technique is diminished in value. Information can be provided to motorists through use of changeable message signs, lane control signals, and highway advisory radio. Also an incident management team and motorist aid patrol should be available to assist motorists once an incident has occurred. Similarly, if the public is accurately informed, but they cannot choose flexible working hours, cannot modify their routes because control systems are not adjusted, or cannot change their modes of travel, then the detection system and the information system diminish in value.

Research and design activities also need to be coordinated as part of the integrated approach. Research feeds the design process, which, inevitably, uncovers questions or ideas that need further research in the same area or related areas. The integrated approach should recognize the connection between research and design (or implementation) and structure programs to facilitate the exchange of information, results, and ideas. A fully integrated approach to system management looks at the totality of the system and explores the range of solutions available.

Resource Integration

Resource integration involves sharing facilities, personnel, and financing to use them most efficiently. Examples of resource integration include shared central operations centers, regional control centers, communications facilities, conduit, and design, maintenance, and operation of the shared facilities. Costs and personnel can be shared. Resource integration reduces the costs to all systems, even if control strategies are not integrated.

An example of resource integration is the Surveillance, Control, and Communication (SC&C) system planned for Houston. This program involves three agencies and systems on three types of facilities. The city of Houston, the Texas Department of Transportation, and Houston METRO operate arterials, freeways, and transitways, respectively. In the SC&C system, the three agencies share communication cables and regional control centers for the arterial, freeway, and transitway control systems. Personnel from the three agencies are working together in the design and operation of the SC&C system.

Information Exchange

Information exchange is one of the key elements of system integration. Information exchange may involve sharing data with operators or managers of other systems so they can use the information for planning or to develop control strategies. The data usually come from historical databases. Managers of one system can identify trends in other systems that may affect the operation of their system operation.

Information exchange also takes the form of periodic meetings to share information on ongoing projects. Traffic Management Teams (TMTs) are a type of formal information exchange that helps integrate transportation management. These teams provide the best opportunity for developing an integrated traffic management system. Members of the team discuss problems from various points of view at regularly scheduled team meetings. They reach solutions through mutual agreement.

Integration of Control/Surveillance Systems

The most familiar element or portion of traffic management system integration involves control and surveillance. The integration of multi-agency control and surveillance systems allows agencies to make system control decisions on the basis of conditions in other systems.

Engineers and operators make changes in system operation on the basis of historical data obtained from their own system(s) and data received from other systems. System operators utilize real-time data to make changes to reduce congestion at a particular moment. In both instances, changes made in one or more systems should be agreed upon by personnel from other agencies whose system(s) will be affected by the change.

Information is also shared between the computers of two or more agencies so that traffic patterns can be changed rapidly to prevent and alleviate congestion. The computers are subject to manual override by the operator(s).

An example of manual operation involves construction projects that require control systems to be coordinated for the term of the project. The coordination activities may involve simple retiming of traffic signal systems based on projected diversions, or real-time manual selection of timing plans based on observations of field conditions. During the unusual circumstances of traffic disruption and diversion caused by construction activities, manually coordinated control systems can be very beneficial.

The integration of two or more systems permits smoother flow of traffic throughout the urban area. It also assures that adjacent systems are able to change in time to accommodate traffic arriving from other systems. As an example, a freeway control system should be ready to handle large volumes of traffic released by an adjacent traffic signal system during daily peak periods, incidents, special events, and nearby street construction. An interchange of information permits this and, in so doing, provides the benefit of optimum system operation.

Control and surveillance system integration can take place between control systems with different functions (e.g., a freeway control system and an arterial control system) or between geographically separated control systems. In either case, the systems may be controlled by the same jurisdiction or by different jurisdictions. Some of the types of control systems that can be integrated are outlined below.

- *Freeway management systems* — Ramp metering systems, incident detection systems, closed circuit television systems, and electronic surveillance systems are included in this classification. HOV lanes and transitways are also included.

- *Arterial management systems* — Any kind of coordinated signal control system (time-based or centrally controlled) is included in system integration. (Time-based coordination systems can be integrated with other systems manually.) Conditions on freeways and arterials often have an impact on each other. When severe congestion occurs on one facility, traffic diverts to use the other. The control systems can best handle the added traffic if the systems have been integrated.

- *Traveler information systems* — Traveler information is an effective tool in transportation network management. With current and accurate information, drivers can make intelligent decisions on routes traveled, time of travel, and mode of travel. To be most effective, the system must be based on current data. Those data come from other systems, such as freeway or arterial management systems; hence, the importance of system integration.

- *Incident management systems* — One of the primary elements of incident management is incident detection. Incident detection can be accomplished through the electronic surveillance and closed circuit television components of freeway management systems, through field observation, and through reports from motorists with cellular telephones. Information on alternative routes may come from either arterial or freeway systems. Freeway or arterial systems can use information on incidents to modify control strategies. Traveler information systems inform the public about the incident and may direct traffic to alternative routes. Therefore, there are benefits in integrating incident management systems with freeway management, arterial management, and motorist information systems. An incident management team is part of the incident management system. The team clears the incident and reroutes traffic when necessary. The team, working with the operators at a traffic management center, can reduce delay and secondary accidents through rapid response and proper action at the scene. Although motorists can reroute on their own when an incident occurs, they can do much better when they receive assistance from the incident management team.

- *Construction traffic management systems* — Construction traffic management systems usually integrate combinations of the above systems. Because of the magnitude of most freeway reconstruction projects, construction traffic management systems modify freeway management strategies, improve coordination or update control plans on arterials, heighten incident management efforts, and improve driver information techniques. Construction traffic management systems, by their very nature, are highly integrated with other management systems.

- *High technology systems* — Most of the high technology systems being researched today will be implemented as part of overall integrated systems. Automatic vehicle identification and automatic vehicle location systems will provide information to freeway and arterial management systems. In-vehicle route guidance is a form of traveler information system and uses information from freeway management, arterial management, and incident management systems. Integrated traffic management systems designed at present should be capable of adding high technology systems in the future.

The above is not an all-encompassing list. Any traffic management system or action may be part of an integrated system. Any of those mentioned above may be joined with systems of the same type in different geographical areas or under different jurisdictions.

IMPLEMENTATION, OPERATION, AND MAINTENANCE

An integrated system includes communication, cooperation, and coordination between agencies during implementation, operation, and maintenance. The agencies work closely during the planning, design, construction, operation, and maintenance stages. A review of items to consider included in these areas is discussed in the Appendix.

Integrated system development includes solving institutional and funding issues early on in the planning stage. It also includes development of a Traffic Management Team (TMT) to develop goodwill and an appreciation and use of the views of representatives from all of the agencies involved. The TMT approach goes a long way to solving problems as they arise. Information on the TMT concept, which is working in Texas, Washington, Florida, and other locations, is discussed in a publication included in the Appendix of this paper.

An integrated and dedicated team approach is needed in all stages of implementation, operation and maintenance, to assure that the system will achieve its goals.

CONCLUSION

Studies show that traffic volumes can be expected to increase vehicle delay between 1986 and 2005 by 435 percent on urban freeways and 240 percent on urban streets if no action is taken to improve existing conditions. Integrated traffic management will serve to significantly reduce this delay.

Integrated traffic management systems include:

- Handling traffic at incident locations;
- Integrating resources available to the agencies within an urban area;
- Sharing information and developing a research to implementation approach to further research;
- Developing a team approach to all aspects of the work for planning, designing, implementing, operating, and maintaining the integrated control and surveillance system;
- Obtaining needed funds to install, operate, and maintain and integrated control an surveillance system; and
- Implementing an integrated traffic control and surveillance system by interconnecting the operation of systems within different agencies.

Adequate funding and installation of an integrated control and surveillance system are the most important parts of the integrated traffic management system, but the other elements are also necessary to assure success.

The development and operation of an integrated traffic management system is a challenging process, but the benefits to the public make the effort worthwhile. The development of integrated traffic management systems is necessary for the continuing growth of our urban areas. Transportation is this nation's lifeline, and the integrated traffic management system is now and will continue to be a major element in this lifeline within urban areas.

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APPENDIX: Development, Implementation, and Operation/Maintenance of Integrated Systems

Introduction

The development of an integrated traffic management system follows the same steps as that of every traffic control and surveillance system. These steps are as follows:

- Planning
- Design
- Implementation
- Operation and Maintenance

The steps for developing an integrated system can be more complex and difficult to carry out than those for an individual system. The purpose of this section is to discuss some of the issues that may be more applicable to integrated systems and not those common to the development of individual systems.

Planning

Adequate and proper planning is required to assure that all issues are considered and accommodated and that potential (and existing) problems are resolved. These issues include the following:

- Initial and future use of the system;
- Types of control systems to be included initially and in the future;
- Type of control and communications (i.e., central control with or without distributed control, fiber optic and/or twisted wire pair communications);
- Addition of IVHS components in the future;
- Location of the traffic management center;
- Problems which may be encountered during design and implementation;
- Responsibilities of each agency and its personnel for design, operation and maintenance;
- Amount of funds and number of personnel to be contributed by each agency, and
- Institutional issues previously noted.

Planning needs to be done jointly by all agencies involved. A team (project team) effort makes each agency a part of the integrated system during the other steps of the process.

