

GAO

Report to the Chairman, Committee on
Energy and Commerce, House of
Representatives

March 1994

TRANSPORTATION INFRASTRUCTURE

Benefits of Traffic Control Signal Systems Are Not Being Fully Realized



**Resources, Community, and
Economic Development Division**

B-256094

March 30, 1994

The Honorable John D. Dingell
Chairman, Committee on Energy
and Commerce
House of Representatives

Dear Mr. Chairman:

Traffic congestion, particularly in urban areas, degrades air quality, jeopardizes safety, impedes efforts to conserve energy, and results in delays that affect the quality of life. Its adverse effects on the local and national economy are estimated to cost \$40 billion annually. While adding more road capacity can reduce traffic congestion, states and localities can also reduce congestion by implementing transportation control measures, such as improving public transit, encouraging employers to provide incentives for carpooling, and making better use of existing roads with effective traffic control signal systems.

You asked us to evaluate federal, state, and local efforts to use traffic control signal systems to reduce congestion. As agreed with your office, this report discusses (1) the benefits of traffic control signal systems; (2) the problems that state and local agencies face in implementing, operating, and maintaining effective signal systems; (3) the relationship of the current signal systems to emerging technologies like Intelligent Vehicle/Highway Systems; and (4) the role of the Federal Highway Administration in assisting state and local governments with their signal systems through reviews of plans and other means. We also agreed to provide information on related issues that can affect the operation of traffic control signal systems, such as left and right turns on red signals and the practice of running red signals. This information is presented in appendix I.

Results in Brief

Studies by states, local governments, and the traffic industry have consistently reported substantial benefits when localities have installed new traffic control signal systems and upgraded or changed the timing of existing systems. These benefits include reducing accidents, congestion, travel time, fuel consumption, and air pollutants.

Signal systems can provide optimum benefits only when they are properly designed, operated, and maintained. However, states and localities have

experienced problems in these areas that have had an impact on the effectiveness of their systems. In a 1990 review of 24 signal systems, the Federal Highway Administration found that 21 systems did not meet the minimum standards of performance and that some localities were designing systems that were outdated or did not meet their needs. In addition, the Institute of Transportation Engineers estimated in 1989 that 74 percent of the approximately 240,000 signalized intersections in the nation's urban areas needed upgraded physical equipment or improved signal timing.¹ The state and local government officials we contacted said that they often do not have sufficient resources to operate and maintain their systems.

While such problems are preventing the achievement of optimum results today, the implications for the future may even be greater because of the limitations these problems place on new technologies. Signal systems provide data on traffic volume and flow that traffic control centers need to fully utilize many of the emerging Intelligent Vehicle/Highway Systems technologies. If states or localities continue to experience operating and maintenance problems and resource constraints, the benefits anticipated from these technologies may not be fully realized.

Federal Highway Administration headquarters and the regions and divisions we visited are inconsistent in their approach in reviewing state and local governments' operations plans for signal systems and otherwise offering assistance. For example, officials from these offices expressed differing views about whether the plans were required, what the plans should contain, whether plans existed for certain projects, and whether staff had reviewed the plans. The Federal Highway Administration also reported in 1990 that it had insufficient technical expertise at all levels (headquarters, regional, and division) to assist state and local governments with their traffic control signal systems. Our work shows that this situation has not significantly improved.

Background

Under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), increased attention is being paid to congestion management. Under ISTEA, congestion management planning and the development and operation of transportation control measures, such as traffic control signal systems, are eligible for capital funding under the Department of Transportation's National Highway System, Surface Transportation

¹A Toolbox for Alleviating Traffic Congestion, Institute of Transportation Engineers (Washington, D.C.: 1989).

Program, and Congestion Mitigation and Air Quality Improvement Program. According to Federal Highway Administration (FHWA) officials, National Highway System and Congestion Mitigation and Air Quality Improvement Program funds can also be used for operating costs for up to 2 years, while Surface Transportation Program funds can be used for such costs indefinitely. Maintenance costs are not eligible for federal funding and must be borne by the state or local agency. According to FHWA officials, in fiscal years 1991, 1992, and 1993, state and local governments chose to use about \$221 million, \$289 million, and \$503 million, respectively, in federal transportation funds for traffic control signal systems.

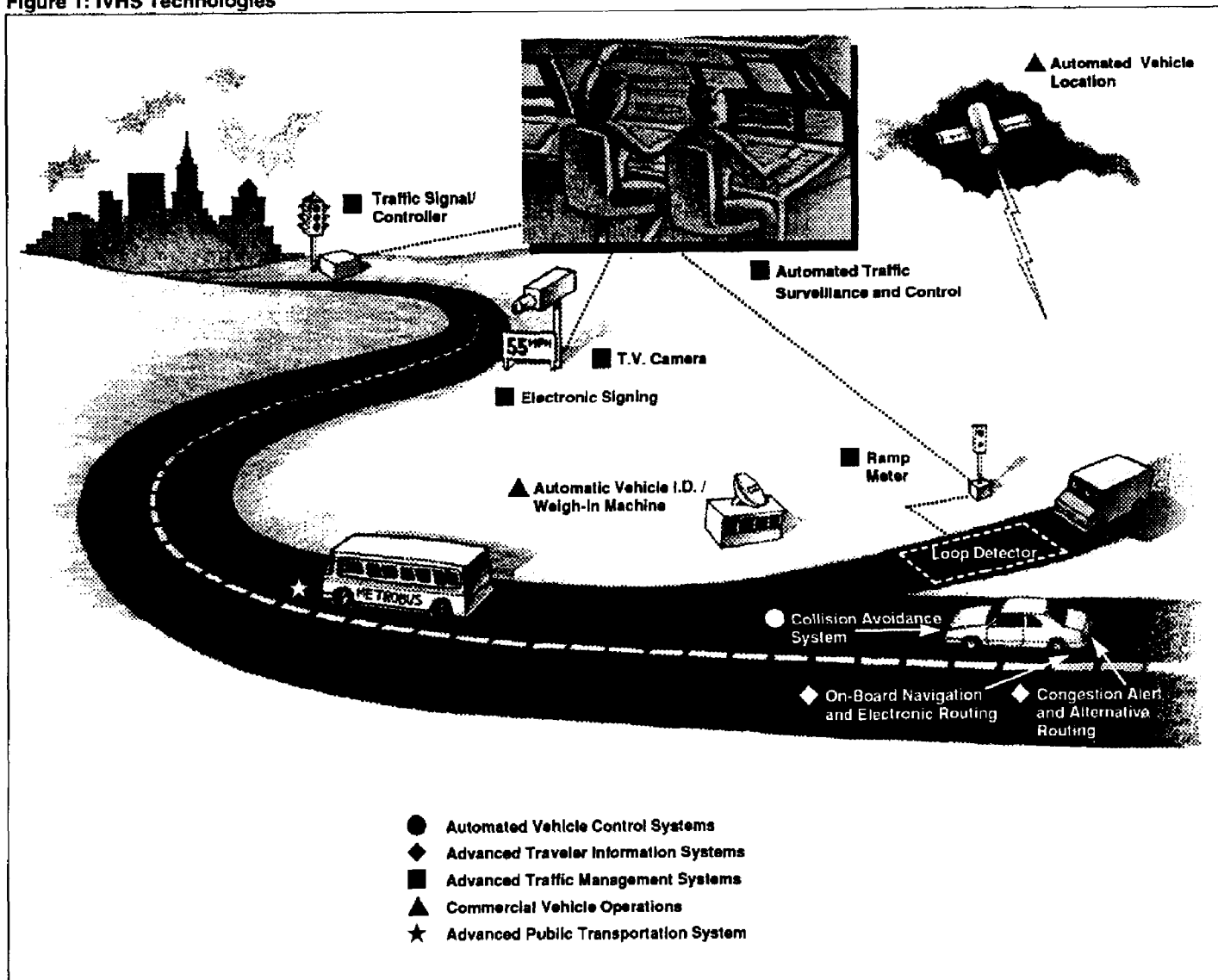
Traffic signal technology is evolving rapidly. While some signals operate independently, many are part of coordinated systems that link signals at several intersections in order to provide progressive traffic flow. Some systems have sophisticated control, surveillance, and communications components. For example, numerous signals can be connected by one or more master controllers (on-street computers) that operate the signals either according to pretimed plans or in response to information about traffic flow detected by devices embedded in the road. Signal systems can also be controlled by centrally located computers that send alternative signal timing plans to the master controllers. Finally, all or a portion of a locality's signals can be controlled by a central computer that communicates continuously with the signals and can change each signal's timing plan periodically or continuously, using information from traffic detectors and other sources.

