APPENDIX B TRANSPORTATION AGENCY MAINTENANCE PLANS

This appendix highlights the six transportation agency plans that were reviewed for this maintenance plan.

B.1 Metropolitan Area Plans

The literature review indicated that the most extensive maintenance planning for ITS has been done in metropolitan areas. This section analyzes four plans based on metropolitan areas, produced through the California Department of Transportation (Caltrans), the Washington State Department of Transportation (WSDOT), the Minnesota Department of Transportation (Mn/DOT) and a plan developed for the national ITS architecture. The first three plans were designed specifically for existing systems, whereas the fourth plan is intended as a blueprint to identify the resources necessary to maintain new ITS infrastructure deployments in a variety of regional settings.

B.1.1 Caltrans District 7

The Caltrans document forecasts the operations and maintenance requirements for the Traffic Operation System (TOS) and Transportation Management Center (TMC) in Los Angeles and Ventura Counties (6). The plan predicts maintenance costs over a ten-year period (1996-2006), with annual requirements gradually increasing as new elements are added to the system. The report evaluates maintenance for TMC hardware and support, as well as the following ITS devices.

- Closed-Circuit Television (CCTV) Cameras
- Variable Message Signs (VMS)
- Ramp Metering
- Vehicle Detection Systems
- Highway Advisory Radio (HAR)
- Changeable Message Signs (CMS)
- TOS Communication System

The Caltrans plan emphasizes the importance of maintenance documentation to track, document, and budget future maintenance tasks. Once a problem in the ITS system is identified, a "trouble ticket" or job control number is opened with information on the problem including a general description, and the part of the system it concerns. An appropriate support group is then assigned to systematically make repairs, documenting all equipment and repair time requirements. The Caltrans plan divides maintenance management into five staffing support groups responsible for specific maintenance categories:

- field support engineers, who are trained on field equipment and responsible for corresponding scheduled and unscheduled maintenance activities;
- system engineers, who are responsible for technical support, and maintenance of the TMC computer system;

- TMC users/operators, who are responsible to report difficulties/problems in the system, thus preventing breakdowns;
- technicians, which "consist of the electrical maintenance workforce"; and
- contract staff, who are responsible for contracted maintenance activities.

In addition to these support groups, the plan describes two seven-person technician teams who are responsible for communications and TOS/TMC terminal equipment and twisted-pair, coaxial, and fiber optic cable maintenance, respectively. While each support group is assigned a specific responsibility, frequently they are required to collaborate to maintain certain ITS elements.

Maintenance is divided into categories of scheduled maintenance and unscheduled maintenance. Both preventative maintenance and repair maintenance are included in each of these categories. Preventative maintenance is considered primarily a scheduled maintenance activity, although it is also included in the unscheduled maintenance category. For example, if a repair takes place at a given site a technician might also perform preventative maintenance at the same site. Repair maintenance is primarily an unscheduled maintenance activity that is prioritized in order to organize backlogged maintenance tasks. Tasks are divided into four priority levels.

1. Immediate response including overtime and after-hours call-back
2. Requires early attention should be undertaken by next work day
3. Requires early attention should be undertaken within 72 hours
4. Should be undertaken within one month

All repair and preventative maintenance tasks are prioritized on the basis of public safety, traffic service, preservation of facility/operational integrity, and general appearance of equipment to the public.

The plan recommends that some of the maintenance responsibilities be provided by contractors, due either to the specialized nature of some sub-systems or because of manpower limitations. Training is recommended for tasks regularly performed, but Caltrans would rely on outside support if the cost of training is deemed greater than contract/vendor support. The manufacturer generally covers failed components for the local area network and computer, and replacement of these components is not the responsibility of Caltrans staff. For equipment not covered by manufacturer warranty, the plan includes an extensive list of parts that should be kept in stock along with specialty tools that may be necessary.

Once responsibility for maintenance tasks was established, the Caltrans report determined scheduled and unscheduled maintenance support costs for each element based on the required hours of labor, travel time, spare parts and agreements, training, tools, and test equipment necessary to maintain each of the system devices. The combined labor costs (derived from assumed labor salaries), and maintenance support costs were then totaled to determine the required funding for the entire Caltrans system per year over the given ten-year period. This plan acknowledges that the costs of the Caltrans system will rise as elements approach their expected life, however, does not examine the associated replacement costs.

The Caltrans report addresses many of the same goals as the ODOT ITS plan, and provides a sound methodology for estimating maintenance budgets. As a regional plan, however, it makes assumptions about travel time that would not be as applicable to a statewide plan. It also does not provide much information on how personnel will be trained to perform maintenance activities.