The project team should include planning, engineering, law enforcement, and maintenance personnel. The presence of law enforcement and maintenance personnel is important to ensure that their needs are met once the system has been built and to obtain their input on design questions. An architect should be included if a new traffic management center is included in the project or if an existing facility will be expanded. If a traffic engineering consultant will be employed for the design stage, he or she should be included on the team. Also, a public relations representative is desirable to provide well prepared information to the media and administrators. Additional personnel may be included as the planning and design process proceeds.

The planning process, as well as the design, implementation, and operations work, can be assisted to a high degree by the development of a Traffic Management Team (TMT). Actually, the TMT should, if possible, be developed before the beginning of the planning process.

The TMT, which comprise representatives of agencies involved in traffic operations within the urban area, can study local traffic operations, safety, and enforcement problems. By looking at problems from different points of view (i.e., city, county, state, enforcement, and engineering), the TMT can obtain solutions that might not have been developed by one agency alone. The members are not the top administrators for their agencies but are in a position from which they can speak for the administrators.

The TMT can develop trust and respect among team members and their agencies, provided that all members enter the TMT with openness and willingness to work together. The good working relations developed by the TMT can be applied in the initial design of an integrated system.

Although TMT members may serve on the project team, the TMT studies problems on a broader urban scope than the project team. Members of the two teams may want to discuss problems encountered by the project team, and monthly project team progress reports could be given at TMT meetings.

The TMT concept is working in Texas, Washington, Florida, and other locations around the country. A copy of a publication developed by the Texas Department of Transportation (formerly known as the Texas State Department of Highway and Public Transportation) is included in this appendix.

Design

The results of the planning process, along with solutions to institutional and funding problems, are incorporated into the design of the system. The design incorporates existing systems and provides for future system expansion and the addition of new systems, including additions at the traffic management center, as well as in the field.

If the agencies do not have expertise in some or all parts of the system design, a traffic engineering consultant should be hired.

One or more agencies (together with the consultant and architect where needed), develops the plans and specifications. Where more than one agency is involved in the development of the plans and specifications, initial guidelines must be developed to assure that all parts of the design work (including nomenclature and symbols) are the same. This procedure eases integration of the plans and specifications, reduces confusion and misinterpretation (especially as the project is installed), and reduces the contractor bid prices (by eliminating the contractor's guess work).

A thorough review of the plans and specifications must be carried out by personnel who have not prepared them. Also, it is very important to obtain the necessary expertise in carrying out the design. Both the thorough review and expertise will pay for itself many times over during the installation and operation/maintenance stages.

Implementation

Assuring that the equipment, software, and materials meet specifications before installation and that all aspects of the plans and specifications are met during installation is a primary responsibility of the project engineer. He or she must employ qualified inspectors and persons familiar with the equipment and its intended operation.

Representatives from different agencies may inspect or observe the work, but these people must report any noted discrepancies to the project engineer by these representatives and not to the contractor, subcontractors, or the project engineering inspectors. The project engineer must in turn confer with the contractor on the discrepancies. Representatives from various agencies should also attend the factory demonstrations of hardware and software. In all cases, the project engineer is in charge and makes the final decision in case of different interpretations of the plans and specifications.

Operation and Maintenance

The old adage that taste is the proof of the pudding applies to operation and maintenance. The proper design and implementation of a system goes a long way in achieving good operation and maintenance.

Each agency must provide enough personnel to properly operate and maintain the system. The agencies can either have one group to maintain and operate the integrated system or carry out the operation and maintenance of its own portion of the system. Where a central computer supervises computers of several agencies, the central computer and its peripheral equipment (communications, work stations, displays) must be maintained by one agency or group.

The operation of the integrated system must be carried out as one unit within the confines of the design and interagency agreements. Operators of various agency systems should be able to work together best if they are located within the same traffic management center. They should also be able to formulate and implement appropriate responses for different traffic conditions more easily.

Operation and maintenance is a continuous process, and quite often funding must be obtained each year. It is important to maintain good relations with the administrators in each agency and assure that they realize that the system is providing a necessary function. When a new agency administrator is appointed or hired, every effort must be made to sell him or her on the concept of integrated traffic management.

Integrated systems operation is complex and requires constant vigilance and considerable patience, but it is worth the work involved.

TRAFFIC MANAGEMENT TEAMS IN TEXAS

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

MAINTENANCE AND OPERATIONS DIVISION

January 1990

The first Traffic Management Team in Texas was officially formed in 1975. By 1980, there were five teams and there are currently 24 operating in the state. These teams cover nine of the largest metropolitan areas, as well as other smaller areas. The rapid spread of the team concept and the wide acceptance among the larger cities in Texas lead us to believe that it is a very beneficial organization.

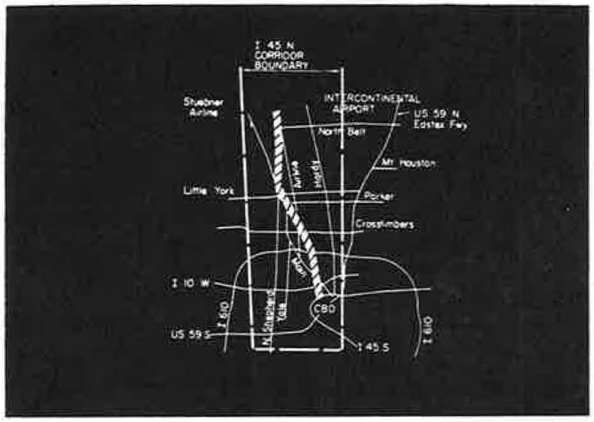
The team brings together professionals from the various transportation related agencies in the area and helps them to work together to solve the area's traffic problems. It aids in the development of mutual respect among members, but more importantly, it also aids in the understanding of others and breaks down perceived barriers. This is accomplished through enhanced communication, which leads to coordination and cooperation.

We hope this booklet will help introduce you to how the Traffic Management Teams operate in Texas. If you would like further information or have any questions, please write to:

State Department of Highways &
Public Transportation
Maintenance and Operations Division
11th and Brazos Streets
Austin, Texas 78701

What does a Traffic Management Team do?

A Traffic Management Team improves the overall traffic operation and safety along principal arterials and/or urban area corridors by coordinating the activities of the principal operational agencies in the area.



What is a corridor?

A corridor is a system of roadways which interact and serve as alternate routes to each other. Corridors can consist of two or more parallel streets or a freeway with parallel streets. All cities have several different corridors serving different origins and destinations which intertwine and change in size depending on the time of day and day of week. Any change made to the capacity of one element of the corridor affects the others by shifting the demand from one roadway to another; therefore, alterations must be coordinated between the various elements for the traffic to move in an efficient manner. The different elements of the corridor, though, are quite often controlled by different agencies and communication and coordination between them is sometimes weak.

What is a network?

A network is made up of the various corridors in an area. Just as roadways within a corridor interact with each other, the same is true for corridors within a network. There must be coordination between corridors in order to have an efficiently operating transportation network. In large metropolitan areas for example, a typical trip to and from the workplace may traverse two or three corridors. If a problem occurs in a corridor which encompasses a portion of an inner loop freeway, traffic on an outer radial freeway must be informed and given the opportunity to choose an alternate route.

The network is usually of major concern in the smaller city. Even though the corridor of a smaller city may contain only one or two roadways and the network consist of arterials instead of freeways, coordination is important. An efficient network will help maintain the level of service that citizens are accustomed to and expect.

How can traffic operations be improved?

There are basically three ways to improve the operation of a corridor and a single city street. The first is to improve safety. Much of the work done by the teams in Texas is directly related to safety and it is always a consideration in any other action. Some common safety improvements are adjusting the clearance intervals at signals, restriping faded lane lines, increasing enforcement of speed limits and improving confusing signing.

Operation can also be improved by increasing passenger capacity. This includes adding lanes, providing good signal progression, eliminating geometric bottlenecks, and providing mass transit facilities. Without good coordination, each agency will build those improvements specific to their needs, but may find that the new facility doesn't work as well as it could. For example, the state highway department and the local transit authority must work together closely in designing a separate priority entry ramp onto a freeway for high-occupancy vehicles. Other agencies can also, however, contribute to the design. The police department can suggest ways to make the ramp restrictions easier to enforce and less likely to be violated. The city traffic department can alter the geometry or signal operation of nearby intersections to make the ramp easier to access.

The third basic way to improve operation is to decrease the vehicular demand. This is more difficult to do since it requires convincing the driver to change his or her normal route or mode of travel (bus, carpool, etc.). Some suggestions are to encourage use of mass transit, less traveled alternate routes, and variable work hours. A temporary decrease can be obtained by the use of media releases explaining the need for diversion and how it can be accomplished. Installing freeway entrance ramp meter control may cause a more positive shift in motorist travel.

What different agencies should be represented?

Different cities have different situations, so representation is seldom the same on every team. However, some agencies are almost always included on the team. These include the city and state traffic engineering offices, city and state law enforcement agencies, and the local transit authority. In some cities, one agency may represent two disciplines on the team. In Kerrville, for example, the state resident engineer represents both traffic and design engineering disciplines. Other agencies and divisions should be included if they are significantly involved in the operation of the network. Possibilities include the maintenance, design and public works sections; the fire department; railroads and the port authority. It is important, however, to keep the team as small as possible to minimize red tape. Table 1 shows the disciplines represented on teams in ten various-sized cities in Texas.

