INTELLIGENT TRANSPORTATION SYSTEMS MAINTENANCE PLAN

VOLUME ONE: *MAINTENANCE PLAN*

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GLOSSARY OF ABBREVIATIONS

ADOT	Arizona Department of Transportation
ATMS	Advanced Traffic Management System
ATR	Automatic Traffic Recorder
AVC	Automatic Vehicle Classification
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
CAD	Computer-Aided Dispatch
Caltrans	California Department of Transportation
CCTV	Closed-Circuit Television
CDPD	Cellular Digital Packet Data
CMS	Changeable Message Sign
COATS	California-Oregon Advanced Transportation System
COMET	CorridOr ManagEment Team
CPU	Central Processing Unit
CSEPP	Chemical Stockpile Emergency Preparedness Program
CVO	Commercial Vehicle Operations
DAS	Department of Administrative Services
DB	Design-Build
DBM	Design-Build-Maintain
DBW	Design-Build-Warrant
DOT	Department of Transportation
DSAS	Downhill Speed Advisory System
FMS	Freeway Management System
FTE	Full Time Employee
GPS	Global Positioning System
HAR	Highway Advisory Radio
HazMat	Hazardous Materials
HTCRS	Highway Travel Conditions Reporting System
ICTM	Integrated Corridor Traffic Management
ILD	Inductive Loop Detection
IS	Information Services
ITS	Intelligent Transportation Systems
LED	Light-Emitting Diode
LOS	Level of Service

MCTD	Motor Carrier Transportation Division
MLT	Maintenance Leadership Team
Mn/DOT	Minnesota Department of Transportation
O&M	Operations and Maintenance
ODOT	Oregon Department of Transportation
ORS	Oregon Revised Statutes
OSP	Oregon State Patrol
PAD	Passive Acoustic Detection
PDA	Personal Digital Assistant
PECOS	Performance Controlled System
RPU	Remote Processing Unit
RWIS	Road and Weather Information System
SC&DI	Surveillance, Control & Driver Information
SCATS	Sydney Coordinated Adaptive Traffic System
SSI	Surface Systems Incorporated
STIP	Statewide Transportation Improvement Program
T&M	Time-and-Materials
TDS	Transportation Data Section
TMC	Transportation Management Center (for Caltrans District 7)
TMOC	Traffic Management Operations Center (same as Region 1 TOC)
TOC	Transportation Operation Center
TOS	Traffic Operation System (for Caltrans District 7)
TSMC	Traffic Systems Management Center (for WSDOT)
TSSU	Traffic Signals Services Unit
TWI	Texas Weather Instruments
TxDOT	Texas Department of Transportation
VMS	Variable Message Sign
VSLS	Variable Speed Limit Systems
WIM	Weigh-in-Motion
WSDOT	Washington State Department of Transportation
WTI-MSU	Western Transportation Institute at Montana State University – Bozeman

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EXECUTIVE SUMMARY

As part of fulfilling its mission "to provide safe and effective transportation systems that support economic opportunity and livable communities for Oregonians," the Oregon Department of Transportation (ODOT) is increasingly relying on the use of Intelligent Transportation Systems (ITS). ITS devices use advanced technology to improve the safety and efficiency of the transportation system. ODOT's increased emphasis on ITS was demonstrated in the development of a statewide strategic plan governing ITS deployment from 1997 through 2017.

In order to ensure that ITS devices will meet the needs of both ODOT and the traveling public, proper maintenance is essential. For this reason, ODOT partnered with the Western Transportation Institute at Montana State University-Bozeman (WTI-MSU) to develop a long-term maintenance plan to address not only the technical issues associated with ITS maintenance, but the institutional issues as well.

<u>Stakeholder Outreach</u>

To provide an initial context for the development of this plan, staff from WTI-MSU engaged in meetings with many diverse groups of ODOT stakeholders. Stakeholder meetings identified the following as critical issues with ITS maintenance:

- inadequate staffing levels and/or conflicting priorities,
- ambiguous responsibilities,
- inadequate training,
- poor logging and tracking systems, and
- non-standardized devices.

Stakeholders were supportive of the need for a comprehensive ITS maintenance plan that would serve as a foundation for addressing all issues and regions, develop a process for maintaining new technology once it is implemented, raise awareness of staffing, training, maintenance, and standardization needs, and clearly define organizational responsibilities.