Current traffic control signal systems form the foundation for emerging Intelligent Vehicle/Highway Systems (IVHS) technologies, which are aimed at addressing the nation's growing travel and congestion problems. IVHS technologies integrate advanced computer, communications, and sensor technologies to improve the flow of passenger and freight transportation. IVHS projects range from automated traffic surveillance and control systems to on-board navigation systems that help drivers plot safe and efficient routes. To further develop these technologies, ISTEA authorized \$659 million for IVHS research and testing in fiscal years 1992-97.

One important component of IVHS, the Advanced Traffic Management System (ATMS), integrates a system of traffic signals, traffic detectors, ramp meters, and a traffic operations center. To minimize traffic delays, ATMS will collect the basic data on traffic flow and conditions needed to make real-time changes to traffic signals, ramp meters, and electronic signs.

Figure 1 illustrates ATMS and other IVHS technologies, and these technologies are further described in appendix II.

Figure 1: IVHS Technologies



Traffic Signal Systems Can Provide Substantial Benefits

Properly designed, operated, and maintained traffic control signal systems yield significant benefits along the corridors and road networks on which they are installed. They mitigate congestion and reduce accidents, fuel consumption, air pollutants, and travel time. These benefits are documented in numerous evaluations, provided to us by FHWA, states, cities, and other sources, that compared before-and-after results when signal systems were installed, expanded, or retimed. Although the results varied because of differences in the base conditions, each evaluation identified positive results and benefits. In fact, an FHWA official told us that in the late 1980s, FHWA eliminated the requirement that a cost-benefit evaluation be submitted for signal system projects receiving federal highway funds because the reported benefits always exceeded the costs, and the studies were becoming redundant.

Several examples illustrate the benefits of traffic signal systems. An analysis of a new signal system implemented in 365 intersections in Orlando, Florida, showed \$2.2 million in fuel savings per year, a 56-percent reduction in both vehicle stops and delays, and a 9- to 14-percent reduction in air pollutants. According to recent congressional testimony by the former general manager of the Los Angeles Department of Transportation, a new traffic control signal system in Los Angeles reduced travel time by 18 percent, signal delays by 44 percent, vehicle stops by 41 percent, fuel consumption by 13 percent, and air pollutants by 14 percent.

Significant benefits can also be realized from upgrading or retiming existing traffic control signal systems. For example, the state of Washington recently completed studies quantifying the benefits of upgrading and coordinating signal control equipment and retiming existing signals for six signal systems. These studies showed annual fuel reductions of 295,500 gallons and annual reductions in vehicle delays of 145,000 vehicle hours. A recent study showed that retiming several Virginia signal systems reduced delays by 25.2 percent, stops by 25.5 percent, travel time by 10.2 percent, fuel consumption by 3.7 percent, and air pollutants by 16 to 19.5 percent.

Improvements to traffic signal systems such as those discussed above usually address only local problems along the roads or corridors where the signals are located. However, problems such as air pollution often extend throughout a region. We reported in August 1993 that all transportation control measures—of which traffic signal system improvements are just one—are projected to reduce total regionwide hydrocarbon and carbon

monoxide emissions by a maximum of 5 percent,² which is considerably lower than the reductions attributed to improved signal systems on specific roads or corridors.

We also reported that market-based transportation control measures—those that impose financial disincentives on automobile users—may be the most effective means of reducing emissions-producing travel. However, localities that consider these measures politically infeasible may have to rely on traditional measures as they devise strategies to control emissions. We reported that metropolitan planning organizations frequently identified improvements to traffic signal systems, from a list of 20 measures, as having the potential to reduce emissions of ozone and carbon monoxide from automobiles.

Several Problems Prevent State and Local Governments From Gaining Maximum Benefits From Signal Systems

Achieving and sustaining the benefits of a traffic control signal system depends on selecting the appropriate system and making the necessary commitment of resources to operate and maintain it over its design life. However, many of these benefits are not being fully realized because of challenges that states—and local governments, in particular—face in designing, selecting, operating, and maintaining their signal systems. For example, some cities do not have the expertise and information needed to select systems appropriate for their needs or do not have the resources needed to operate and maintain the systems for maximum benefit.

FHWA reported in 1990³ and its expert panel of transportation officials reported in 1992⁴ that several county and city governments had limited expertise on complex signal systems. As a result, these counties and cities rely on design consultants for technical expertise. According to FHWA, the consultants also often lack the required expertise or have not kept current with new technologies. To illustrate the need for technical expertise, according to FHWA, 50 percent of the computerized signal systems it

²Urban Transportation: Reducing Vehicle Emissions With Transportation Control Measures (GAO/RCED-93-169, Aug. 3, 1993).

³Operation and Maintenance of Traffic Control Systems, Office of Program Review, FHWA, Department of Transportation (Sept. 1990). This report evaluated the effectiveness of states, counties, and cities in operating and maintaining traffic control systems and the adequacy of FHWA's monitoring efforts.

⁴Expert Panel Report: Traffic Control Systems, Operations and Maintenance, FHWA, Department of Transportation (Mar. 10, 1992). FHWA convened a panel of transportation experts, including consultants and representatives from state agencies, local agencies, and universities, to review the Office of Program Review's 1990 report and make recommendations for improving the operations and maintenance of traffic control systems. The panel made 34 recommendations, 9 of which were designated as priorities.

reviewed were operating with obsolete computers. While some of the computers had been in service for several years, several were obsolete when installed. One city was replacing its computer after 6 months of service because it did not have the speed or memory capacity required for the job. According to FHWA, this lack of technical expertise means that localities incur unnecessary added costs and risk operations and maintenance problems in the future.

