CHAPTER 9
CONCLUSION

It is generally agreed that advanced transportation management concepts begin with the collection and interpretation of surveillance information. The term surveillance has been used in the highway terminology for almost 50 years and denotes the observation of conditions in time and space. Thus, without reliable, credible, and/or real-time surveillance information, there will be no way to draw valid conclusions on which to make correct transportation management decisions.

Although the Measures of Effectiveness (MOE) of transportation management decisions have been primarily the reduction in traffic delay and accidents, concerns for environmental quality and energy consumption have become a part of these MOEs. Consequently, the interpretation of surveillance has been expanded to include the observation of traffic, travel, and environmental conditions in time and space. This interpretation is consistent with the l-95 Corridor Coalition' s goals and activities derived from its adopted mission. As stated in the l-95 Corridor Coalition' s 1994 Business Plan, the Coalition will strive to:

+ "Enhance the capabilities of transportation agencies within the Corridor to effectively manage non-recurring incidents which disrupt the transportation system. Improve environmental quality in the Corridor through reduced traffic congestion and other factors that contribute to mobile-source emissions to help achieve conformity with the federal air quality standards established as a results of the Clean Air Act."

+ "Cooperatively develop and assist in the operation of an inter-regional traffic and travel information network, focusing primarily on communicating traffic, construction, incident, and weather information. Using the current ITS technologies, the system would provide trip planning and real-time information to motorists and to public transit users at home, on the road, and in major activity centers (e.g., employment centers, shopping centers, etc.)."

+ Transform the l-95 Corridor into a showcase of ITS technologies through the use of advanced technologies for integrated, adaptive, and real-time traffic control strategies for both arterial and freeway management control, and for providing in-vehicle traffic information and route guidance. Establish the Corridor as an operational test bed to evaluate other ITS technologies as they evolve."

+ Foster cooperative relationships among all involved transportation organizations to address issues of information gathering and sharing, joint procurement, joint funding, and other areas of mutual interest in meeting the transportation needs and environmental goals of the Corridor."

The above Coalition' s goals and the described interpretation of surveillance have served as the guiding principles for the work accomplished in this SFUT Project. These principles again provide a framework for the recommendations to be described in this concluding chapter of the Report. As a prelude to the recommendations, a brief summary of task accomplishment and findings is presented in the next section.

9.1 PROJECT SUMMARY

This SFUT Project has seven tasks with the last one being the development of the project Report. It began with a survey of Coalition member agencies (Task 1) to identify the primary goals for the Corridor-wide surveillance system and to obtain a consensus opinion on the most mutually important system objectives. The candidate system goals and objectives included in the survey were developed from a multi-modal transportation system context, a multi-jurisdictional and operational context, a federal legislative context, and a functional and technology context. The survey results (discussed in Chapter 2 of this Report) have shown the following relative importance of the surveillance system goals (in descending order):

+ Enhance traffic incident management.

+ Enhance real-time traffic control operations.

+ Enhance traffic management during snow storms and other emergencies.

+ Improve multi-modal and inter-modal transportation operations.

+ Support Traveler Information Services.

+ Enhance the transportation systems planning database.

+ Facilitate Travel Demand Management strategy implementation.

+ Support traffic law and regulation enforcement.

The above relative importance of the system goals provides a perspective of the needs of the Coalition. This perspective has been used to aid in the development of the recommended Field Operational Test (FOT) program and an evolutionary surveillance system deployment. The results of this survey have also indicated that the member agencies will likely continue to use inductive loops as a primary means of traffic detection, though there is a strong indication that radar and image processing technologies will be employed in the future.

Another survey (Task 2) was conducted concurrently with the goals and objectives survey to identify surveillance systems that are existing or under development by Coalition member agencies. To support this identification, data on the types, scope, costs, usage, and operational effectiveness (qualitative) of surveillance systems (traffic, weather, and environmental) were collected. Also collected were data on communication systems supporting the surveillance functions. The results of this survey are provided in Chapter 3 of this report.

Out of the 26 agencies surveyed, 21 responses were received (which is 81 percent), making the inventory database incomplete. Furthermore, some data items requested on the survey forms (such as the mileage of roads that is covered by a surveillance system) were either missing, unavailable, or ambiguous (e.g., a total number of sensors was given for both incident detection and ramp metering). Given that this is an incomplete database, the following summary is provided only for illustrative purposes.