B.1.2 Washington State Department of Transportation – Seattle area

The Surveillance, Control, and Driver Information (SC&DI): Implementation and Operations Plan outlines the ITS system operated by the Washington State Department of Transportation (WSDOT) for metropolitan Seattle (7). This plan was written for WSDOT as an SC&DI system expansion guide, and "also to allow other agencies to observe the progress on the system." The subsystems used and analyzed in the SC&DI system are:

- surveillance, including vehicle detection system, CCTV cameras, computer aided dispatch (CAD), scanner, and Northwest Region Radio Dispatch;
- control, including ramp meters; and
- driver information, including VMS, HAR, commuter information telephone line, Internet, and direct access to the central computer.

The WSDOT report outlines its recommended maintenance model within this document, describing maintenance tracking and documentation procedure. WSDOT uses a fundamental three-step tracking procedure.

1. Report the problem.
2. Verify and repair the problem.
3. Log the maintenance activity.

Traffic Systems Management Center (TSMC) operations staff and SC&DI maintenance personnel perform the majority of the repair maintenance tasks within this system. To ensure a "smoothly operating system," WSDOT emphasizes the importance of "direct contact between the SC&DI engineers and the maintenance technicians." All performed maintenance activities are logged into a Microsoft Access database where they can be used for forecasting future maintenance needs and costs, and for tracking system problems.

System maintenance has been divided into two categories: preventative maintenance and repair of malfunctions, or repair maintenance. While WSDOT affirms the importance of preventative maintenance, it recognizes that most preventative maintenance does not follow any given schedule. In general, preventative maintenance is performed while a technician is at the location for repairs on another system. For this reason, WSDOT keeps accurate records of preventative maintenance as it is performed to avoid duplicating maintenance tasks unnecessarily. This report included a table of the ideal frequency for preventative maintenance activities on each of the given ITS devices.

To avoid slow repair of malfunctions on crucial equipment, each of the given ITS components is prioritized in this plan according to the amount of time necessary to make a repair, and the importance of the ITS equipment. The document lists recommended response times for each device. To further increase efficiency of repairs, spare parts are stored for ITS

components that frequently are in need of repair, and an inventory is kept for reordering information.

The plan lists the staff required to adequately operate the TSMC, and their respective monthly salaries. The staff includes freeway operations, SC&DI operations, flow, and software engineers, as well as flow operators, computer programmers, and traffic system operations specialists. Unfortunately, the relationship between maintenance tasks discussed and the tabulated staffing levels required to perform these tasks is not provided in this document. WSDOT offers maintenance training for technicians to learn software and equipment used in the ITS system, so that staff can further their ability to perform system repairs. When enough interest is shown in additional training classes, WSDOT provides the class for its staff, either directly or indirectly through other institutions.

The maintenance and personnel costs are provided along with power, phone and vehicle costs to determine the total monthly cost of operating and maintaining the SC&DI system. The estimate for SC&DI maintenance costs, including parts, labor, and equipment, is $115,000 per month or $1,380,000 annually, which is expected to increase as preventative maintenance is incorporated into maintenance procedures. Personnel costs are determined using average hourly salaries. This plan assumes that all new or planned ITS equipment will be on line by the year 2000. The procedures for bringing new equipment on line are suggested in this report, so that SC&DI system failure will not occur due to faulty equipment.

ODOT staff has identified this report as a good model for ODOT's ITS maintenance plan. Indeed, the SC&DI plan provides clear maintenance procedures, preventative maintenance schedules, and budgets. It does not, however, establish a clear relationship between the number and type of device deployed, and the maintenance staff needed to maintain them.

B.1.3 I-494 Corridor – Minneapolis area

The Integrated Corridor Traffic Management (ICTM) Project is a federally-funded advanced technology implementation test designed to demonstrate improved traffic along the Interstate 494 corridor in Minneapolis/St. Paul. The ICTM Maintenance Plan report was submitted to the I-494 ICTM Operations Committee to describe the maintenance roles and responsibilities of the agencies participating in the ICTM project [6]. This maintenance plan reviews the maintenance requirements of the following ICTM/ITS systems and devices:

- CCTV cameras,
- emergency vehicle signal preemption systems,
- ramp meters,
- video detection systems,
- loop detectors,
- traffic control signs (fixed & portable VMS, route guidance, static signs),
- HAR signs,
- signal controllers,
- hardware interconnect systems,
- fiber optic communications systems, and
- twisted pair cable.

Because several agencies are involved in the ICTM project, each incoming system error is monitored by a system operator who notifies the appropriate agency of possible system failures. The agency then dispatches the on-call technician to repair the failed system, at least temporarily, and log the repair activities performed and further repair requirements. This work log is then faxed to the system operator who tracks future activities to ensure the problem is rectified. The final results of maintenance activities are logged and kept on record.