The FHWA field officials and state and local officials we contacted corroborated these concerns. Among examples they cited were (1) cities that purchased more sophisticated systems than they needed, (2) cities that tried to implement complex systems they did not have the ability to maintain, and (3) a city that is acquiring a system on the basis of 10-year-old specifications. According to these officials, such instances occur at the local level because of a lack of technical expertise, insufficient staff, budgetary constraints, or burdensome procurement processes.

One way FHWA responded to these issues was to establish, in partnership with private industry, a mobile exhibit on traffic control equipment and software, which has been touring the country for over a year. The exhibit provides information on and demonstrations of state-of-the-art traffic control technology and equipment, and attempts to create an awareness of (1) the significant role signal systems play in traffic management and (2) the need for adequate resources to operate and maintain these systems. This exhibit has been in heavy demand by state and local governments.

Even properly designed systems must be well operated and maintained over their design life if they are to deliver optimum benefits. FHWA's 1990 report disclosed that of the 24 signal systems it reviewed, 21 did not meet minimum standards of performance. The performance deficiencies varied and some systems had multiple problems: 8 of the 24 systems were understaffed for their size, 6 lacked staff who were knowledgeable about the system, 17 lacked documentation on how to run the system, and 7 did not have or did not plan to acquire state-of-the-art equipment. In its 1989 report, the Institute of Transportation Engineers (ITE) also said that traffic signals are often installed with little attention to the cost and procedures required for maintenance. According to the report, the problem has become critical as more sophisticated traffic control devices are installed. ITE estimated that about 74 percent of the approximately 240,000 signalized intersections in urban areas in the United States were in need of

improvements. About 30,000 needed improved signal timing, and 148,000 needed both improved signal timing and upgraded physical equipment.

A significant factor in these performance problems is the difficulty that localities have in obtaining the resources needed to operate and maintain their traffic control signal systems. This concern was expressed in FHWA's 1992 expert panel report and by the majority of the state and local officials we contacted.

FHWA's expert panel reported in 1992 that without new funding mechanisms for operations and maintenance, it was highly possible that the problems being experienced in operating and maintaining the systems will continue to grow worse and that jurisdictions may choose not to proceed with the implementation of advanced traffic control systems. The panel recommended that the provisions in ISTEA making operating costs eligible for federal funding be liberally interpreted to include as many maintenance functions as possible. It also recommended that FHWA work with the American Association of State Highway and Transportation Officials and others to make maintenance eligible for funding under ISTEA. An FHWA official stated that FHWA is, within limits, liberally interpreting the definition of operations in ISTEA. Another FHWA official stated that FHWA has not acted to make maintenance eligible for such funding because the maintenance of transportation projects has generally been the responsibility of the states and localities. FHWA indicated that it will try to solicit input from the association on this matter.

Several state and local government officials told us that in their jurisdictions, traffic control signal systems generally receive low priority for capital and maintenance costs. According to these officials, states and localities prefer more visible projects, such as highways or bridges, and it is easier to get funds for major capital expenditures than for maintenance. ITE reported in 1992 that 35 percent of the state and local respondents to its survey on traffic signal systems indicated that they did not have the necessary manpower to adequately operate and maintain their signal systems.⁵ In addition, the Transportation Research Board reported in 1990 and again in 1992 that state and local governments typically face budgetary constraints in maintaining their traffic signal systems.⁶

⁵Results of the 1991 North American Traffic Signal Inventory, ITE (Washington, D.C.: Jan. 1992).

⁶Traffic Signal Control Equipment: State of the Art, Transportation Research Board, National Research Council (Washington, D.C.: Dec. 1990) and Signal Timing Improvement Practices, Transportation Research Board (Feb. 1992).

The low priority accorded to traffic control signal systems may be changing. In our August 1993 report, we noted that as a result of ISTEA and the Clean Air Act Amendments of 1990, states and metropolitan planning organizations plan to include more traffic control measures (which include traffic control signal systems) in their transportation and clean air plans. Several provisions in ISTEA are expected to encourage greater use of transportation control measures. These provisions include (1) the Congestion Mitigation and Air Quality Improvement Program, which authorized \$6 billion for fiscal years 1992-97 to fund transportation projects that enhance air quality, and (2) the possibility for states and localities to use ISTEA funds flexibly. We reported that while only 8 percent of the metropolitan planning organizations we surveyed in 1992 said that they had strongly emphasized transportation control measures in 1987-92, 56 percent intended to emphasize them strongly in their transportation plans for 1993-98.

Well-Operated and -Maintained Signal Systems Are Vital to IVHS

IVHS projects are intended to have positive impacts on congestion, safety, the environment, energy consumption, mobility, and productivity. However, realizing the benefits of some of these projects will depend in part on having traffic control signal systems in place and functioning properly. These systems provide much of the basic information on traffic conditions that is needed to adjust traffic signal patterns and inform drivers of changing traffic conditions. ATMS—the traffic management system envisioned under IVHS—is more complex than current traffic control signal systems. However, it will include many of the same components as today's signal systems. Unless the level of maintenance is adequate, an ATMS could be rapidly degraded to the operational level of the system it has replaced. As noted above, states and localities already have difficulty finding resources to operate and maintain systems that are less complex.

FHWA's expert panel stated in its 1992 report that deficiencies in the operation and maintenance of current signal systems present an untenable situation for the future of IVHS. The expert panel further cautioned that (1) large investments in new traffic control systems will not fully yield the expected benefits until the existing deficiencies are corrected and (2) these problems will continue and worsen as more complex systems are built. The federal, state, local, and industry officials we contacted also consistently expressed these views.

According to a recent estimate by the Center for Transportation Analysis at the Oak Ridge National Laboratory, deployment of ATMS for fiscal years 1993 through 1997 could cost between \$8.5 billion and \$26 billion for systems in the nation's 75 largest metropolitan areas.⁷ The Center further estimated that operating and maintaining these systems could cost between \$640 million and \$1.76 billion annually. Investments in such systems may be necessary, in part because many existing traffic signal systems were installed in the late 1970s and early 1980s and some of the systems are now functionally obsolete.

With the operation and maintenance of current signal systems already hampered by funding constraints, state and local officials are unwilling or unable to take on greater indebtedness to support the deployment of IVHS technologies, according to a September 1993 report on impediments to the implementation of these technologies, which was undertaken for the Volpe National Transportation Systems Center.⁸ These state and local officials question their ability to support the operation and maintenance of the systems after they have been installed. According to the report, these officials want the federal government to provide both more money and more guidance to ensure successful deployment of ATMS.

FHWA Plays an Important but Changing Role in Traffic Control Signal Systems

In the last few years, FHWA, its expert panel, and our work have identified a number of the problems that state and local governments are experiencing with their traffic control signal systems and with FHWA's role and expertise in this area. FHWA has taken actions to address some of the problems identified, but we found that a number of them persist. FHWA headquarters and the regions and divisions we visited were inconsistent about the appropriate role for FHWA in reviewing state and local governments' signal systems and assisting with these systems. In addition, FHWA's field offices often do not have the technical expertise required to review such systems.