+ Approximately 630 miles of the Corridor-designated roads were reported as being presently covered by about 4000 traffic detection devices (inductive loops and radars). In addition, there are about 2700 existing traffic detection devices without reported mileage covered.

+ Approximately 504 miles of the Corridor-designated roads were reported as being planned for deployment of about 3400 traffic detection units (inductive loops, radars, video image processing systems, and AVI systems). it was unclear from the reported data whether or not some of this road mileage overlaps with the existing one.

If one assumes that the density of traffic detector (units per mile of road) would be uniformly distributed throughout the road network, and that the planned deployment of traffic detection systems would not overlap with the existing systems, then the estimated existing and planned

surveillance coverage would be about 1600 miles. This mileage of coverage is approximately 30 percent of the Study Team' s estimated Corridor-designated road mileage of 5400 miles. This leaves a large portion of the Corridor-designated roads uncovered by electronic surveillance. Although electronic surveillance gaps exists, the results of this survey and those of Project #2' s (Incident Management) Resource Inventory have shown that human surveillance is used extensively by Coalition member agencies. However, detailed information on geographic coverage of human surveillance (such as mileage and frequency) was not available during the course of this study.

With respect to surveillance system costs, data received from the survey varied widely and did not have a sufficient sample size. This makes it very difficult to compare the cost and effectiveness of different surveillance technologies. The cost data variation may be attributed to three reasons. First, existing surveillance systems have evolved through many years and their component costs have changed significantly. Second, costs were usually available at the system levels, making it very difficult and time consuming for the responding agency to break the costs down to the component level. Third, system costs depend on the design characteristics; and since different agencies have different system designs, the resulting cost estimates varied.

In Task 3 of this Project, a broad range of surveillance and communications technologies were reviewed and assessed. The surveillance technology assessment (presented in Chapter 4) covered three major categories of surveillance; traffic detection, environmental conditions sensing, and weigh-in-motion. Each of these categories includes a number of technologies as shown in Table 9-1.

The focus of the assessment was primarily on the advantages and disadvantages of each technology in terms of performance, installation and maintenance requirements, communications requirements, as well as any potential issues related to public acceptance of the technology. Although there is a wide range of potential traffic detection technologies (both point and wide-area surveillance systems), specific information on their performance, cost, and deployment experiences was very limited (especially for emerging technologies such as radar, IR, and video image processing), making it very difficult to draw any specific conclusion. The main reason for

Table 9-I. Surveillance Technologies Reviewed In This Project

TRAFFIC SURVEILLANCE	VEHICLE WEIGHT SENSING
inductive loop detectors	Bending Plate Systems
Magnetic Detector and Magnetometers	Shallow Weigh Scales
Sensing Cable, Pressure Plates and Bending Plates	Deep-pit Weigh Scales
	Bridge Weighing System
Infrared/Photoelectric detectors	Capacitive Systems
Acoustic detectors	Piezo-electric Sensors
Microwave radar detectors	Fiber-Optic Sensors
Vehicle probes (AVI/ETTM, and AVL)	ENVIRONMENTAL CONDITIONS SENSING
Video vehicle detection systems	SCAN (Surface Conditions Analyzer)
CCTV	LIDAR (Light Detection And Ranging)
Aerial Surveillance	HANDAR™

this lack of information is the fact that many traffic surveillance systems are being tested and validated through operational tests and, in some cases, actual deployment. A major source of surveillance technology assessment information is the current “Detection Technology Study for IVHS” study sponsored by FHWA. This study, however, was coming to a conclusion at about the same time as that of this S&T Project; therefore, the study’ s field test results were not available to be included in this Report.

From the literature reviewed for the technology assessment task of this Project, concerns about public acceptance of some new technologies were mentioned. These concerns center around the potentially negative public reaction to increased exposure to electromagnetic radiation. The potential health hazards of such exposure may only be a perception, but need to be addressed to ensure public support of ITS.