When discussing a topic which affects an agency not represented on the team, that agency should be invited to attend that meeting. For instance, several teams have met with local ambulance services to discuss ways of clearing accidents off of a freeway with as little disturbance to traffic as possible. Most teams invite a representative from a satellite city to attend a meeting at which a subject affecting that city will be discussed; however, some teams include representatives from satellite cities as permanent members of the team.

TABLE 1
COMPOSITION OF SELECTED TMT'S IN TEXAS
(SAMPLE BASED ON POPULATION SIZE)*

Agency	Brownwood (18,720)	Kerrville (19,890)	Tyler (75,440)	Laredo (117,060)
City				
Traffic	X	X	X	X
Police	X	X	X	X
Fire				X
Transit				X
State				
Traffic	X	X	X	X
Design	X	X		X
Maintenance	X	X		X
Highway Patrol	X	X	X	X
County				
Engineer		X	X	
Sheriff		X	X	X
Other				
Naval Air Station				
Traffic Safety Assoc.				
Railroad Assoc.				

*All populations are 1986 U.S. Census Bureau estimates.

– Continued –

TABLE 1 (CONTINUED)
COMPOSITION OF SELECTED TMT'S IN TEXAS
(SAMPLE BASED ON POPULATION SIZE)*

Agency	Beaumont (119,900)	Midland and Odessa (199,270)	Corpus Christi (263,900)	Fort Worth and Arlington (679,320)
City				
Traffic	X	XX	X	XX
Police	X	XX	X	XX
Fire				
Transit				X
State				
Traffic	X	X	X	X
Design	X			X
Maintenance	X		X	X
Highway Patrol	X	X	X	X
County				
Engineer		XX	X	X
Sheriff				
Other				
Naval Air Station			X	
Traffic Safety Assoc.				
Railroad Assoc.				

*All populations are 1986 U.S. Census Bureau estimates.

– Continued –

TABLE 1 (CONTINUED)
COMPOSITION OF SELECTED TMT'S IN TEXAS
(SAMPLE BASED ON POPULATION SIZE)*

Agency	San Antonio (914,350)	Houston (1,698,200)
City		
Traffic	X	X
Police	X	X
Fire		X
Transit	X	X
State		
Traffic	X	X
Design		X
Maintenance		
Highway Patrol		X
County		
Engineer	X	X
Sheriff	X	X
Other		
Naval Air Station		
Traffic Safety Assoc.		X
Railroad Assoc.		X

*All populations are 1986 U.S. Census Bureau estimates.

What actions need to be coordinated?

Virtually all work done in a freeway corridor can be coordinated between the agencies of the team to the benefit of traffic operations and safety. Listed below are a few common examples.

1. **Work Zone Traffic**

   Congestion in varying degrees often accompanies maintenance operations and new construction, causing traffic to divert to alternate routes. If maintenance is also being performed on that alternate route, the entire corridor can break down. Even along city streets and rural highways adjacent to a city, traffic can be affected by improperly designed work zones. Therefore, traffic control which affects the capacity of a route should be brought to the attention of the team to prevent any conflicts.

   In severe cases, such as where an entire freeway is closed, the entire team should be involved in planning and implementing the closure. The police department can direct traffic and enforce special signing while the city traffic office adjusts the coordination of the signals on the alternate route to provide an efficient operation. The highway department and city can provide signs warning of the closure and identifying the alternate route while the transit authority modifies its routes, if possible.

   The team as a whole can prepare media releases to warn drivers of the closure and recommend an alternate route. By coordinating the plan within the team, most problems can be worked out beforehand and the traffic control can be jointly carried out to provide a safe and efficient operation.

2. **Route Improvements**

   Permanent modifications to any roadway in a corridor or arterial network may affect the other elements. Therefore, team members often give updates on proposed projects so that all members can have advance notice. For maximum efficiency, all arterials which might be involved should be analyzed to prevent a bottleneck during construction and afterwards. Controlling entrance ramp volumes through ramp metering, for example, can improve freeway operation in terms of total volume, but it can also cause congestion on city streets. The team is well equipped to analyze the effects of new construction and to prepare for the changes in traffic flow.

3. **Normal Operations**

   In their day-to-day work, police officers often notice locations where there is a violation or accident problem. The team provides a ready line of communications to the traffic engineering agencies who can act to correct the problem.

   A change in operation can also be important to the team because of the interaction between the elements of the corridor or overall network. For example, banning left turns at an intersection during peak hours will force traffic to use another cross street. This information is vital to the transit authority, which may need to alter its routes. The traffic could possibly start using a different on-ramp to the freeway, thus creating a weaving problem or a need to change ramp meter timings.

4. **Emergency Planning**

   In case of severe weather such as flooding or freezing, it is very helpful to have a plan delineating each agency's responsibilities to prevent delay and possible omission of those jobs which must be done to insure the safety of the driving public. This same type of planning can also be used for major incidents such as truck accidents, which can close an entire freeway. Once again, the advance planning fosters quick response and action.

5. **Special Event Traffic Handling**

   The team can often quickly and efficiently design, analyze and operate a traffic routing plan for a special event such as a parade or fair. The transit authority can provide express bus service to the event while the highway department and city can provide signs telling the driver how to get to the bus service and the event. The police department can direct the traffic around the event and provide temporary traffic control at intersections.

What is a Team Meeting like?

The team should be a group of transportation professionals with mutual respect and confidence. Below are a few guidelines which might help in setting up and running team meetings. Each team is different though, and this is reflected in the way the team operates.

1. Most teams in Texas hold monthly meetings, but some only hold them every other month or quarterly. It is important to schedule the meeting well beforehand so that all the members will have ample time to arrange their calendars.

   This can be easily done by setting a standard meeting date, such as the second Tuesday of each month at 2:30 in the afternoon.

2. The same people must attend the meeting each time rather than send an alternate. This helps to create a spirit of cooperation and respect among the team members and a more comfortable working situation.

3. The meetings should be informal. A chairperson helps in coordinating the discussion; however, with such a small body, formal rules that tend to stifle the interaction of the team are not needed. Most teams use a short prepared agenda of three or four items submitted by the team members and leave time for impromptu items. One type of problem should not be allowed to dominate the meeting; rather, an attempt should be made to have a mixture of subjects on the agenda that will keep everyone interested and involved.

4. After discussion, the team reaches a verbal consensus on the solution to a problem. Generally, actions are not taken in the name of the team; however, the responsible agency or agencies will take steps to implement the plan. The team members must be able to make decisions about committing their agency's resources to a team project and also be close enough to the operation to be able to effectively discuss the issues.

How are the team and its projects funded?

Generally, in Texas, the teams have not had dedicated funding sources. Rather, each agency funds its own improvements with its normal budget.

How much time does being involved in a team take?

Attending team meetings does take time away from a busy schedule, but most team members feel that this time is more than compensated for by the reduction in time wasted because of misunderstandings, redesigns, and letter writing. The team gets problems out in the open early and everyone benefits from the improved communication, coordination, and cooperation.

Teams are being formed in all areas of the state.

There are currently 24 Traffic Management Teams operating in Texas in areas ranging in population from 5,000 to 3,000,000, including nine of the largest metropolitan areas. Many of these teams are operating effectively in rural and smaller urban areas. Our experience has shown that teams are of considerable help in guiding agencies toward their common goal of improving traffic conditions.

The team is a local effort. It is geared toward looking at all aspects of traffic operations, not just one issue or project. However, for a large, on-going project, a separate task force may be needed to coordinate efforts.

Traffic Management Teams are needed now and in the future.

As our streets and highways become more and more congested and the cost of purchasing right-of-way escalates, the role of traffic operations will assume an even greater importance in the years to come. And as a forum for the transportation related agencies of a city or metropolitan area, the Traffic Management Team will play an important part in the enhancement of traffic operations. The team will provide a systematic and effective approach toward the improvement of traffic operations in a city and surrounding areas.

Institutional Issues in ITMS: TRANSCOM's Experience in NY and NJ

Matthew Edelman and Paul A. Einreinhofer[§]

TRANSCOM is a coalition of traffic, transit and police agencies in the New York metropolitan region. The Bergen County, New Jersey Police is one of the participants in this coalition. One of us writes from the perspective of the manager of this coalition. The other writes from the perspective of a key agency participant who has helped to make the coalition work. We have worked together in the last few years with an appreciation of each other's perspective, and we have faced many of the institutional issues involved in integrated traffic management systems. We have faced these institutional issues in dealing with basic problems, such as sharing information on incidents. They come up again as we develop coordinated, regional responses to incidents and major construction. They are with us as we implement proven traffic management technologies, such as remote video surveillance (CCTV) and highway advisory radio (HAR). Further, we have overcome a number of these institutional problems to the point that this region, despite its institutional fragmentation, has set the stage for being an active participant in IVHS.