FHWA Has Responded to Some Identified Problems

According to FHWA's expert panel, the 34 recommendations it made in 1992 were aimed at improving the performance of the state and local transportation agencies that are ultimately responsible for operating and maintaining the signal systems. The panel noted, however, that FHWA needs

⁷Cost Estimates for Near-Term Deployment of Advanced Traffic Management Systems, Final Report, Center for Transportation Analysis, Oak Ridge National Laboratory (Oak Ridge, Tennessee: Feb. 15, 1993).

⁸Institutional Impediments to Metro Traffic Management Coordination, Task 5—Final Report, Booz, Allen & Hamilton, Inc., Volpe National Transportation Systems Center, TTD No. RA-2064 (Sept. 13, 1993).

to provide overall leadership in implementing the recommendations. The nine recommendations that the panel identified as priorities primarily addressed the need to develop (1) technical expertise at the state and local levels and (2) standards for the operation and maintenance of signal systems. FHWA was to accomplish this by providing technical information and guidance on the operation and maintenance of traffic control signal systems as well as training opportunities.

FHWA has developed an action plan for addressing the priority recommendations, and FHWA officials informed us that actions have been initiated on at least part of seven of the nine priority recommendations. For example, FHWA has established traffic system support teams consisting of FHWA, state, and local officials in two FHWA regions to assist with traffic control signal systems when requested to by state and local governments. In addition, FHWA contracted with ITE to establish a national clearinghouse for the distribution of current information on traffic control systems. The clearinghouse, a toll free hotline, and an electronic bulletin board are operational. Through these services, ITE provides information on urban traffic engineering technology, traffic control systems, education and training, operations and maintenance, and innovations to address traffic congestion.

Some of the other projects that FHWA has undertaken are behind schedule, and others have not been implemented. FHWA contracted with ITE to develop standards and guidelines for state and local governments on (1) the minimum skills and knowledge required for operations and maintenance functions, (2) the minimum levels of staffing for operations and maintenance functions, and (3) operations and maintenance model plans. According to an ITE official, these projects have been expanded to improve the required products, and, as a result, some required tasks are currently about a year behind schedule. Nevertheless, an ITE official said the projects are expected to be completed by September 1994.

FHWA officials told us that limited resources are hampering their efforts to fully address the recommendations. For example, FHWA has not issued new guidance to its field offices on the need for operations plans, nor has it initiated actions on the nonpriority recommendations. Appendix III details the expert panel's recommendations and FHWA's responses.

FHWA's Role Is Not Well Defined Under ISTEA

Under ISTEA, FHWA's traditional role of performing detailed project reviews has changed to one of providing technical assistance and oversight on

certain projects or oversight at the program level. However, we found that FHWA's role in providing that assistance and oversight has become more confusing since the passage of ISTEA.

Federal regulations (23 C.F.R. 655, subpart D), issued in 1984, call for states and local governments that use federal funds for traffic surveillance and control systems to develop an operations plan that provides for the needed personnel and budget resources required to operate and maintain the proposed system. In its 1990 report, FHWA said that an operations plan is critical to the effective operation of any traffic control system and that not having a well-defined operations plan could lead to staffing and budgeting constraints, resulting in a system that cannot operate as designed. As discussed earlier, states and localities are experiencing these problems. FHWA also reported that on many projects, a number of factors were hindering its input into the design, construction, operation, and maintenance of signal systems. These factors included a lack of definitive guidance on whether the agency had review and approval authority for the projects and whether the requirements for operations plans applied to all of the projects.

FHWA and its expert panel reported that most jurisdictions had not prepared satisfactory operations plans. Furthermore, FHWA field offices lacked a general understanding of the contents of an operations plan and were not strongly enforcing the requirement that one be prepared.

During our review, we found uncertainty among FHWA officials about whether operations plans were required, what the plans should contain, whether plans existed for certain projects, and whether FHWA staff had reviewed the plans. Some FHWA officials told us that the requirements for operations plans were still in effect for all projects receiving federal funds. Others told us that they could no longer require plans from "certification acceptance" states⁹ or states that have declared themselves exempt from FHWA's oversight, review, and administration under provisions in ISTEA.¹⁰ Still others told us that they had been unsure for some time whether operations plans were required or optional. Nevertheless, some FHWA officials said they intended to encourage states to prepare the plans by relying on the good working relationships they had with the states.

⁹"Certification acceptance" states are those that can carry out some of the oversight functions normally performed by FHWA for certain projects once FHWA has accepted the states' certification that their regulations meet federal requirements.

¹⁰All projects except those costing over \$1 million and those on the National Highway System may be exempted from FHWA's oversight, review, and administration.

During the course of our work, we reviewed information on 43 traffic control signal systems to determine whether they had operations plans. We were only able to confirm that 10 jurisdictions had such a plan or were in the process of developing one. The other 33 jurisdictions either did not have a plan or the respondents could not confirm that a plan had been prepared.

Many of the FHWA, state, and local officials we contacted agreed that it made sense to develop operations plans. However, in their view there is insufficient federal guidance on the conditions under which plans are required, what the plans should contain, and how much detail they should include.

FHWA Has Limited Technical Expertise

None of the seven division offices that FHWA visited for its 1990 report believed they had adequate technical expertise to review the design or construction of traffic control signal systems. As a result, FHWA's Administrator assembled a task force of field personnel to examine the level of technical expertise in this area within FHWA. In March 1991, the task force reported serious shortcomings in staffing and technical expertise on signal systems in FHWA headquarters, regions, and divisions.¹¹ According to the report, the focus of the highway construction program continues to change from constructing new highways to optimizing the efficiency of existing systems. The report further said that new programs such as IVHS will expand the use of sophisticated traffic control systems and that the staffing of FHWA must be adjusted to provide the expertise necessary for FHWA to assume a leadership role in traffic operations.

Our visits to FHWA regional and division offices disclosed that some FHWA field offices had taken actions to strengthen the staff's technical expertise in this area. Officials at several regional offices reported that they were using more people with traffic system experience and/or sending their area engineers to traffic operations training programs. One region had reorganized to bring together traffic signal systems and IVHS work, had created traffic engineer positions in its divisions, and was giving more attention to traffic operations.

FHWA headquarters officials could not provide us with detailed information on field office staff members' expertise on signal systems or the extent to which staff members are being trained as traffic engineers or urban traffic

¹¹Traffic Control Systems, Operations and Maintenance, Internal FHWA Task Force Report, FHWA, Department of Transportation (Mar. 1991).

specialists. However, officials in 6 of the 10 field offices we visited told us that their offices do not have sufficient technical expertise to review signal systems. Signal systems plans are thus often sent from the division to the regional office for review and then to headquarters if the region does not have the expertise. However, several division and regional officials pointed out that headquarters has only one person to help review systems. In their view, additional staff with the required technical expertise in this area would benefit the FHWA field offices as well as the states and localities. Headquarters officials agreed that they could use more staff but said they had been unsuccessful in obtaining any. Many of the regional and division office staff we contacted stated that expertise within FHWA was needed because most localities lacked this expertise and were in need of information on the rapidly advancing technologies. However, their views varied on whether divisions, regions, or headquarters should have this expertise.