Despite the lack of information to draw any specific conclusion on traffic surveillance technology, the survey of Coalition members has shown a strong endorsement for and satisfaction with human surveillance techniques such as police patrol, freeway service patrol, and motorist call-ins. It is therefore recommended that such surveillance techniques be continued and enhanced using appropriate supporting technologies. The technology review has indicated a number of technologies (e.g., AVL and two-way data and voice communications) that may be used in human surveillance to accurately notify and locate incidents. These technologies are proven and should be considered for enhancing traffic incident management operations.

Building upon the knowledge gained from the previous three tasks, the Study Team developed a set of surveillance system requirements and a conceptual system design in Task 4. The results of this task were documented in Chapters 5 and 6 of this Report, respectively. The requirements cover many aspects of the l-95 Corridor-wide Surveillance System, including operational and functional requirements, communications and interface requirements, and hardware and software requirements. The functional requirements were developed based on the system goals and objectives identified through the survey of the Coalition member agencies. These requirements cover the following eight primary functions that are necessary to support the system goals and their associated ITS services:

+ Monitoring traffic conditions, including incident.

+ Monitoring road weather conditions and their effects on driving conditions.

+ Monitoring air quality.

+ Monitoring road hazards.

+ Monitoring travel security.

+ Monitor parking facilities.

+ Monitor transportation law adherence.

To support the conceptual system design, the above functions were decomposed into lower-level functions with their inputs, outputs, and inter-relationships identified. The complete set of functions obtained from the decomposition process form a surveillance system requirements model, upon which an operational responsibility framework for participating agencies was built. Because of the geographic characteristics of the Corridor, the conceptual system design was developed for both urban roads and rural roads. In either case, the conceptual system design emphasizes the integration of surveillance information from multiple sources and the use of multiple technology types (including both point detection and wide-area surveillance).

With this conceptual system design, cost estimates for the Corridor-wide Surveillance System were developed in Task 5 of this Project. The emphasis of this effort was not to provide the Coalition with a number representing an estimate of the required investment in the Corridor-wide

Surveillance System but, more importantly, the assumptions and rationale leading to such a cost estimate. The Study Team felt that a cost estimate methodology would be of more value to the Coalition than just a number because of the following reasons:

+ Many surveillance products begin entering the ITS market, causing their prices to change rapidly.

+ New technologies with improved performance are expected to enter the ITS market as more and more companies are seeking new market for their products. The Coalition should have the flexibility to replace old technologies with new ones to meet its needs; and this requires an ability to revise the cost estimates.

+ A individual Coalition member agency may want to implement the conceptual system design in its jurisdiction according to its local needs, which might result in a different set of equipment to be deployed and different costs.

To accommodate the above possibilities, a tool for cost estimation was developed and used in estimating the total surveillance system cost. The cost estimate assumptions and results are contained in Chapter 7 of this Report. In Chapter 7, six scenarios for cost estimation were described. The resulting cost estimates are summarized in Table 9-2.

Table 9-2. System implementation Cost Under Various Scenarios

Scenario	Description	Cost, million $
1	Optimum Approach (full implementation)	2,299
2	Minimal Approach (full implementation but with less CCTV and AVI coverage)	2,171
3	Minimal Approach (Scenario 2 with no ramp control)	2,022
4	Minimal Approach (Scenario 2 with no ramp control and roadway condition sensors)	1,998
5	Minimal Approach (Scenario 2 with no ramp control, roadway condition sensors, and WIM)	1,976
6	Minimal Approach (Scenario 2 with no ramp control, roadway condition sensors, WIM, and air quality/weather	1,957

The last task of the Project is to develop a Business Plan for the Corridor-wide Surveillance System (i.e., Task 6 as described in Chapter 8 of this Report). The Business Plan describes the principles and issues for public/private partnerships in ITS that have been learned from efforts conducted in the Corridor and elsewhere in the country. It also described the potential opportunities for such partnerships in the Corridor as summarized in Table 9-3.

Table 9-3. Potential Public/Private Partnership Opportunities in Surveillance

Category	Opportunities
Information service providers	Cooperative efforts to gather traffic surveillance information.
Defense/Aerospace electronics firms	Application of defense sensor technologies in transportation systems surveillance (e.g., traffic, pavement, and environmental).
Communication companies	Communication services and infrastructure development, especially for rural areas.
AVL service providers	Vehicle probe data collection and incident detection services.
Fleet operators	Exchange of probe data and traffic condition information.