Two Different Agencies - One System — Located in Jersey City, New Jersey, TRANSCOM is frequently referred to as a United Nations of traffic and transportation.[†] Like the U.N., it has considerable responsibility, but limited authority—yet, it can be quite effective when the members see how their collective interest can be enhanced through cooperation. TRANSCOM is funded, staffed and governed by its members. It has an Operations Information Center (OIC), open 24 hours/7 days a week, which shares incident information by alphanumeric pager, phone and fax, among over 100 highway and transit facilities, police agencies and the radio traffic services. It also serves as a forum for incident management planning, construction coordination and for the shared testing and implementation of traffic and transportation management technologies.

The Bergen County Police, based in Hackensack, New Jersey, is not one of the 14 members but they are active in the network. Bergen County is a heavily developed suburban county with a population of approximately 850,000. It is home to a number of corporate headquarters including Lipton and Volvo America. The key north-south corridor, I-95, passes through Bergen County, as does I-80 to the west. It is also the western terminus of the George Washington Bridge, the busiest vehicular crossing in North America. The Bergen County Police are responsible for, among other things, incident response on key Primary Highways, including Routes 4 & 17, the former feeding into the George Washington Bridge. On paper, the Bergen County Police is a local entity but, in reality, given the county's strategic location, it is constantly affecting and is affected by regional traffic.

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[†] The 14 member agencies are: New York State Thruway Authority, Metropolitan Transportation Authority, New Jersey Department of Transportation, New Jersey Highway Authority, New Jersey State Police, New Jersey Transit, New Jersey Turnpike Authority, New York City Department of Transportation, New York State Department of Transportation, New York State Police, Palisades Interstate Park Commission, Port Authority of New York and New Jersey, Port Authority Trans-Hudson (PATH) and Triborough Bridge and Tunnel Authority.

Many Jurisdictions, In All Sizes — Traffic officials visiting from other regions have said to us at times, there are "too many" jurisdictions in the New York metropolitan area, how do you get anything done? Since we have to deal with our world as it is (i.e., we are not about to have states, municipalities and toll authorities surrender control to a new regional authority), we prefer to say that we have "so many jurisdiction" rather than "too many jurisdictions." Within these constraints, we look at the relationships among the agencies and within each agency. We then find ways of appealing to the self interest of each agency that are consistent with the collective, regional interest of all the agencies.

Before we discuss how we work to overcome institutional barriers, let's first look at the jurisdictional structure in a bit more detail. We have five toll authority members. One deals with bridges and tunnels within New York City, one with bridges and tunnels between New York City and New Jersey, two with limited access highways in New Jersey and one with limited access highways in New York State. In addition to having two state DOTs (NYSDOT and NJDOT), NYCDOT and NYSDOT have joint jurisdiction within the city of New York, with day to day operations the responsibility of NYCDOT. The bridge and tunnel authorities handle their own incident response. The highway authorities contract with state police to do this. In New York City, incident response is done by NYCDOT and NYPD. In New Jersey, incident response on the non-toll interstates is done by the State Police. On the primaries, it is done by varying combinations of county and local police. (For example, the six miles of Route 1-9 from TRANSCOM's offices in Jersey City to Newark are owned by NJDOT but incident response is done in different segments by the Jersey City, Kearny and Newark police departments.)

In the name of saving space, we have by no means described the complete inter-agency structure. It does give a starting point, though, for demonstrating an environment in which institutional barriers are a fact of life.

Picking Up The Phone — No matter how much cooperation you have among commissioners, no matter how much enthusiasm and support you have among operations directors, no matter how large or stable your funding is, no matter how many cooperative incident management plans you've developed, we have found that unless the communications officer at the desk picks up the phone and notifies the outside world when an incident takes place, all of this support and cooperation can be for naught. The number of notifications coming through TRANSCOM have increased many times over since the OIC was opened in 1986. Bergen County Police were some of the first to "pick up the phone" and call TRANSCOM. This didn't happen overnight either; it involved time to get communications personnel to expand the framework in which they view the impact of an incident.

As people at this conference already know, and will undoubtedly hear throughout, local police already have their hands filled with an incident just thinking locally, e.g., helping the victims, doing accident investigations, arranging for vehicle removal, clearing debris and addressing any hazardous materials concerns. The fact is, though, that incidents in the Bergen County Police's jurisdiction can affect, among others, the New Jersey Turnpike, the Garden State Parkway, the Palisades Interstate Parkway, the New York Thruway, the George Washington Bridge and even, from time to time, New York City. What helped to motivate Bergen County Police to make the call to TRANSCOM was the appreciation that these linkages work both ways. A major incident on NYC's Cross Bronx Expressway can not only back up to the George Washington Bridge, but beyond into Bergen County. Now, when someone at the communications desk sees that Route 4 is backed up despite there being no incidents on that highway, he knows through TRANSCOM that the source of the problem lies on another agency's roadway. He also gets updates on the incident's severity and a notification when it clears. The importance of reaching out to others is hit home by seeing how it is in your self interest for others to reach out to you.

How Inclusive Should You Get? — The picture we painted above is one in which the jurisdictional structure is comprised of large agencies: DOTs, state, city and county police forces, and toll authorities. There is another level of jurisdictions as well, namely, numerous suburban police jurisdictions (in our region, literally hundreds). Along some of our busiest suburban corridors, you can have a different local police force at each exit. To include them in implementing ITMS can add more players than is manageable. To exclude them could be taken by local police as arrogance on the part of the larger agencies, because their communities often can be severely impacted by the handling of an incident in a major corridor.

Finding the appropriate balance between inclusiveness and exclusiveness is difficult and varies from corridor to corridor. TRANSCOM has put together traffic and incident management planning teams for six major corridors, four of which involve numerous small police forces. In this case, the decision has been made to invite the locals in. This often involves doubling the number of participants (in one corridor, between toll authorities, state DOT's, county agencies and locals, we have well over 20 agencies). It is understood that this can be a deliberate and complex process—adding more players to ensure proper implementation has, from our experience, been worth it.

With regard to our interagency incident notification network, the decision has been to be less inclusive. In Bergen County, Route 4 & 17, two major high incident roadways, go through 7 and 19 municipalities, respectively. For TRANSCOM to bring each of these agencies on to the network (for what in most cases could be a few major incident phone calls per year), it would not be worth the time invested in working with and motivating each local agency to get involved. Thus with the exception of Fort Lee (which lies in the critical location at the west end of the George Washington Bridge), TRANSCOM relies on Bergen County Police for reporting incidents on these roadways. We have found that in our region, agencies such as this have both the local sensitivities and the regional perspective.

"Turf Battles" and Personality Conflicts — Sometimes the former get mixed up with the latter, but in finding solutions, it is important to differentiate between the two. Turf battles can be based on substantive issues—while you as the advocate for ITMS believe the system as a whole will benefit, that doesn't mean that individual agencies will not be impacted in terms of a change in their role or powers. These conflicts should be dealt with head on whenever possible—ITMS advocates should not pretend that there aren't problems in their dealings with these agencies. Personality conflicts are harder to work through (though it is remarkable how some seemingly intractable turf problems suddenly go away when certain individuals go to new positions). Personality conflicts are also a function of people's training and how broadly they define their professional loyalties. Thus, a change in personnel is not so much a change from "bad guys" to "good guys" as it is a change in different individuals' views of themselves in relation to their working environment.

TRANSCOM's experience in developing its construction coordination program, while not ITMS, provides an illustration of how we work to overcome turf problems in an interjurisdictional environment. The dilemmas we had to deal with were quite similar to those that arise in implementing an ITMS. TRANSCOM set out a number of years ago to develop a program that was designed to reduce the likelihood that different member agencies would simultaneously restrict capacity by closing lanes on parallel facilities in the same direction. While it was each agency's responsibility to avoid parallel closings within its own network, it was TRANSCOM's role to get involved when the parallel facilities involved more than one agency.

In an era of tight budgets and complex infrastructure renewal projects, this kind of intervention by TRANSCOM was not always welcomed by some construction engineers. Their jobs are already complex enough, and the pressures to get projects done on time and within budget in a difficult working environment can be enormous. The appearance of TRANSCOM, requesting an alteration of construction schedules would, understandably, not always be greeted enthusiastically. TRANSCOM did not pretend these turf issues didn't exist—indeed, we have enormous respect for the constraints these engineers work under. Rather, we have added an additional set of constraints into the equation: reductions in capacity on parallel facilities can create operational problems, customer inconvenience and political problems for all of us. While we will not go into detail on how this program then developed, the result is now a process in which agencies modify schedules to accommodate the needs of other agencies a number of times a year. Turf conflicts are implicit in a program like this—they are dealt with by understanding that, personalities aside, the agencies' engineers are expressing legitimate concerns.

Implementing Technology Improvements — The interchange of Routes 4 & 17 in Bergen County is, by the agreement of just about everyone concerned, the worst in New Jersey in terms of number of incidents. Designed generations before the current level of development in the county, it is known not only for problems for commuters, but for those trying to patronize the large shopping malls that have been built in its vicinity. Bergen County Police, NJDOT and TRANSCOM had long wanted to put some form of incident detection and motorist information system there. When FHWA funds were made available in 1990 for TRANSCOM to implement CCTV and HAR systems, this site was a prime candidate. Since we are not dealing with a region with a single agency with control over all of the limited access highways, we were faced with new interjurisdictional issues in allocating these funds and then implementing these improvements.