Maintenance activities are divided into preventative, critical, and non-critical maintenance tasks. This report gives a limited list of required maintenance tasks on traffic signal components, CCTV and Autoscope (video detection) equipment. For other devices, the ICTM maintenance plan requires agencies working on the ICTM project to incorporate a preventative maintenance plan into their existing maintenance plan. The ICTM plan recommends that preventative maintenance be performed "at time intervals as specified by the equipment suppliers/manufacturers." Estimations on the required preventative maintenance tasks and costs are also provided in this report for each individual component.

Critical and non-critical maintenance costs are tabulated in this report for each system component in the ICTM project. These tasks are performed based on their priority and importance to the overall system. Each ITS element is prioritized, and the maintenance activities are identified as critical or non-critical tasks based on its importance to the overall system. Minimal repairs may be made on lower priority components, to ensure higher priority systems remain operational. Estimated annual replacement and service costs are tabulated in the ICTM maintenance plan. Support for these figures is not clearly explained in the report; however, some assumptions are listed with these figures.

All new equipment is required to have a minimum one-year warranty according to the contract provided by manufacturers of the equipment. The manufacturers are also required to provide support during the equipment test period along with maintenance training for new equipment. This report assumes all maintenance will be performed using in-house support, except in the case of specialty equipment requiring detailed maintenance. The plan identified the following specialized equipment as requiring outside support:

- Sydney Coordinated Adaptive Traffic System (SCATS) hardware and software,
- CCTV systems,
- VMS,
- communication systems, and
- video detection systems.

The use of outside support will eliminate the need to stock expensive equipment for infrequent specialized maintenance tasks. This report recommends that all agencies involved should develop a procurement process, which would allow staff to hire outside assistance without unnecessary delays.

The report lists new equipment which will be installed and estimated quantities; however, the report simply addresses the maintenance costs for a fully operational system. The replacement costs of equipment are assumed to be identical to the original costs, and maintenance costs are assumed to be the same with newly implemented equipment as with older

equipment. Based on the cost of repairs and replacement estimations, the annual maintenance cost for each system component is tabulated in this report along with the person-hour requirements to perform the maintenance tasks. The costs of maintenance are estimates based on manufacturer reliability predictions and assumptions made by the report itself.

This plan shares many common elements with the purpose of the ODOT plan. It places great emphasis on coordinating activities between different jurisdictions, and on prioritizing maintenance activities. The biggest drawback in the ICTM plan in relation to ODOT's goals is that it is geographically narrow in scope.

B.1.4 National ITS Architecture

The ITS Cost Analysis Document (8) is a segment of the ITS National Architecture program whose purpose is "to produce a high-level estimate of the expenditures associated with implementing the physical elements and the functional capabilities of ITS services," and also "to provide a costing tool for ITS implementers." The document provides cost estimates for individual ITS equipment packages, develops deployment packages for three generic geographic areas, and then produces final cost estimates for ITS in each of these areas.

An extensive array of ITS equipment packages is discussed in this document, along with the life cycle of each component, its unit price, comparative technologies, and retail price. Component information varies based on the availability of data. This document assesses the non-recurring expenditures and recurring expenditures, in five-year increments, for the next twenty years. The non-recurring costs are considered one-time capital costs, including replacement costs at the end of the useful life of equipment. The recurring costs listed are the annual operations and maintenance costs averaged for each five-year segment.

The document then evaluates the total ITS costs associated with typical ITS infrastructure that might be deployed in major urban areas, inter-urban areas, and rural areas. Non-recurring and recurring costs are tabulated for each of these three system locations, providing a final ITS budget.

This report provides brief background information on each ITS device under evaluation, as well as specific budgeting costs for each item. However, the document is unclear as to what maintenance tasks make up the recurring costs (i.e. preventative versus repair maintenance tasks), and no budgetary distinction is made between operations and maintenance costs. Consequently, it would be difficult to assess maintenance staffing requirements based solely on this report. The more specific cost detail required by the ODOT ITS maintenance plan is not provided by this report, and therefore this report can only provide limited support in the ODOT effort.

B.2 Statewide Plans

In researching other state DOTs, it does not appear that there are any maintenance plans similar to what ODOT is pursuing. Other states have deployment plans for ITS elements or the communications infrastructure to support ITS, but these plans have not addressed future

maintenance needs in great detail. Two states were identified as having made and documented systemwide efforts to identify maintenance needs for the ITS infrastructure: Arizona and Texas.