Conclusions

Traffic control signal systems are among the many tools for managing traffic congestion in urban areas. Systems that are appropriately designed and properly operated and maintained provide safety improvements, reduce travel times and vehicle operating costs, and lower fuel consumption and vehicle emissions. They will also form one of the essential components of future Intelligent Vehicle/Highway Systems aimed at addressing growing urban traffic congestion. However, many state and local governments have experienced problems in designing, operating, and maintaining their systems. Our work is consistent with studies by the Federal Highway Administration and its expert panel showing that the full benefits of the current network of traffic control signal systems are not being realized.

While state and local jurisdictions have primary responsibility for their traffic control signal systems, the Federal Highway Administration also has an important role to play in ensuring that the federal funds used for these systems are wisely invested and that the systems deliver the anticipated benefits over their design life. The agency recognizes that it needs to assist state and local jurisdictions with their signal systems and has developed an action plan to improve its efforts in assisting the jurisdictions. However, a number of the actions are behind schedule or have not been initiated. In addition, the agency's field offices are inconsistent about their proper role in providing this assistance, particularly their role in requiring states and localities to prepare operating plans that lay out the future resource needs of their signal systems. The

field offices often do not have the technical expertise needed to assist the states and localities with their signal systems.

Until the Federal Highway Administration clarifies the role of its field offices, issues guidance on the preparation of operations plans, and develops the necessary expertise, the current and future benefits of traffic control signal systems and several emerging technologies may not be fully realized.

Recommendations

To better assist states and localities in designing, implementing, operating, and maintaining traffic control signal systems, we recommend that the Secretary of Transportation direct the Administrator of the Federal Highway Administration to

- identify critical activities in relation to signal systems that require the agency's oversight and assistance;
- develop the expertise needed to carry out this role and assist the states and localities with their traffic control signal systems; and
- develop guidance for its field offices defining the conditions under which operations plans are required, the content of operations plans (particularly their provisions for the systems' long-range resource requirements), and the review that field offices are to undertake to ensure that the plans are adequately prepared.

Agency Comments

We discussed the information in this report with officials of FHWA's Office of Traffic Management and Intelligent Vehicle/Highway Systems, including the chiefs of the Traffic Management Systems Division and the Traffic Management Branch, and officials from other FHWA offices. They generally agreed with the facts presented, and we incorporated their comments where appropriate. They stated that FHWA was giving increased attention to traffic management operations and attempting to improve expertise in this area at FHWA and in states and localities. They also pointed out that they have prepared draft guidance for their field offices on operations plans and that this guidance should be issued shortly. Finally, they told us that FHWA is now finalizing a follow-up review to its 1990 study on the operation and maintenance of traffic control signal systems and that the findings of this review are consistent with the information presented in this report. As requested, we did not obtain written agency comments on a draft of this report.

Scope and Methodology

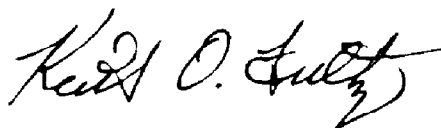
We conducted our work from November 1992 to February 1994 in accordance with generally accepted government auditing standards. To determine the benefits of traffic control signal systems, we reviewed cost-benefit studies prepared for FHWA by cities receiving federal funds for their signal systems and cost-benefit studies supplied to us by states, cities, and traffic consultants.

To determine what problems states and localities are encountering with their traffic control signal systems, the relationship between the signal systems and IVHS technologies, and FHWA's role, we reviewed reports by FHWA, its panel of transportation experts, and an internal FHWA task force. We also reviewed files maintained by FHWA headquarters and field offices on traffic control signal systems and interviewed (1) officials from FHWA headquarters and 10 field offices, (2) transportation officials from 6 states and 10 cities, and (3) officials from transportation organizations and consulting companies. We also visited five traffic control centers. (See app. IV for a list of the organizations we contacted.) Finally, we reviewed reports and other documents prepared by FHWA and other organizations on the design, operation, and maintenance of traffic control signal systems and the development and deployment of IVHS technologies.

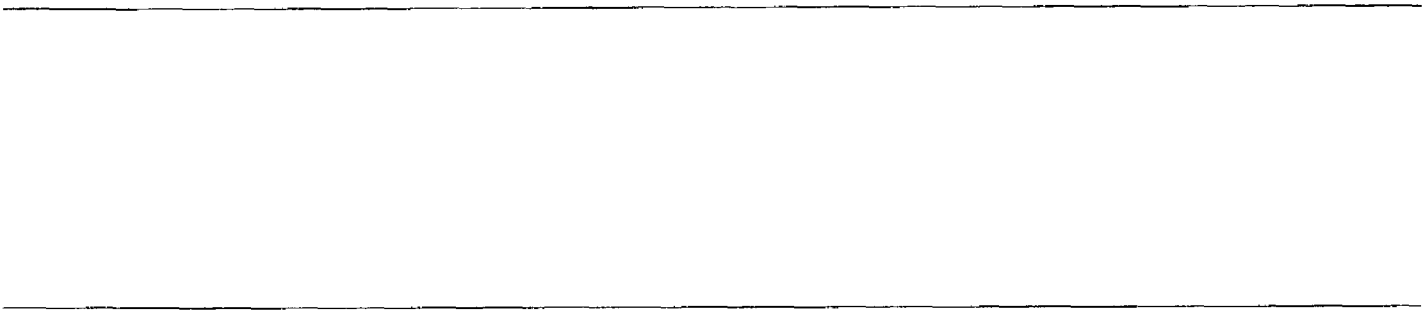
As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to interested congressional committees, the Secretary of Transportation, and the Administrator of FHWA. We will also make copies available to others on request.

This work was performed under the direction of Kenneth M. Mead, Director, Transportation Issues, who can be reached at (202) 512-2834 if you or your staff have any questions. Major contributors to this report are listed in appendix V.

Sincerely yours,



Keith O. Fultz
Assistant Comptroller General



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Figure 1: IVHS Technologies

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Abbreviations

APTS	Advanced Public Transportation System
ATIS	Advanced Traveler Information System
ATMS	Advanced Traffic Management System
AVCS	Advanced Vehicle Control System
CVO	Commercial Vehicle Operations
FHWA	Federal Highway Administration
ISTEA	Intermodal Surface Transportation Efficiency Act
IVHS	Intelligent Vehicle/Highway Systems
ITE	Institute of Transportation Engineers

External Issues and Practices Affecting Traffic Control Signal Systems

Traffic signal systems have become a critical element in the safe and efficient control of traffic flow on the nation's streets and highways. The primary objective of improving traffic flow is to enhance the efficiency of the existing roadway system and to alleviate traffic congestion and related problems, such as air pollution. However, traffic control signal systems are affected by a number of factors external to their operation and maintenance, such as jurisdictional issues, right and left turns on red signals, and traffic violations such as running red signals. All of these factors can hamper the effective coordination of a signal system.