<u>Literature Review</u>

WTI-MSU also engaged in a literature review to identify experiences in other transportation agencies and the private-sector. In reviewing the literature, it was determined that ODOT's ITS maintenance planning efforts are unique. No similar statewide effort in the United States has been attempted. Efforts in some cases were identified as having some applicability, especially from a couple of metropolitan areas. These efforts provided some guidance into alternative methods for processing maintenance through an organization, methodologies for developing maintenance budgets, criteria for prioritizing maintenance, and recommendations for preventative maintenance. However, none of these plans reflected the diversity of ODOT's organizational structure, the rural character of some of ODOT's regions, or the variety of devices planned for deployment under ODOT's Strategic Plan. Contacts with the private sector yielded some anecdotal assistance, but no documented plans that would assist in ODOT's efforts.

Maintenance Model

One clear fact that emerges through the literature review is the necessity of having a maintenance model: a method for logging, tracking and processing repairs and requests through the organization so that maintenance is done efficiently and effectively. Several alternative maintenance models were developed and presented in a series of stakeholder meetings. Based on these meetings, a two-tier maintenance model was selected as the consensus preferred model. Some of this alternative's highlights include the following.

- It has different maintenance procedures for newer, emerging technologies and older, mainstream technologies.
- It includes a support coordinator position, whose primary role would be to serve as a single point-of-contact to log and track maintenance activities.
- It relies on district and regional maintenance staff to perform maintenance tasks on field devices, and on Information Services staff to perform maintenance on back-end computer support and communications links from the field device to the Transportation Operation Center (TOC).
- It allows for vendor / contractor support to be used at the discretion of the support coordinator.

The consensus in support of this model served as a starting point for implementation of this model and resolution of some of the concerns cited by stakeholders.

Priority Guidelines

Having a maintenance model provides a framework for performing ITS repairs, but it provides little guidance as to which activities should occur when. While not addressing ITS specifically, electrical repair priority guidelines in ODOT's current highway maintenance manual indicate that ITS devices would likely merit 24-hour/7-day-a-week maintenance support. Based on meetings with stakeholders, it was determined that there were varying perspectives on the relative repair priority of different types of ITS devices based partly on regional needs. In order to harmonize these guidelines across regions, stakeholders were surveyed as to how they normally prioritize repairs within their jurisdiction. Survey results indicated that stakeholders believe that devices should be prioritized for repair not on the basis of a particular technology but on the basis of how critical it is to the mission of ODOT. Identification of mission-critical devices is expected to vary between urban and rural regions, as well as between summer and winter weather conditions. The following guidelines represent the general order of prioritizing repair.

1. Fulfill legal mandates.
2. Address safety hazards, such as devices physically impeding the safety of the traveling public or devices providing motorists with errant and potentially harmful information.

3. Repair safety-critical devices, generally focusing on field devices first, communications links next, and information dissemination third.
4. Repair operations-critical devices, generally focusing first on where traveler benefit is maximized.
5. Restore all other devices, focusing first on devices that have the most visibility to the traveling public.

Preventative Maintenance

The need to perform repair maintenance may be partially mitigated through the proper prescription of preventative maintenance activities. Through research into practices at other agencies as well as practices recommended by vendors, guidelines were developed describing – in broad terms – the type and frequency of preventative maintenance activities that should be undertaken for each device in ODOT's ITS infrastructure. These guidelines will need to be refined by technicians more familiar with individual devices in order to develop a checklist, which can be used to ensure that all tasks are performed properly. Stakeholders indicated that preventative maintenance is often neglected in favor of performing repair maintenance. Efforts to emphasize preventative maintenance – through integration of preventative maintenance tasks into logging and tracking procedures and through allocation of resources to preventative maintenance – are needed to ensure that these activities will not continue to be neglected.

Resource Analysis

The next part of the maintenance plan is to identify the resources involved in maintaining ODOT's existing and planned ITS infrastructure. In order to properly identify the resources required, a device-by-device investigation was conducted to identify maintenance needs for the six types of components that may comprise a given ITS device, including sensors, communications, field processors, software, center sub-systems and information delivery. For each component, preventative maintenance guidelines may serve as a foundation for estimating the amount of time that needs to be devoted to ITS maintenance activities, but the relative frequency and severity of repair maintenance tasks needs to be considered as well. Estimates for each component were developed from a variety of sources, including ODOT staff, other transportation agencies and vendors. Resource needs per device were multiplied by inventory estimates of each device in each of ODOT's regions, with consideration given to travel time between device locations, in order to develop regional and statewide estimates of the staffing resources required to maintain ODOT's ITS infrastructure. Three forecast years were used in this analysis: the existing deployment, the deployment after completion of ODOT's Statewide Transportation Improvement Program 2000-2003 (STIP), and the deployment after completion of the ITS Strategic Plan mentioned earlier.