B.2.1 Arizona Department of Transportation

The Arizona Department of Transportation (ADOT) commissioned a study to develop cost models for forecasting future costs for operating and maintaining ADOT's existing and planned ITS infrastructure (9). Using ADOT's highway maintenance work management system, called the Performance Controlled System (PECOS), a majority of the operations and maintenance (O&M) costs for ADOT have been recorded including costs for several ITS devices, and this information has been used in this report to forecast future O&M costs. O&M cost estimates from other DOTs have also been used for elements that have not been adequately studied by ADOT. Cost estimates are developed for the following ITS devices:

- automatic vehicle classification, which is based on piezoelectric sensors;
- CCTV cameras;
- node room, which is the communication hub for the Phoenix Freeway Management System (FMS);
- power cabinet, which serves as the electric power service for the FMS;
- ramp meters, using both inductive loop detection (ILD) and passive acoustic detection (PAD);
- road and weather information systems (RWIS), including central processing units (CPU) and remote processing units (RPU);
- traffic monitoring systems, including existing ILD and PAD, as well as future vehicle detection stations;
- VMS;
- vehicle detection systems, for automatic vehicle counting systems deployed as part of rural ITS; and
- weigh-in-motion (WIM) systems, including piezoelectric- or bending plate-based sensors.

ADOT uses PECOS to track their O&M costs for their ITS infrastructure. The system requires that information such as type of inventory feature and labor, equipment and materials expended on the job are recorded and entered into PECOS by each maintenance organization via a dial-up communication link. Fiscal year O&M costs can then be predicted using this recorded data.

O&M costs are tabulated in this report as preventative maintenance, demand maintenance, replacement costs, and operations costs. Preventative maintenance and demand maintenance costs are subdivided into labor, equipment, materials, and man-hours categories. Preventive maintenance costs were founded on the previous year's costs and performance guidelines, which define standard labor, equipment and material quantities for various preventative maintenance activities. Demand maintenance also used the previous year's information, but due to insufficient data on the subject, the cost models used additional assumptions not listed in this report. Replacement costs were based on the device life cycle information provided by ADOT staff members and people familiar with equipment repair and breakdown history. Replacement costs

listed in this report used current equipment costs, assuming that the cost of state-of-the-art equipment in the future will be the same as the cost of the state-of-the-art equipment available in the present.

Staffing requirements are listed in terms of required man-hours for each of the ITS elements tabulated. Most ITS maintenance for ADOT is centrally performed out of Phoenix, and the costs of maintaining the ITS infrastructure are evaluated as such. However, future ADOT facilities may be established at decentralized locations to monitor other elements of the system. Any decentralization of ADOT would alter the O&M costs of the system and these costs are not evaluated.

This report provides an excellent database of historical costs of maintenance on individual ITS elements. Its use of historical cost data in forecasting future maintenance needs provides a clear example of the benefit ODOT can yield in budgeting through developing a statewide maintenance management system. The document does not, however, describe the maintenance model used for processing ITS maintenance, nor does it address training or contracting issues.

B.2.2 Texas DOT

The Texas Department of Transportation (TxDOT) commissioned a study, completed by the Texas Transportation Institute, which sought to provide a policy-level analysis of the funding issues associated with ITS and advanced traffic management system (ATMS) operations and maintenance (10). This study intended to lay out an accurate method of predicting the O&M costs for their ITS/ATMS system, and to identify options for obtaining appropriate funding levels. This report covers more than sixty ITS devices, which are divided into the following categories.

- Traffic Management Center. This includes all elements associated with traffic management centers, including facility utilities and security, computers, transmission and multiplexing equipment, associated software and hardware, and CCTV video display.

- Field Communications/Processing. This includes communications media, processing satellites, communication hubs, and controller cabinets.

- Surveillance Elements. Elements included in this plan include various freeway-monitoring devices, weather and environmental sensors.

- Traffic Control Elements. This includes all elements associated with traffic control, such as traffic signals and ramp meters.

- Traveler Information Elements. All elements used to convey traveler information to the motorist are included in this, such as VMS, HAR and kiosks.

- Incident/Emergency Response Elements. All elements used to monitor and manage freeway incidents are included in this category, such as freeway service patrols, portable VMS, and incident management vehicles.

The report develops a table, which includes O&M cost estimates for each element on a per unit basis. Elements are listed by category, along with the estimated maintenance costs, operations costs, and key cost assumptions for each element. Maintenance costs includes both preventative and repair maintenance necessary to keep the system operating at "tolerable" levels. The cost assumptions listed identify which components make up the operations and maintenance costs. This table gives TxDOT a budgeting technique for their system and indirectly a method for establishing funds. However, as the report states, "The table does not provide guidelines for determining appropriate operations or maintenance staffing levels, only the estimated cost per employee." The primary emphasis of this report is "funding issues associated with ITS/ATMS O&M," and not establishing a maintenance plan for ITS/ATMS systems.

The financial and budgetary aspects of running the TxDOT's system are extremely detailed in this report. The funding difficulties of the existing and future system are discussed, as well as possible solutions to funding problems. This report also gives recommendations for the reinvestment of funds into the current ITS system for upgrading or replacing equipment.

The estimates of maintenance costs for each element by unit could be an approach for the ODOT ITS maintenance plan. However, the report does not provide adequate detail for a maintenance plan, relying on others to develop plans within allotted funding levels.