Jurisdictional Issues

Treating the transportation network as a single system in a metropolitan area requires the cooperation of federal, state, regional, and local agencies as well as numerous other groups. Many transportation officials insist that new partnerships and coalitions will be needed to ensure the future success of traffic control signal systems, particularly those that cross jurisdictional boundaries.

FHWA officials in one area cited an example of an arterial system that should handle more traffic coming off a saturated interstate highway. However, the arterial system is not operating optimally because of resistance from the local jurisdictions that control the operation and maintenance of their own signals. According to these officials, the jurisdictions design and operate the traffic control systems for their own constituents rather than taking a regional view of traffic management.

Sometimes the potential threat of legal liability prevents jurisdictions from cooperating in installing, connecting, or adjusting the timing of traffic signals. FHWA cited an example of one local agency that was unwilling to connect a local signal to the adjacent state system for fear of potential lawsuits that might result from malfunction of the state's master control equipment. FHWA pointed out that while it recognized the local agency's concern, this kind of resistance makes congestion problems more difficult to resolve.

FHWA's expert panel has pointed out that artificial boundaries often impede coordinated traffic management at the interfaces between state and local systems and between local systems. Urban and local organizations responsible for the management of traffic control signal systems need to know who is in charge and whether the responsible entity has (1) the ability to monitor local traffic and (2) the human and financial resources needed to operate and maintain the system. FHWA's expert panel stated that

the implementation of more complex Intelligent Vehicle/Highway Systems traffic management strategies, such as route diversion, may not be feasible until the fragmentation of jurisdictional authority is corrected.

Permitting Right and Left Turns on Red Signals

Permitting right turns on red signals after a stop was adopted as an energy conservation measure during the energy crisis of the 1970s. The Energy Policy and Conservation Act (P.L. 94-163), enacted in 1975, directed the states to adopt right turns on red and provided for the loss of energy funds as a penalty for states that did not do so. Before that date, some western states had already adopted right turns on red. To avoid confusion and ensure uniformity, in 1976 the Department of Transportation ruled that states were required to follow the "generally permissive" form of right turns on red, permitting the practice at all intersections unless there are signs forbidding it.

Implementation of left turns on red is much more diverse among the states. According to an FHWA official, at least 41 states allow left turns on red onto one-way streets in some form, such as allowing such turns from either one- or two-way streets, allowing them from either one- or two-way highways, or various combinations of the above.

Traffic Violations Related to Signals

Red signal violations can have far-reaching effects beyond the obvious ones of being dangerous and against the law. Violations of left- and right-turn-on-red rules and the practice of running red signals defeat the purpose of well-timed and coordinated traffic signals. The problem of running red signals has become so serious that in some areas the local jurisdiction has resorted to all-red sequences (changing all the signals at an intersection to red for a few seconds before returning one direction to green) to avoid accidents. At least one jurisdiction has decided to replace several hundred signals with stop signs.

According to some transportation officials, violations of left- and right-turn-on-red rules, like the practice of running red signals, have become detrimental to the safe and efficient operation of their signal systems. Most state officials we talked to believe that both problems are the responsibility of local law enforcement agencies. Officials recognize, however, that police forces are shorthanded or have more pressing duties.

It is difficult to obtain statistical data, especially data on deaths and injuries related to such violations, on a national basis. However, the

Appendix I
External Issues and Practices Affecting
Traffic Control Signal Systems

Insurance Institute for Highway Safety conducted a study of police reports for 4,526 crashes in Akron, Ohio; New Orleans, Louisiana; Yonkers, New York; and Arlington County, Virginia in 1990-91. They reported that running red signals and other traffic controls (stop-and-yield signs, for example) was the cause of the most frequent type of crash in an urban area, amounting to 22 percent. Also, data collected for 1992 by the National Center for Statistics and Analysis indicated that there were 1,076,000 accidents at junctions with traffic signals. Of those accidents, 149,000, or about 13.8 percent, involved drivers' being charged with running a traffic signal. In addition, the 1991 report for the Department of Transportation's Fatal Accident Reporting System indicated there were 2,218 fatal crashes at intersections with traffic signals, amounting to about 25.4 percent of all fatal crashes at intersections. Of these, 2,031 fatal crashes occurred at intersections in urban areas, representing about 37.4 percent of all fatal crashes at urban intersections. As previously mentioned, these figures do not reflect associated deaths or injuries or reveal the detrimental impact of accidents on existing traffic conditions.

States and localities are not ignoring the problem of running red signals. Among other things, they have tried or considered the following techniques in an attempt to reduce violations: (1) lengthening clearance intervals between red and green signals, (2) increasing fines for violations, (3) using cameras to detect violators, (4) implementing all-red intervals, (5) increasing public awareness campaigns, and (6) increasing spot enforcement.

For some time, other countries have used cameras at intersections to photograph violators. This technique has been used in England and Israel but does encounter some resistance in the United States because of privacy issues.

For the past several years, the Metropolitan Washington Council of Governments has sponsored an annual 3-week "Respect Red" campaign to increase public awareness and step up law enforcement efforts against signal violations. In 1993, 20 participating law enforcement agencies issued a total of 6,389 citations during that 3-week period, 707 of which were for violations of right-turn-on-red rules.

The Energy Policy Act of 1992 (P.L. 102-486), requires the Administrator of the National Highway Traffic Safety Administration to conduct a study on the safety impact of permitting left and right turns on red signals. The report is due in October of 1994.

Intelligent Vehicle/Highway Systems Technologies

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) established the Intelligent Vehicle/Highway Systems (IVHS) program under the Secretary of Transportation. IVHS has evolved to include five major system areas, each focusing on one application of IVHS technology to the needs and opportunities of highway systems. While the five are developing along different time lines, each offers early opportunities for deployment of individual elements. Over time, the five will become more interdependent and evolve into a fully integrated system. These five areas are described below.

Advanced Traffic Management Systems (ATMS)

ATMS permits real-time adjustment of traffic control systems and variable message signs to advise drivers of road conditions. Its application in selected corridors has reduced delay, travel time, and accidents. ATMS components include coordinated signaling systems, video surveillance of corridors, ramp metering, automated toll collection, and variable message signs.

Advanced Traveler Information Systems (ATIS)

ATIS involves the acquisition, analysis, communication, presentation, and use of information to assist the surface transportation traveler in moving from origin to destination in the way that best satisfies the traveler's needs for safety, efficiency, and comfort. Travel may involve a single mode of transportation or linked, multiple modes. ATIS lets travelers know their location and the location of the nearest services. ATIS permits communication between travelers and ATMS for continuous advice on traffic conditions and alternate routes. Additionally, ATIS provides the driver with safety warnings.