The TRANSCOM members established criteria for selecting sites for CCTV and HAR. Criteria, such as frequency of incidents and impact of incidents on other agencies, were designed not only to find the best sites but, ideally, to strengthen mutual support among the member agencies, as well. Even with some very stiff competition, 4 & 17 came out as one of the top projects. Again, without unified management of the limited access highway system, a separate process for design and operation of each of the selected sites had to be set up. For 4 & 17, design has been done by the owner of the roadway, NJDOT. Operation of the system, monitoring the cameras, responding accordingly to problems on site, and operation of the HAR system is to be performed by Bergen County Police. TRANSCOM will be given access to the system for messages of regional impact. An additional set of actors is involved because one of the other selected sites, CCTV at Exit 163 on the New Jersey Highway Authority's Garden State Parkway, is within a few miles of the 4 & 17 interchange. Thus, part of the Parkway's mainline is covered by the 4 & 17 HAR. The New Jersey Highway Authority will do the design for its cameras, monitor them from its communications center in Woodbridge 30 miles to the south and be given access to the HAR as well.

Certainly, we have a lot of actors involved for a fairly basic system involving three or four cameras and an HAR. All these jurisdictions are a fact of life we accepted; we all worked face to face and developed an understanding of each other's concerns. We all understood though that we all benefitted by maximizing the use of the system and this is what motivated each of us to overcome interjurisdictional issues.

Crossing State Lines — What would seem to be a more dramatic institutional issue than a major corridor separated by a state line right in the heart of a major metropolitan area? From our experience, this may be less of a problem than it seems. Advocacy for ITMS often comes from DOTs. Their staffs appreciate the spill over effects of incidents and understand that they need the help of others across state lines. (Simply put, if there is one thing a state DOT has particular respect for, it is a state line). From an administrative standpoint, having more than one state involved can be a complicating factor, as is noted further on.

State lines in themselves, do not produce any more problems for our coalition than other adjacent jurisdictional boundaries. The more complex institutional issue for our coalition has to do with identifying and appreciating one's linkages with agencies that are not immediately adjacent to one another. For the Bergen County Police, it took more time to develop an appreciation of our interdependence with NYCDOT, for example, than it did with the immediately adjacent George Washington Bridge.

One way that this institutional issue was addressed was through the development of a working interagency variable message sign (VMS) and HAR inventory. In effect, the existing investments that each agency has in these technologies are made available to other agencies through TRANSCOM. Since one often strives in using these resources to divert regional flows as far upstream from the incident as possible, one agency is often called upon to deploy resources for other agencies that are quite distant. The New York State Thruway in suburban Westchester County will put up a message on a fixed VMS sign to warn motorists that the Triborough Bridge and Tunnel Authority's Whitestone Bridge between the NYC boroughs of the Bronx and Queens is closed. The New Jersey Turnpike Authority will place a portable VMS in central New Jersey advising truckers of a temporary truck ban on the Verrazano Bridge between Staten Island and Brooklyn.

We noted before how the communications officer at the Bergen County Police was motivated to think in a regional context and call TRANSCOM. The VMS/HAR inventory has a similar effect with operations personnel. They have an incentive to deploy motorist information resources to help distant agencies because they appreciate how these agencies can help them out during major incidents and construction, as well.

Different Goals Depending Upon Professional Backgrounds — We have found that engineers and police are motivated in different ways. Police are often more resistant to ITMS initially than engineers, the latter being more responsive to the technical arguments for ITMS. Engineers are more inclined to see regional linkages because of their training. Police, on the other hand, must live from day to day with the actual on site affects of an incident, they know first hand just how bad it can be out there. So when they are ultimately convinced that ITMS will help them in their work, they can become extremely enthusiastic proponents of regional approaches.

A police lieutenant on one of our interagency incident management teams was skeptical that TRANSCOM could mobilize so many regional motorist information resources at one time. In the midst of a major incident, unknown to us, he took off in his car to Long Island, Westchester and New Jersey to see if all the messages really were put up. They were. He called up to tell us what he did and that he is convinced the system works. Since then he has been a strong advocate for our efforts—he can even push the rest of us farther than we expected to go.

Balancing Freeway vs. Local Traffic — In the forthcoming implementation of CCTV and HAR at the Route 4 & 17 interchange, the Bergen County Police are working under the assumption that quicker detection and clearance of incidents on 4 & 17 will benefit local roadways as well. Within a 3-mile radius of the Route 4 & 17 interchange there are five municipalities, and one toll authority. This represents six police departments in addition to the Bergen County Police.

Many state DOTs understandably have a major responsibility just focusing on state highways. They often lack the authority or resources to coordinate the entire network. For example, the Bergen County Road Department spends large amounts in upgrading intersections and in road widening projects. These projects are partially necessitated by the volume of vehicles attempting to by-pass the traffic congestion on the two state highways. NJDOT invests money in attempts to keep the corridor traffic moving, while doing its best to consider the secondary road traffic caused by the same congestion.

The state police department is not charged with patrolling the state highways, leaving that responsibility to local governments. The local governments believe that response and enforcement on the state roads should ideally be the state's responsibility, so dedication of municipal resources to that task is minimal. The Bergen County Police fills that "jurisdictional" gap within its own capabilities.

The objective is to balance the freeway and local road traffic into common goals for facility operations. The completion of the CCTV/HAR project will hopefully improve the quality of information to everyone and further enhance cooperation.

In Bergen County, how does one resolve the diversion of traffic from freeways onto local streets? No locality wants traffic off a freeway, yet Bergen County Police certainly don't want to keep people sitting indefinitely behind a freeway incident. In dealing with this, the state, county and localities have come to terms with the fact that diversion is going to happen anyway—they can either work together, or they can just let things happen. The county and state understand that it is incumbent upon them to use whatever technologies possible to keep traffic on the freeway system, bringing about regional diversions and minimizing the traffic stuck behind an incident requiring a local diversion. The localities have a growing appreciation of the state and county's continuing efforts and in turn, when some local diversion is inevitable, they are showing an increasing understanding of this reality.

Finding Personnel to Develop Plans — TRANSCOM has definitely found this to be an issue for its incident management planning teams, as well as some of its other programs. You can have a dozen major agencies in a room agreeing to a diversion strategy, but no one has the staff to put it all together. TRANSCOM has found that the key is to serve as staff to the interagency teams and do the work for them. Going back to the U.N. model, the best way to bring a team together is to give them authority to define and implement the plan while TRANSCOM has the responsibility to do the technical work.

This approach requires a regional entity with the staff and funding to do this in a number of corridors. TRANSCOM has found that to go beyond its six corridors to put teams together for every major corridor would require far more staff and local funding than is currently available. Given these constraints, TRANSCOM has taken the approach of building on what it learned with these teams and developing a generic approach that is applicable to major incidents and construction anywhere in our region. The VMS/HAR inventory noted previously is one element of this approach.

Developing a Regional Entity to Facilitate ITMS Implementation — Building on the point above, we have found that volunteers and the goodwill of busy people from participating agencies can only take you so far. Staff is needed with a local funding base to support this. First of course, you need the willingness on the part of all the agencies involved to create a regional entity. Those whose regions are in one state are the more fortunate ones. When creating, funding, staffing and directing a new entity, life is simpler when you only need to deal with one state's administrative process.

Again, as with the U.N. model, TRANSCOM does not have, nor does it pretend to have, power over the dozens of agencies on its network. Everything works by voluntary compliance and motivating people by linking their self interest with the regional interest. It works for us, but in a region like ours, we have no choice but to do it this way. This constraint has not limited us as we move as a region into IVHS. This year, seven agencies (three DOTs and four toll authorities) are working with FHWA to implement IVHS in the corridor between Staten Island and central New Jersey. The effort will determine the feasibility of building on electronic toll collection technology for incident detection. With IVHS, we are dealing with a complex problem, and as with other things we do, we don't pretend that there is always harmony. What matters most though is that there is a forum where people can work things out face to face for the benefit of the region and traveling public.

Funding ITMS

Alan Clelland[‡]

INTRODUCTION

The successful implementation of any traffic management system is a combination of several factors such as sound design, well managed implementation and competent operation and maintenance. A common thread through all these activities is the availability of adequate funding for every stage of the project. Yet, while much has been written to assist the engineer in all these project tasks, little is offered to help in securing the all important funding.

This was recognized by the then Orange County Transportation Authority when it commissioned a study for a Traffic Operations Center (TOC) for the county's freeways. The freeways fall into District 12 of the California Department of Transportation (Caltrans). As well as a thorough analysis of TOC operations and Traffic Operation System (TOS) alternatives, the study included an investigation of potential funding sources.

This paper aims to provide some insight into pursuing the funding of integrated traffic management systems and is based upon the results of the funding opportunities analysis carried out as part of the TOC study (*1*). The characteristics of the Orange County system are described with respect to integrated traffic management system components. This is followed by an overview of general aspects of the pursuit of funds and a description of those funding sources identified by the study as being applicable to the implementation, operation, and maintenance of the complete Traffic Operations Center (TOC). All aspects of project funding are addressed, including operations and maintenance.