The potential public/private partnership opportunities and challenges were incorporated in the design of a recommended Corridor-wide surveillance FOT Program as described in Chapter 8. The Program consists of the nine projects which account for three key considerations of a Corridor-wide surveillance system; technology, institutional and organizational arrangement, and multi-project integration. Out of the nine projects summarized below, the Region-wide Information Integration Project provides the mechanism to tie all other projects together and serves as a catalyst for integrating other I-95 Corridor Coalition projects into a seamless Corridor-wide ITS.

1. Project S.1: Region-wide Information Integration. Its objective is to create and validate a mechanism for fusing surveillance data from multiple sources and organizations. The data will be supplied by systems of other FOT projects or agencies, and by the existing surveillance assets. The fused data will be available for use by all ITS applications (e.g., TIS, CVO, and Incident Management).

   Project S.2: Service Patrol Vehicle Probe Integration. In this Project, AVL and two-way communications equipment will be installed on service patrol vehicles. The

vehicle location data provided by the AVL system will be used to support incident management and vehicle fleet management functions, while the vehicle tracking data will provide probe information for surveillance. The result of this test will help to determine the feasibility to expand the service patrol operations Corridor-wide.

3. Project S.3: Cellular Telephone Traffic Probe Integration. If the currently tested system in the Washington, D.C. area is technically feasible, this recommended test will focus on the technical and institutional data integration issues for a Corridor-wide deployment of the system.

4. Project S.4: Transit Vehicle Probe Integration. Many transit properties in the Corridor use or plan to use AVL technologies to track their vehicles. For those that travel along the Corridor-designated roads, their tracking data may be used as probe data in surveillance. The purpose of this FOT project is to test the integration of transit vehicle probe data with other surveillance data and to assess opportunities to enhance inter-modal coordination.

5. Project S.5: Public/Private Surveillance Information Exchange. This project is to assess the feasibility of collaborating with private organizations that collect traffic surveillance data for their ITS services. Besides the technical feasibility, institutional issues regarding public/private partnership will be examined.

6. Project S.6: Multi-Sensor Surveillance Aircraft. The purpose of this recommended FOT is to assess the feasibility of using a multi-sensor surveillance aircraft for regional traffic surveillance, including its ability to complement other land-based traffic surveillance systems.

7. Project S.7: Aerostat Traffic Surveillance. This system has a similar sensor suite as that of the multi-sensor surveillance aircraft and can provide continuous, long-range surveillance coverage. The purpose of this project is to assess the feasibility of the aerostat surveillance system and its complementary aspects to other systems.

8. Project S.8: “Wide-Area” Land-based Radar Sensor. This sensor technology offers a larger surveillance coverage compared to many existing point detection systems. Its output may be used to detect traffic congestion and accurately determine congestion locations. The purpose of this project is to test the feasibility of this radar in both urban and rural conditions.

9. Project S.9: Road Weather Information Integration. Road weather information systems (RWIS) are currently in use by many member agencies. The purpose of this test is to assess the feasibility of using RWIS data, combined with other traffic surveillance data to generate wintry travel advisory information.

Using this brief summary of the project accomplishment and findings as background information, the Study Team would like to make the following recommendations to the l-95 Corrfdor Coalition.

9.2 RECOMMENDATIONS

The continuation of work for the Surveillance Requirements/Technology project will encompass operational tests of surveillance technologies and the commencement of deployment of surveillance systems toward the realization of the Coalition's objectives. To support this continuation, a number of recommendations are made as summarized below.

The Study Team' s recommendations are organized under three major headings:

+ Immediate Actions.

+ FOT Implementation Process.

+ Deployment Preparation.

Under each heading, the Team' s specific recommendations are described and the rationale for the recommendations provided.

9.2.1 Immediate Actions

I-95 Corridor ITS Architecture

The development of an ITS architecture for the I-95 Corridor Coalition is recommended. This architecture shall provide a framework for integrating all relevant I-95 CC Projects that are already defined or to be defined based on the vision set forth by the Coalition.