Commercial Vehicle Operations (CVO)

CVO makes use of those features of ATIS that are critical to commercial and emergency vehicles. CVO expedites deliveries, improves operational efficiency, improves response to incidents, and increases safety. Many of the technologies used in CVO are already available in the marketplace. Automatic vehicle identification devices are available to allow the electronic transfer of funds so travelers can pay tolls without stopping. Satellite technologies are available to track the location of individual vehicles as an aid to fleet management. Weigh-in-motion technology, combined with automatic vehicle classification, is available to sort vehicles for weight inspections. On-board computers are available to monitor truck performance.

**Appendix II
Intelligent Vehicle/Highway Systems
Technologies**

**Advanced Vehicle Control
Systems (AVCS)**

AVCS includes vehicle- and/or roadway-based electromechanical and communications devices that enhance the control of vehicles by facilitating and augmenting driver performance. Examples are speed control systems, which are currently available, and radar braking, a future technology under consideration.

**Advanced Public
Transportation Systems
(APTS)**

APTS works in conjunction with ATMS to provide mass transportation users and operators (e.g., buses, van pools, high-occupancy vehicle—HOV—lanes, car pools, taxi cabs) with up-to-date information on the status, schedules, and availability of public transit systems. Automatic vehicle location and monitoring systems provide information to improve fleet management and better inform riders of their connections. New HOV priority schemes using IVHS technologies will be devised and monitored automatically to enforce rules on the use of HOV facilities.

FHWA's Progress in Responding to Recommendations in the Expert Panel's Report

In 1991 FHWA convened an expert panel of state and local traffic engineering experts to review and analyze problems with traffic control systems that FHWA had identified in a September 1990 report. FHWA's expert panel issued its report on March 10, 1992 and recommended a comprehensive package of 34 recommendations. If implemented, these recommendations should correct the problems noted in the 1990 report and provide the basic level of traffic control system operations and maintenance that will be required for the more demanding IVHS environment. Nine recommendations were considered pivotal to the success of the entire IVHS program. The nine priority recommendations (2 of the 34 recommendations were combined into one priority recommendation) are described below, along with the current status of FHWA's response. In addition, the remaining recommendations awaiting FHWA's action are listed.

Priority Recommendations

1. "Establishment of the necessary rules and procedures under the ISTEA as may be necessary to allow the use of Federal gas tax funds for operations and maintenance work on state/local traffic control systems."

Status: FHWA worked with the Congress during the development of ISTEA so that federal funds could be used more flexibly for operational improvements. According to FHWA officials, federal funds can be used for operating costs for up to 2 years for National Highway System and Congestion Mitigation and Air Quality Improvement Program projects; funds can be used for such costs for an unlimited time under the Surface Transportation Program. An FHWA official stated that FHWA is, within limits, liberally interpreting the definition of operations in ISTEA to include as many maintenance functions as possible. He added that FHWA has not acted to make maintenance eligible under ISTEA because maintenance of transportation projects has generally been the responsibility of the states and localities.

2. "Development of minimum standards for the skills and knowledge required for operations and maintenance functions."

3. "Development of guidelines for minimum levels of staffing and appropriate job classifications for the operations and maintenance functions."

4. "Development of operations and maintenance guidelines and model plans."

Status: FHWA took action on these three recommendations by contracting with the Institute of Transportation Engineers (ITE) to develop (1) minimum standards for the skills and knowledge required for operations and maintenance functions, (2) guidelines for minimum levels of staffing for operations and maintenance functions, (3) operations and maintenance guidelines and model operations plans. However, according to ITE, these projects have been expanded to improve the desired products and as a result, some required tasks are currently about a year behind schedule. ITE officials said the projects are expected to be completed by September 1994. FHWA also plans to issue guidance to its field offices on the need for operations plans for traffic control signal systems. In February 1994, FHWA officials told us that draft guidance had been prepared and final guidance should be issued shortly.

5. "Development of design guidelines for traffic control systems that consider operations and maintenance requirements and related long term costs."

Status: During 1995, FHWA plans to reissue a previous publication that contains design guidelines for traffic control systems that consider operations and maintenance requirements and long-range costs.

6. "Establishment of a national clearinghouse for distribution of current information on traffic control systems."

Status: FHWA also contracted with ITE to establish a national clearinghouse for the distribution of current information on traffic control systems. This clearinghouse data base is to include information on operations and maintenance problems and solutions based on user experience. The clearinghouse, a toll free hotline, and an electronic bulletin board have been established and are operational. An ITE official told us that these services are being used extensively and that ITE is obtaining information from clearinghouse users and FHWA to improve the data base and its usefulness.

7. "Development of new and/or revised National Highway Institute courses covering operations and maintenance of traffic control systems." [The National Highway Institute is an FHWA organization that administers scholarship and fellowship grant programs to assist state and

local agencies and the FHWA in developing transportation expertise and programs.]

Status: During fiscal year 1994, three new courses covering the operation and maintenance of traffic control systems are to be available to FHWA, state, and local officials. In addition, in order to inform state and local governments of the best current traffic control technologies and their applications, FHWA established a mobile exhibit on traffic control equipment and software that has been touring the country since 1992. The exhibit covers state-of-the-art traffic control technology and equipment used at signalized intersections. A 2-day workshop and demonstration is given to interested parties.

8. "Establishment of a Task Force to develop updated FHWA procurement regulations."

Status: FHWA has not established the recommended task force to review and update FHWA's procurement regulations for traffic control systems because of staff limitations and time constraints.

9. "Facilitate the formation of Regional Traffic Management Committees to provide for improved inter-jurisdictional coordination and technology transfer."

Status: Traffic system support teams consisting of FHWA, state, and local officials were established in two FHWA regions. These teams will assist state and local governments with their traffic control signal systems on request. FHWA's goal is to have teams in all the regions by fiscal year 1995.

**Remaining
Recommendations**

10. "As a supplement to the National Highway Institute, University Extension type short courses related to traffic control systems should be developed at the Regional University Transportation Centers and other interested universities. National Highway Institute course material should continue to be made readily available to universities for this purpose."

11. "The FHWA should consider the development of selected self-instruction courses in videotape and/or CD-ROM format."

12. "Establishment of a certificate program [for traffic control systems] administered by the FHWA for completion of a specified series of courses would be desirable."

**Appendix III
FHWA's Progress in Responding to
Recommendations in the Expert Panel's
Report**

13. "Establishment of a training program in which selected staff are temporarily assigned to established Control Centers would provide 'hands-on' experience under actual operating conditions."
14. "Establishment of one or more simulated traffic Control Centers would provide for training under semi-realistic conditions as well as [a] lower cost means of testing new operational concepts prior to actual implementation."
15. "The FHWA in conjunction with state and local agencies should encourage Universities, especially the University Transportation Centers, to establish within their transportation engineering curriculums credited courses which will provide basic and advanced information about the operations and maintenance of state-of-the-art traffic control systems."
16. "New budgetary procedures which will provide a more assured flow of funding for training purposes need to be developed at the state and local levels."
17. "With the advent of IVHS and more technically complex traffic control systems, it is essential that the FHWA reassert its leadership role in the area of technology transfer through the distribution of useful current information to operating agencies."
18. "The FHWA should give a high priority to establishing new routing procedures for distribution of technical information on traffic control systems."
19. "New modes of information distribution such as computer bulletin boards and E-mail should be considered."
20. "The FHWA should organize a pool of experts that could be drawn on to assist state and local agencies with specific operations or maintenance questions."
21. "The FHWA should take the lead in organizing workshops and user groups on traffic control systems."
22. "The FHWA should increase the size of its Equipment Quality Assurance Program in order to enable more frequent [site] visits."