The funding sources are categorized as:

- Locally generated
- State-based funding
- Federal sources

While some of the sources described are obviously specific to Orange County, it is anticipated that there will be available local parallels in many regions. The intention is to draw attention to funding sources which may not be traditionally available to traffic operations projects.

THE ORANGE COUNTY TRAFFIC OPERATIONS CENTER

Up until the late 1980s, the freeways in Orange County came under the jurisdiction of Caltrans District 7, headquartered in Los Angeles. The rapid growth in Orange County coupled with an equally rapidly expanding freeway network led to the formation of Caltrans District 12 for the county. With the locating of the Caltrans District 12 offices in the Santa Ana facility, came the reservation of limited space for a Traffic Operations Center. However, the district's freeways are still monitored by the Semi-Automated Traffic Surveillance System (SATMS) located in the District 7 TOC. Similarly, District 12's full matrix changeable message signs (CMS) are controlled by District 7's CMS central.

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District 12 produced a 10-year Traffic System Management Plan in 1989 which identified the expansion of the freeway surveillance and CMS and introduced elements such as closed circuit television (CCTV) and highway advisory radio (HAR).

One of Orange County's major cities is Anaheim which is the home of several special event generators such as Disneyland, the Anaheim Stadium and the Convention Center. The city has been successful in developing and implementing a Traffic Management Center with such system elements as a centralized traffic management system (TMS), CCTV and CMS.

The need for access to freeway conditions as part of event management in the city has led to the installation of an intertie between the Caltrans District 7 TOC and the Anaheim TMC (*2*). Freeway conditions and CMS status are transferred from the TOC to the TMC for display on real-time high-resolution graphics displays. District 12 receives the data for similar display via the Anaheim TMS through a TMC to District 12 TOC intertie. This intertie also allows Caltrans District 12 access to Caltrans traffic signal controllers operating under the Anaheim TMS through a remote terminal support capability. Recent projects in the Anaheim Stadium area will add the capability of transferring video images on this intertie and providing for the integrated operation of CMS and HAR motorist information systems between Caltrans and Anaheim operations personnel in several areas of the city.

The TOC study identified future Caltrans operations as being coordinated with other cities such as Irvine and Santa Ana as well as the forthcoming Transportation Corridors Agency (TCA) toll roads (see below). Amid all this activity, the SATMS and CMS central equipment is rapidly approaching end-of-life, causing District 12 to analyze options for replacement and implementation of its own TOS and CMS central.

FUNDING PREPARATION

Clearly, the developing District 12 TOC and its associated TMS fall into the category of an integrated traffic management system (ITMS) comprising diverse system elements complicated by the coordination of several independent operating agencies. This, however, is likely to become an increasingly common construct in urban traffic management projects; freeway and surface street agencies will develop the need to coordinate their operations to mitigate the impact of recurring and non-recurring incidents and maintain mobility on their facilities.

How then should these agencies best pursue the securing of funding to support such projects? This section suggests key components for a successfully funded TMS as a prelude to the identification of specific funding opportunities.

Development of an Action Plan

An ITMS will be comprised of either multiple system components or multiple agencies or both. It is inevitable, therefore, that the design and implementation of the ITMS will not occur in one major step, but in a piecemeal fashion. Individual agencies will get separate funding and individual components will come on-line independently. It is essential, however, that there exists an overall implementation plan which forma the blueprint for ITMS implementation.

This Action Plan identifies the system components, their interdependence, costs and responsibility for implementation. With this information, the pursuit of funding can be focused to address ITMS elements at appropriate points in the program and avoid premature deployment and incompatible activities. Equally important, this should also avoid "gaps" in the system at agency or sub-system interfaces.

It is also recommended that, in the case of multi-agency projects, one agency takes a lead role in managing the overall ITMS implementation and coordinating activities. This may be very much a secretarial role in arranging meetings, setting agendas and distributing minutes of meetings but these provide an essential framework for project implementation. An excellent example of this has been the Katella Avenue Signal Coordination Project (*3*).

Phased Implementation

The complexity of an ITMS demands that a phased implementation approach is followed. This means that system components are identified which can be implemented and brought on-line independently. In this way, component functionality is confirmed prior to integration. Any problems arising during integration are automatically reduced in complexity.

An additional advantage is that the incremental benefits of the system components can be experienced. Through phased implementation, the ITMS will progress as a series of successful steps; this will generate support for the project as a whole and help support the securing of funds for successive stages of the program.

Targeted Applications

Successful funding applications are those which are targeted at the most appropriate funding source for the project element to be funded so that the application can score highly against the selection criteria. This basic fact is often overlooked under the pressure to secure funds and submit applications on time. As stated above, the availability of an Action Plan will assist the matching of the targeted fund to the most appropriate element.

Leveraging

This can be summed-up by the phrase "Big oaks from little acorns grow." It may prove difficult or even impossible to totally fund an ITMS because of the magnitude of the program and the diversity of system elements, hence the need to target individual elements for implementation. However, as it can be shown that any given element forms part of a coherent, integrated plan, funding form one source can be used as leverage to gain funding from another.

Consider the case of an agency which has access to a limited amount of local funds, e.g. $100,000 of city monies which could be used to fund a small element of the ITMS Action Plan. This can be used to support an application for state funds and gain an advantageous position by asking for a reduced state match, for example $400,000 at an 80:20 state to local match. The total $500,000 can then be used as leverage for a similar federal matching arrangement, resulting in a total funding of some $2 million.

FUNDING SOURCES

Locally Generated

Transportation Corridors Agency (TCA)

The TCA has been established specifically to construct three toll road facilities within Orange County. The combined facilities total approximately 65 miles of new construction. Funding for the construction is to come from two primary sources: dedicated developer fees and tolls. After the facilities are constructed, they will turned over to Caltrans for continuing operation and maintenance. TCA projects are to be implemented over a 7-year time period, with the first section available in 1993. There is some uncertainty with the funding, because of the dramatic slow down in development in the county. However it is expected that development will accelerate when the economy strengthens and that the funding will ultimately be available.

> *Opportunity* — The plan for the TCA facilities includes a complete traffic operations system. This includes all of the features identified as needed for the District 12 TOC. A fiber optic-based communications network is to be provided to support the TOS and the toll collection system. The toll collection system is to emphasize automated collection using AVI technology. The TCA program, as defined in their concept plan for traffic management, includes a traffic control center and all related system software, system integration, and operational planning services. The TCA feasibility study identified a total cost for the traffic management system of $70-75 million, including a significant value for the TOC and related services.
>
> The TCA funding, then, could be used to build the TOS infrastructure on the new roadways that they construct. Funds could also be made available to assist in developing the traffic operations center in lieu of building a separate facility.
>
> *Constraint* — The TCA funds cannot be used for infrastructure outside their roadways. Also, timing of availability of funds is questionable given current development conditions. It is also likely that the funds will not be available for continuing operations and maintenance, although some latitude might be available and should be considered.

Measure "M" Funds

Measure M, a one-half cent local sales tax increase to fund transportation improvements, was passed by Orange County voters in November, 1990. Over the next 20 years, revenues from this tax are projected at $3.1 billion. As part of this ballot measure, the Orange County Transportation Commission (OCTC) developed a 20-year Master Plan which allocates Measure M Revenues toward specific projects in the categories of Freeways, Streets and Roads, and Transit (including rail). The implementation of this spending plan will be supervised by a Citizens Oversight Committee and any changes must be approved, in advance, by this group. Funds were to become available in July, 1991.

Despite having received approval from Orange County voters, Measure M is currently undergoing a legal challenge that was filed by several groups who opposed the measure during the campaign. This has delayed the availability of the funds.

Based on the existing Measure M funding split between freeways (43 percent), local streets and roads (32 percent), and transit (25 percent), it is possible that part of these revenues could be used to construct and maintain a TOC. In addition, any funds spent on a TOC would benefit from a public perception that improved traffic flow on regional freeways provides the greatest overall benefit for the largest number of drivers.

Several segments of existing freeway are to be partially funded for reconstruction with Measure M funds. The infrastructure for the TOS would be expected to be included in the reconstruction projects and the Measure M funds might be applied on a pro-rata basis to this element. It might also be feasible to use a pro-rata portion of the funds for elements of the TOC.

Opportunity — Measure M funds can be used on the facilities identified in the program.

Constraint — Funds may only be used for identified sections of roadway with any deviation approved by an oversight committee. The funds do not appear to be available for continuing operations or maintenance, however there is a category for "maintenance and operations" noted in one element of Measure M. The allowance of use funds for these purposes needs to be examined further. (As a note, the one-half cent sales tax measure in Los Angeles County is funding the continuing tow services on the more congested freeways.)

Privatization Projects

There are two "privatization" projects being developed in the Orange County area. The first, covers a toll and HOV facility for a section of SR-91 from SR-55 to the Riverside County Line. The facility is to provide two lanes in each direction, reserved for toll and HOV vehicles. Toll collection is to be by fully automatic means.