To achieve the vision of the Coalition for the transportation system in the l-95 Corridor, each of the Coalition's projects, from the Information Exchange Network to the Corridor-wide Decision Support System, must be tied together within an overall system architecture to form a functioning, cohesive system. The Corridor-wide surveillance system, whose functional requirements and conceptual design were developed for this project, provides the information required by the majority of the other projects of the Coalition. As such, it may be considered the foundation for the overall system architecture.

The l-95 Corridor Coalition ITS Architecture should be based on the identified Coalition' s projects which represent the various ITS capabilities envisioned for the Corridor. It should incorporate the features of the National ITS Architecture that are relevant to the needs, partnership framework, and operational environment of the Coalition. Finally, it should contain a framework for integrating the Corridor-wide ITS functionalities with those that are being developed or will be developed for many jurisdictions within the Corridor through the current ITS early-deployment initiatives.

Region-wide Information Integration Prototype

A prototype of the proposed Region-wide information Integration System (Project S.1) is recommended. This prototype serves as a means to further explore the potential technical and institutional issues of the Corridor-wide Surveillance System.

The recommended Region-wide Information Integration system is a common platform for launching various Corridor-wide transportation management and traveler information services requiring surveillance information. It is thus critical for the proposed Operational Test S.1 of this system to succeed. By prototyping this system before the commencement of the actual operational test, the following benefits may be realized:

+ Many of the specific integration issues (both technical and institutional) may be resolved in advance of committing the level of effort and funding required for conducting the field operational test. The resolution to such issues would enhance the success of demonstrating the benefits of ITS to the public, and of the beneficial partnership with the Coalition to potential private partners.

+ The scope and requirements of a test bed for advanced technology evaluation and validation may be realistically defined. A realistic definition of those requirements will provide long-term benefits to the Coalition because the resulting test bed will be used to support not only the currently recommended projects but also others as they evolve. As one of the priority corridors identified by the USDOT, the I-95 Corridor is intended to "provide a long-term site for multiple operational tests and serve as a showcase for implementation of IVHS technologies."

+ The risk of relying on the availability of new technology would be minimized because one aspect of the prototype is the integration of existing technologies according to the recommended system design concept - that is, the use of old technologies with new operational concepts (information integration).

Consensus Building for System Requirements and Conceptual Design

A consensus building effort among Coalition member agencies on the recommended Corridor-wide Surveillance System is recommended. This consensus will pave the way toward a successful system deployment.

Since the work of the next phase will be built upon the system requirements and conceptual design established in this Project, Coalition member agencies should develop a consensus with respect to specific objectives and features for the Corridor-wide Surveillance System. The system requirements, conceptual design, business plan, and recommendations embodied in this Report have been developed in accordance with the stated objectives of the member agencies, solicited early in the project. Now that those stated objectives have been translated into a "vision" for the system, a consensus on this vision would be an endorsement for the Coalition to proceed to the next phase of the Corridor-wide surveillance system development.

Formulation of Surveillance FOT Program Plan

The development of a detailed Surveillance FOT Program Plan is recommended. This Plan shall address the issues of where, when, and how each recommended Surveillance FOT Project may be implemented.

As the effort to develop a Corridor-wide Surveillance System progresses toward the field operational tests, there needs to be a Program Plan to ensure their successful implementation. In Chapter 8 of this Report, a plan was proposed for the implementation of the recommended FOT Projects. This plan, however, could only address the technical issues of the Program but not the programmatic and administrative ones, which should be addressed by the Coalition. To complete the Program Plan and set the best course for FOT projects to proceed, there are many questions for which answers will be required. These questions relate to the nature of the Coalition and the partnership principles upon which it was founded. Examples of such questions are:

+ Which operational tests should be performed? In what order? When? Where in the Corridor?

+ How much money would the operational test require? How much money should be allocated to the operational test?

+ How much "good" would the proposed operational test do? For whom?

+ Who (which agency) should manage it?

+ How would the test system be integrated into the system to be deployed?

Answers to these questions will be required to properly select and conduct the recommended operational tests to ensure the fulfillment of the Coalition' s objectives.