**Appendix III
FHWA's Progress in Responding to
Recommendations in the Expert Panel's
Report**

23. "The FHWA should consider using its Rural Technical Assistance Program as a model for technology transfer of information on traffic control systems."

24. "The FHWA should establish close liaison and coordination with the professional organizations that have direct ongoing contacts with the end users of traffic control systems."

25. "State and local agencies should be required to develop operations and maintenance staffing plans for new traffic control systems projects in order to qualify for federal funding."

26. "State and local agencies should take the leadership role in the Regional Traffic Management Committees."

27. "To facilitate regional coordination among multiple jurisdictions, one or more traffic control centers should be identified in each metropolitan area. These centers will be operated by the larger more capable transportation agencies. The FHWA should develop model interagency agreements for this purpose."

28. "The FHWA should take the lead in developing presentations and workshops for those professional groups that should have some knowledge of current and future developments in traffic control systems, but are not within the community of direct users."

29. "To the extent possible, responsibility and accountability for the operation and maintenance of traffic control systems should be placed in an unitary organizational structure under one manager."

30. "The FHWA should allow operational test systems to be deployed using innovative procurement techniques such as design/build in order to assess their effectiveness."

31. "The FHWA should take the necessary steps to insure that there is consistency in the administration of system procurement among the regional and division offices."

32. "The FHWA should take the lead in developing generic standards, protocols, and interface requirements for various elements of advanced traffic control systems with a view to reducing design, implementation, operations and maintenance costs."

**Appendix III
FHWA's Progress in Responding to
Recommendations in the Expert Panel's
Report**

33. "In order to better monitor the funding support for the operations and maintenance of traffic control systems, these functions should become line items in state/local budgets."

Organizations Contacted

Federal Agencies	Federal Highway Administration headquarters and Regions 3, 4, 5, and 10 Federal Highway Administration Divisions in Maryland, Georgia, Virginia, Florida, Illinois, and Washington National Highway Traffic Safety Administration
State Transportation Departments	Florida Georgia Illinois Maryland Virginia Washington
Cities	Atlanta, Georgia Bellevue, Washington Chicago, Illinois Orlando, Florida Peoria, Illinois Portland, Oregon Renton, Washington Richmond, Virginia Seattle, Washington Washington, D.C.
Traffic Control Centers	Orlando, Florida Richmond, Virginia State of Maryland Department of Transportation State of Washington Department of Transportation Washington, D.C.
Organizations and Companies	Concurrent Computer Corporation Farradyne Systems, Inc. Frederic R. Harris, Inc. Institute of Public Policy, George Mason University Institute of Transportation Engineers Insurance Institute for Highway Safety Metropolitan Washington Council of Governments National Electrical Manufacturers Association

**Appendix IV
Organizations Contacted**

**Ron Goodin & Associates, Inc.
Sonex Corporation
Science Applications International Corporation
TRW Transportation and Support Systems**

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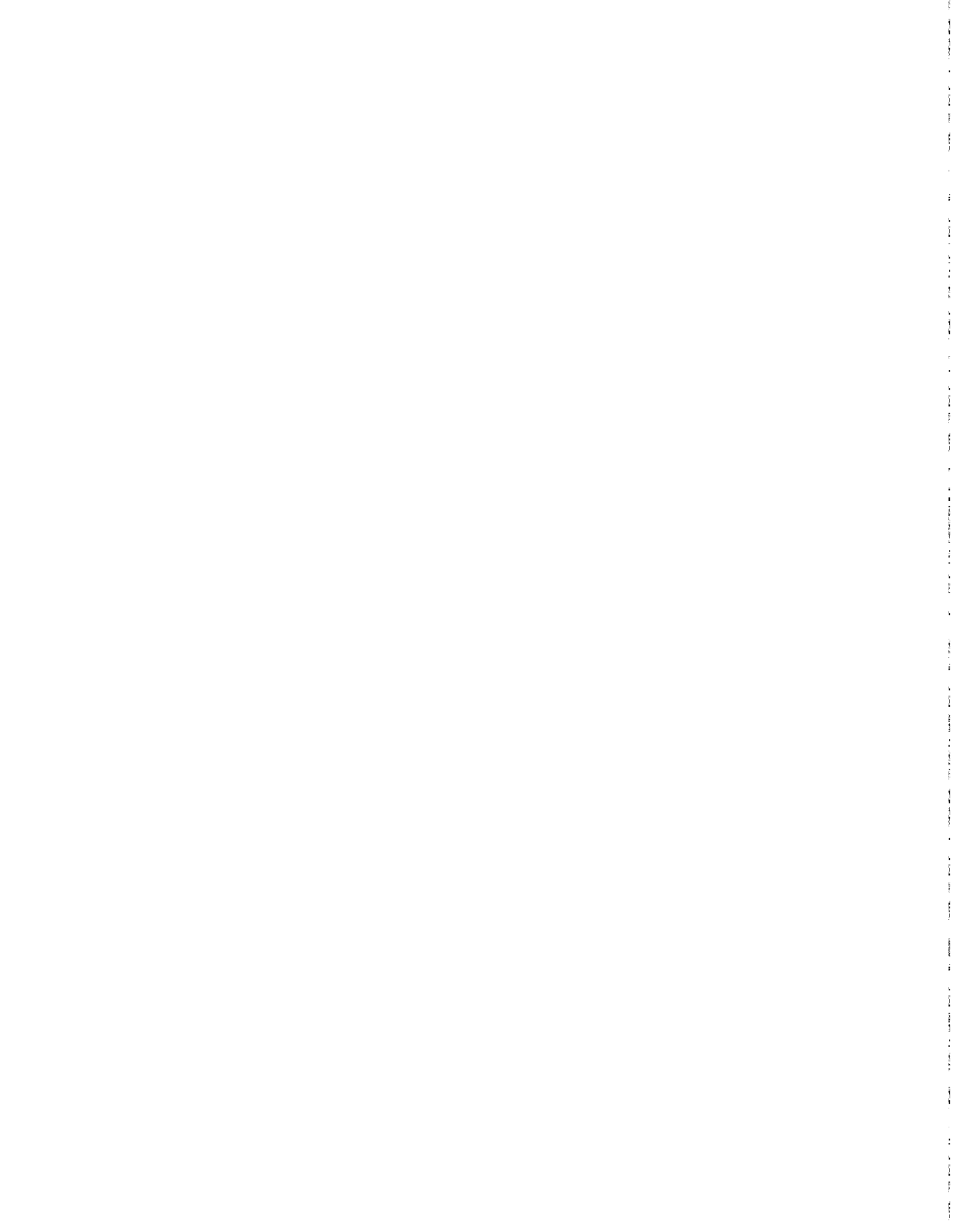
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