The privatization project will include funds for a traffic management system. The working budget provides for the communications network and related infrastructure for the new facility. In general, the infrastructure covers only the new lanes, however, it is also adequate to provide for most of the SR-91 facilities. Additional detection and signing will be required.

Opportunity — The SR-91 project may significantly reduce the cost for the TOS for all of SR-91. This should be treated as a "given" in developing the funding program. Also, the project is expected to generate significant funds for capital recovery (payback in 7 to 10 years). The potential for "charging" the project for operations and maintenance should be considered. Also, the project should be considered for funding of a pro-rata share of the operations center.

Constraint — The area of coverage is limited and funds can be used only for the affected area.

The second privatization project, known as the Santa Ana River Viaduct, involves the construction of a facility in the right-of-way of the Santa Ana River. The link, to be built as a toll facility, significantly improves access to southern Orange County and provides a connector to the TCA projects. Agreements for the project are not as far along in development as the SR-91 project. It would be expected that all TOS-related items will be directly integrated into the project and be paid for by the project. In this sense, the project does not "add" to the initial cost of the TOS. It does add cost to the continuing operation and maintenance of the system by adding mileage and equipment.

At the same time, this project is on a new alignment and does not replace or supplement the need for any planned TOS facilities. Therefore, there is no potential cost savings to the TOS associated with this project.

Opportunity — The project can provide TOS features for the new facility. Further, the project should be examined to determine its potential for contributing to continuing operations and maintenance, particularly since the initial capital investment does not offset any planned investment in the TOC. The project may also be considered for contributing to the initial cost of the operations center on a pro-rata basis.

Constraint — The project involves a new roadway and funding is generally applicable to the new facility only.

Orange County Unified Transportation Trust (OCUTT)

OCUTT funds are those monies which have accumulated, *as interest, since 1985,* on a "transit savings account" of approximately $85 million. This transit savings account has resulted from OCTC's and the Orange County Transit District's (OCTD) annually setting aside a portion of the Local Transportation Funds (LTF), which has been earmarked for the eventual construction of a barrier-separated high-occupancy vehicle (HOV) lane, or transitway, throughout central Orange County.

The OCUTT program is administered by OCTA, with half of the money being spent on local streets and roads, and half on other types of projects such as state highways, freeways or superstreets. This year's OCUTT account is projected to be about $8.5 million. Agencies eligible for OCUTT funds include the county of Orange, the cities, and Caltrans. Also, each year, the funds contained in the streets and roads component of the OCUTT program are directed toward a specific aspect of local jurisdiction needs, with last year's focus on signal coordination, and this year's focus on road rehabilitation and reconstruction.

The OCTA is currently planning to divert the OCUTT, to fund a Commuter Rail Endowment Fund. Based on current subsidy levels, this would use approximately $5.4 million.

Opportunity — Diverting a portion of OCUTT funds may be an option for fast-tracking the expansion of the Phase I TOC. Continuing funding at a relatively low level may also be possible, especially in the emphasis area of interties with local agencies.

Constraint — The funding levels are relatively low and significant demands exist for the funds.

Local Motor Vehicle Registration Fee

In 1990, the California Legislature passed a motor vehicle registration fee increase (Sher-AB 2766), to be assessed to drivers in the South Coast Air Basin, to provide funding for mobile source air quality mitigation programs within that area. Beginning April 1991, an add-on fee of $2.00 per vehicle will be assessed annually, with the fee being increased to $4.00 in 1992. Forty percent of this revenue will be allocated to SCAQMD, 30 percent to local governments on a per capita basis, and the remaining 30 percent toward a "discretionary fund." Any type of project, whether sponsored by government or by the private sector, having some direct connection with air quality would be able to compete for the revenues within this discretionary fund.

It is estimated that with the $4.00 per vehicle fee, by FY 1993-94, *Orange County vehicle registration alone* should generate about $8.3 million towards the discretionary fund. Orange County, however, will not be the sole benefactor of this revenue stream, as the funds will be divided, per legislative formula, to fund both regional and local projects.

With the direct relationship between the TOC and air quality, there should be a strong case for pursuing the discretionary element of these funds. There is also a possibility that authorization will be given to local agencies to increase these fees. Consideration should be given to establishing an annual fee dedicated to supporting continuing operation and maintenance of the TOS.

Opportunity — The funds could be used for any element of the project, especially where a direct benefit to air quality is apparent. Further, given the continuing nature of the funds, opportunities may exist for funding of a portion of the continuing operations costs. This would appear especially appropriate for the elements of tow services, incident management, and traveler information systems.

Constraint — The funding levels are not large, given the likely demands. Also, a clear tie to air quality improvement must be made.

State Funding Sources

State Gas Tax Funds (General)

The state of California levies a gas tax on each gallon of fuel sold. The gas tax is dedicated to transportation improvements, with Caltrans and local agencies as the recipients. The tax has recently been raised from 9 cents per gallon to a programmed 18 cents per gallon. Five cents of the new tax increment is in effect and an additional cent will be added each year until the full value is reached. The new tax increment includes special funding for "TSM" and "Congestion Relief" programs and are discussed separately.

The gas tax fund has classically been the major source of funding for the California freeway system. It is used to "match" federal funds for selected major projects. It is also the funding source for continuing operations and maintenance. Prior to the recent increase, the funds were stretched to the limit to provide continuing operations and maintenance and to match federal funds. Significant cut-backs in Caltrans spending were expected if the new funds were not made available.

As matching funds, the gas tax monies will play a direct role in the implementation of the TOC. Any project financed from federal and/or Measure M sources will be expected to provide the TOS infrastructure needed for that roadway segment. Additionally, under current constraints, the bulk of continuing operations and maintenance costs are likely to come from these funds. (Note that currently federal funds cannot be used for operations and maintenance. However, that may change with the new Surface Transportation Act.)

The gas tax funds are subject to annual budgeting and to a 7-year capital funding plan. The capital funds are administered through the Statewide Transportation Improvement Program (STIP) which is built from project requests at the regional level. Competition for the funds is fierce. With the introduction of the TSM funding program, it is more difficult to receive funding for TOS projects from the general gas tax fund, at least for the capital construction portion.

Opportunity — The gas tax funds are an obvious source of funding for portions of the TOC project and for some or all of continuing operations and maintenance. This is especially true for the elements to be included with major construction projects.

Constraint — Competition for the funds is severe and the availability of the TSM funds makes it more difficult for TOS projects to compete. Even with the increases in the gas tax funds, total funds may be stretched, given all of the projects that are in queue for funding.

Transportation Systems Management (TSM) Program

The recently established Traffic Systems Management (TSM) Program of the gas tax fund seems to hold great promise as a possible funding source. The TSM Program guidelines that were established by the California Transportation Commission (CTC) in October 1989, define the appropriate uses of these funds to be "*those projects designed to increase the number of person-trips which can be carried on the highway system without significantly increasing the design capacity of the highway system...*" According to the CTC guidelines, eligible project types specifically include "*traffic flow improvements such as computerized synchronization of traffic signals and intersection improvements on conventional arterial roads and TV surveillance, computerized message signs, and traffic operations centers on freeways*"; also mentioned are "*traffic metering systems, including meters on freeway on-ramps, freeway-to-freeway connectors, and freeway mainlines.*" Further, "*demonstration projects to implement research and development in the field of traffic operations control systems*" are also identified as an appropriate use.

The California Streets and Highways Code requires Caltrans to submit a TSM plan to the CTC on December 1 of each year. This plan is required to contain a priority list of projects compiled from Congestion Management Programs (CMPs) throughout the state. These CMPs are required to be prepared annually by all counties with at least one urban population center of 50,000 or more persons. Candidate projects are recommended each year by Caltrans' headquarters (from applications submitted through Caltrans' district offices) and funds are awarded through a competitive process, based on availability, need and project merit. *Total annual statewide funding for this program is forecast to be approximately $100 million.*

The TSM program currently operates on a 1-year funding cycle and projects are not required to have been included within the STIP. In fact, because the program was intended to provide for short-term funding, projects that have already been included within the STIP are no longer eligible for TSM funding. In addition, monies *cannot* be awarded to projects which are not yet ready to encumber funds. As a result, when funds are being requested from multiple sources, it is difficult for agencies to coordinate the timing of the receipt of funds from all sources so that they are in a position to receive and *encumber* a TSM funding award. To remedy this situation, in December 1990, the CTC recommended that the California Legislature reorganize existing TSM policies to reflect a multi-year funding program.

TSM funds have been awarded to several projects in Orange County that directly reflect opportunities under this program. Caltrans District 12 has received approximately $0.5 million for the initial stage of the TOC and over $5 million for implementation; the city of Anaheim has received approximately $2.5 million for two projects in the SR-57 corridor and over $3 million for the SR-91 corridor; finally, the city of Santa Ana has received over $5 million for a series of projects which will enable the implementation of an ITMS over a significant percentage of the city.

Much of the city TSM project funds will include the freeway elements of TOS as well as integrated corridor control on the surface streets. Other local agencies applied for TSM funds that would benefit the TOS and may receive funding at a later date. Also, it is expected that Caltrans will continue to apply for funding for the TOS under the TSM program.