9.2.2 FOT Implementation Process

Functional Requirement-Specific FOT Solicitations

> *It is recommended that FOT solicitations for specific groups of functions of the Corridor-wide Surveillance System be prepared. This would allow potential respondents to understand* the *system' s requirements and propose creative solutions to meet* the *Corridor' s needs.*

The operational test concepts proposed in this Report are intended to demonstrate systems and technologies which will satisfy the functional and operational objectives of the Coalition. The

operational tests also serve to validate specific aspects of the system design. To fulfill this purpose, FOT solicitations should clearly state the Coalition' s surveillance objectives and needs to allow industry sources to respond with creative technological solutions.

Transition from Surveillance System Concept to FOT

It is recommended that a mechanism be in p/ace to bridge the gap between the surveillance system requirements and the potential capability of the technologies to be evaluated and validated in the field operational tests.

To ensure the continuity in the system development cycle, there is a need to provide a complete transition from concept development to field operational testing. This need may be fulfilled by having members - who are intimately familiar with the surveillance system requirements, and the needs and concerns of the Coalition - participating in the planning, design, and possibly evaluation, of the FOTs. Such participation would greatly help exploiting the full potential of a technology as well as providing the insight necessary for product improvement.

9.2.3 Deployment Preparation

Identification of Critical Areas for Coverage

A study that identifies and assesses critical areas requiring surveillance coverage in the Corridor is recommended.

The ability to provide the correct solution to a problem requires a thorough understanding of the problem. Although an attempt was made in this Project to determine the availability of the existing surveillance system to support a Corridor-wide operation, the data gathered was not sufficient to provide a thorough understanding of this problem. Since there are so many operating agencies involved in the Corridor, a dedicated study to defining the surveillance needs (in terms of facilities and traffic conditions) is necessary for system deployment planning. The facility needs should encompass both the physical surveillance coverage and the operational status of the existing systems. As discussed earlier in the Project Summary, specific information of human surveillance coverage in the Corridor still needs to be gathered from the agencies. This is also true for traffic conditions data (historical and projected).

Technology Selection

Continual monitoring and periodic assessment of surveillance technologies are recommended. Particular attention should be paid to wide-area surveillance technologies because they may provide cost-effective solutions to meet the Corridor' s needs.

Although a variety of surveillance technologies are available today, many of them are being tested and validated through field operational tests and actual deployment. Thus, information on new technologies found during the course of this Project was insufficient to make any specific recommendation to the Coalition. Because many of these tests and studies will be completed in the near future (e.g., the FHWA' s detection Technology Study, the cellular vehicle probe FOT, and the aerostat surveillance system test) and new studies initiated (e.g., FHWA/JPL Surveillance Technologies Study), their progress and results should be reviewed periodically for Corridor-wide applications. In addition, technology assessment should be a continuous process and should keep up with the rapid evolution of technology. New technologies can greatly influence the conceptual design and their assessment throughout the project life, from system design to its deployment, can provide insight to improve the surveillance system.

System Cost Database Update

The cost database produced in this Project is recommended to be refined and updated periodically. This database will be useful in future cost analyses of the Corridor-wide Surveillance System as the Coalition moves toward deployment.

A lesson learned from this SR/T Project is that to gather surveillance system cost data is difficult, and to obtain consistent cost data from multiple sources is even more difficult. It is therefore necessary for the Coalition to have a common cost database for use in system deployment planning and budgeting. The database and cost analysis tool provided in this Report is the first attempt toward achieving this goal. The database needs to be refined and updated based on the experiences of individual Coalition members, and on new information (e.g., operational test results, deployment experiences) as it evolves.

9.3 CLOSING REMARKS

System development is a continuing process and evolves over the entire duration of a system. The work accomplished in this Project represents only one of the many steps in this development cycle. Because the conception of the Corridor-wide Surveillance System is based on the partnership principles of the Coalition, the initial steps in the development cycle become even more important to achieve consensus among Coalition members, which is essential for the system development to move forward. With this understanding, the Study Team has striven to provide a total system view of the Coalition' s surveillance needs, and the methodology and assumptions leading to the products specified in the Project' s Scope of Work. This approach, the Study Team felt, is necessary for the Corridor-wide Surveillance System to evolve into the 21st Century.