Opportunity — TSM funding would appear to be a major source for near term funding of elements of the TOC and should be aggressively pursued. This will be especially important if the TSM funding program moves to a multi-year program, allowing for planned implementation. Funding can apply to all elements of the project.

Constraint — The current 1-year cycle makes it very difficult to plan around the funding. Also, the funding does not appear applicable to operations and maintenance costs.

Flexible Congestion Relief (FCR) Program

As with the TSM Program, the Flexible Congestion Relief Program was established in 1989. CTC guidelines, adopted in June, 1990, identify "traffic flow improvements" as an eligible expenditure under this annual statewide program. Projects are nominated through OCTA, working in concert with Caltrans to complete a Project Study Report defining project scope and costs. No local funding match is required, but because of county bidding limits, very high cost project applications must be shown as being divided into phases. Conceptually, this has already been done within the TOC draft implementation plan. Applicant projects should also be consistent with the RTIP, the STIP, and regional and state air quality management plans. CTC estimates the fund to be approximately $300 million per year.

Opportunity — The congestion relief funding provides some opportunity for use in the TOC program. However, the opportunity appears limited given the availability of the TSM program.

Constraint — The funding for the program is limited and the competition is significant.

Caltrans IVHS Research

Caltrans has received funding to conduct IVHS research projects and has requested proposals from the various districts. District 12 and the University of California-Irvine led a multi-agency team and submitted a program for the region. The project, oriented toward a test bed for IVHS, is receiving strong support and $7 million or more is being considered for funding over a 3-year period. The project includes elements that can support initial operations center implementation and interties to other agencies. The project will also provide some of the TOS infrastructure on the test bed area. Funds could be available as early as July, 1991.

Opportunity — The IVHS research funds are directly supportive of the overall TOC program and would allow for early implementation of critical support elements of the Caltrans traffic operations center. Limited infrastructure can also be provided.

Constraint — The funds are intended directly for research and development application so the majority of the funding will be used in that manner. The impact on the TOS is not substantial in terms of overall cost, however the early funding is significant.

SB 565 (Bergeson)

Under the California Streets and Highways Code, Section 2557, a $1.00 supplemental vehicle registration fee may be imposed on vehicles registered within a county to fund a motorist aid (callbox) system on freeways, expressways and connecting highway routes within that county. This revenue source is currently used to fund Orange County's callbox system.

Senator Bergeson (Newport Beach) has introduced a proposal to *expand the permitted uses of this existing fee* to include traffic operations and safety improvements. The current proposal requires that approval for these ancillary uses would have to be secured from Caltrans and the CHP. Possible candidates for funding would include, but not be limited to, motorist service patrols, changeable message signs, TOCs, and CCTV cameras for traffic surveillance.

Opportunity — It appears that these funds could be used for both the TOC proper and for field equipment (CCTV cameras, CMS, etc.).

Constraint — The initial purpose of these fees was to fund the cellular phone call box system. Until the system installation is complete, it seems unlikely that funds would be diverted to other uses.

Petroleum Violation Escrow Account (PVEA)

Under existing federal law, funds in the Petroleum Violation Escrow Account (PVEA) funds have been dispersed to the state by the federal government and deposited in the Federal Trust Fund. PVEA monies have been used in the past to fund statewide programs to relieve traffic congestion, such as vanpool grants and loans. Existing state law, however, does not provide for Smart Corridor-type optimized signal timing and corridor demonstration projects. Recently specific bills have been formulated to require county transportation commissions, using funds allocated by the CTC, to coordinate Smart Corridor demonstration projects on the state highway system. The bills would further require local transportation commissions to report on these projects to the Legislature.

In the last legislative session, two such bills went before the state senate for the appropriation of over $6 million of these PVEA funds to the CTC for allocation to these corridor demonstration projects. Unfortunately, competition for PVEA funds resulted in only $1 million being allocated, and that to the Santa Monica Smart Corridor project.

Opportunity — Future proposals could be formulated to provide some funds for implementing suitable corridor projects which might include portions of the TOC.

Constraint — Significant competition from the urban counties in the state is to be expected. Because the corridors also include surface streets, some of these monies will be allocated to the cities involved.

Federal Highway Administration (FHWA) Funds

Intermodal Surface Transportation Efficiency Act (ISTEA)

The Highway Trust Fund, administered by FHWA under the Surface Transportation Act (STA), provided a major element of funding for freeway construction. Interstate reconstruction projects include as much as 90 percent FHWA funds and selected traffic management projects are funded at the 100 percent level. In all reconstruction projects, the TOS elements were eligible for funding as part of the project. Special projects covering TOS elements were also eligible for direct funding. Federal funds could also have been used for the TOC. The STA was in effect through September, 1991 and was essentially obligated for current projects in the STIP.

In addition to funding for the freeway projects, the STA included a category of urban funds, generally used for traffic management improvements on local streets. These funds also allowed a preferential match (100 percent) for traffic management projects. This funding base was generally committed by each local agency and would not generally be used for a freeway TOC.

Congress has recently passed the replacement for the STA, the Intermodal Surface Transportation Efficiency Act (ISTEA) and which is a significant departure from the older programs. President Bush signed the act into effect on December 18, 1991.

ISTEA comprises several funding programs ranging from air transportation to research and other papers in this symposium promise to analyze the total act in detail. However, the act includes several sources which are of direct interest to the funding of ITMS:

- Surface Transportation Program
- National Highway System
- Congestion Mitigation and Air Quality Improvement
- Intelligent Vehicle-Highway Systems Research Funds

ISTEA is very promising for projects such as ITMS. Where the federal portion of general matching has been reduced to 60 percent, traffic management projects are at the 90 percent level. Instead of using a "cost to complete" analysis, the new act requires a cost-effectiveness analysis and TOS projects generally score very well in this regard. As agencies will have to develop congestion management plans as part of ISTEA, California agencies will have a head start because of the current state requirements. TOCs are generally seen as an integral part of an overall congestion management plan, further supporting the project.

ISTEA will continue to support major reconstruction projects, such as along I-5 and the TOS infrastructure will directly qualify for funding as part of the projects. ISTEA also considers a new network of "streets of national significance" that will allow direct federal funding on a network of approximately 160,000 miles, with emphasis in urban areas, again an indication that urban congestion will be an emphasis area.

Another major new element of the act is the opportunity to use federal funds for operations and maintenance. The current draft provides for funding of a two year "start-up period" where matching funds would be available. The appears to be some movement to allow continuing matching, at least for the operation of traffic management systems. Although it is too early to tell the final direction, it is likely that some funding will be available, at least for two years of initial operation.

Opportunity — ISTEA continues all of the features of the existing STA relative to TOS implementation and is an obvious source for funding a portion of the project. The new features of the bill make it an even better and more likely source. The opportunity also exists for operations and maintenance support.

Constraints — The act remains non-specific in several areas regarding criteria for funding, assessment of projects and managing agency. This is likely to fuel competition for the funds and promote extensive lobbying efforts.

FHWA IVHS Research and Operational Field Tests

There has been significant interest at FHWA in moving the IVHS program forward. As an indication of this interest, the 1991-92 obligation for FHWA includes $20 million earmarked for research and field testing of IVHS, up from approximately $4 million in the previous year. As part of ISTEA, $94 million for this fiscal year has been appropriated and the amount will increase to $113 million per year in the remaining 5 years of the act.

The special IVHS funding (although part of ISTEA) is not tied to a distribution formula, but will be made available to the most promising projects. The research activities are to be a smaller part of the total, with emphasis placed on actual field observations and test. With Caltrans' strong interest in IVHS and all of the on-going activities in the state, it is expected that California will receive a fair portion of the funds. The work in Orange County offers an opportunity to qualify for a portion of the IVHS funds, especially in areas that are more innovative and technology based. The IVHS funds are not intended to create the basic infrastructure, but to support continuing development.

Opportunity — Funding could be provided for testing of technology, development and testing of innovative features such as expert systems, and related developments. Although the actual funding might not be at a high level of dollars, the added visibility afforded by being a test site increases the attractiveness of the overall program and increases the likelihood of other funds being available.

Constraint — In general, the funds are not intended to replace direct implementation funds and may not reduce the commitments required from other sources.

SUMMARY

Table 1 summarizes the funds that might be used for an ITMS such as the Orange County TOC project. As can be seen from the table it is very likely that a large variety of funding sources will prove applicable to such a program. However, efficient program development and the aggressive pursuit of funds will remain key to the successful implementation of any ITMS.

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Table 1

Source	Use			
	TOC	TOS	OPS	MNTNC
Locally Funded				
Transportation Corridor Agency	✓	✓	●	●
Measure M	●	✓	—	—
SR-91 Privatization	●	✓	—	—
Santa Ana River Viaduct Privatization	●	✓	●	●
OCUTT	—	—	—	—
Vehicle Registration Surcharge	●	●	✓	●
State Funded				
California Gas Tax (General)	✓	✓	✓	✓
TSM Program	✓	✓	—	—
Congestion Reduction Program	●	—	—	—
Caltrans IVHS Research	●	●	—	—
Federally Funded				
ISTEA	✓	✓	●	●
IVHS Research and Field Testing	●	●	—	—

Legend:

✓ = Significant Opportunity
● = Limited Opportunity
— = Little or No Opportunity

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