These resource needs estimates were compared with the resources ODOT currently has available to identify where staffing gaps may exist. The results, shown in Table A, indicate that ODOT's concerns about staffing gaps are justified. This gap is expected to widen in the future, assuming that ODOT is unable to obtain additional staffing resources.

Type of Work		Region	FTEs							
			Available		Existing		STIP		Strategic Plan	
			Now	Future	Need	Gap	Need	Gap	Need	Gap
Coordination		1	-	0.10	0.10	0.10	0.14	0.04	1.04	0.94
		2	-	0.10	0.33	0.33	0.38	0.28	1.40	1.30
		3	-	-	0.04	0.04	0.05	0.05	1.37	1.37
		4	-	0.10	0.09	0.09	0.18	0.08	1.55	1.45
		5	-	-	0.05	0.05	0.13	0.13	1.48	1.48
		Total	-	0.30	0.61	0.61	0.88	0.58	6.83	6.53
Electrical / Electronic	Diagnostic	1	-	0.11	0.26	0.26	0.36	0.25	0.73	0.62
		2	1.35	1.46	0.31	(1.04)	0.41	(1.05)	0.76	(0.71)
		3	-	-	0.10	0.10	0.12	0.12	0.87	0.87
		4	-	0.11	0.18	0.18	0.41	0.30	1.38	1.27
		5	-	-	0.25	0.25	0.51	0.51	1.26	1.26
		Total	1.35	1.69	1.09	(0.26)	1.82	0.13	4.99	3.31
	Repair	1	-	0.11	0.38	0.38	0.52	0.41	1.48	1.37
		2	1.35	1.46	0.33	(1.02)	0.47	(1.00)	1.19	(0.27)
		3	-	-	0.13	0.13	0.17	0.17	1.29	1.29
		4	-	0.11	0.20	0.20	0.49	0.37	1.88	1.77
		5	-	-	0.31	0.31	0.64	0.64	2.02	2.02
		Total	1.35	1.69	1.34	(0.01)	2.28	0.59	7.86	6.17
	Preventative Maintenance	1	-	0.03	0.30	0.30	0.42	0.39	1.34	1.32
		2	-	0.03	0.23	0.23	0.33	0.31	1.04	1.01
		3	-	-	0.08	0.08	0.12	0.12	1.10	1.10
		4	-	0.03	0.17	0.17	0.39	0.36	1.46	1.44
		5	-	-	0.17	0.17	0.45	0.45	1.39	1.39
		Total	-	0.08	0.94	0.94	1.71	1.64	6.33	6.25
	Total	1	-	0.25	0.93	0.93	1.30	1.05	3.55	3.30
		2	2.70	2.95	0.86	(1.84)	1.21	(1.74)	2.99	0.04
		3	-	-	0.31	0.31	0.41	0.41	3.26	3.26
		4	-	0.25	0.55	0.55	1.29	1.04	4.72	4.47
		5	-	-	0.73	0.73	1.60	1.60	4.66	4.66
		Total	2.70	3.45	3.37	0.67	5.81	2.36	19.18	15.73
Information Services	Diagnostic	1	0.53	0.71	0.24	(0.29)	0.34	(0.37)	1.40	0.68
		2	1.13	1.31	0.38	(0.74)	0.48	(0.84)	1.23	(0.08)
		3	-	-	0.04	0.04	0.07	0.07	1.26	1.26
		4	-	0.19	0.21	0.21	0.45	0.26	1.89	1.71
		5	-	-	0.07	0.07	0.30	0.30	1.60	1.60
		Total	1.65	2.21	0.93	(0.72)	1.64	(0.57)	7.38	5.17
	Repair	1	0.14	0.19	0.14	0.00	0.26	0.07	1.27	1.08
		2	0.30	0.35	0.26	(0.04)	0.33	(0.02)	1.15	0.80
		3	-	-	0.03	0.03	0.05	0.05	1.22	1.22
		4	-	0.05	0.16	0.16	0.39	0.34	1.93	1.88
		5	-	-	0.05	0.05	0.22	0.22	1.60	1.60
		Total	0.44	0.59	0.64	0.20	1.25	0.66	7.18	6.59
	Preventative Maintenance	1	0.04	0.05	0.48	0.44	0.64	0.59	2.21	2.17
		2	0.08	0.09	1.26	1.19	1.75	1.66	2.63	2.55
		3	-	-	0.09	0.09	0.16	0.16	1.23	1.23
		4	-	0.01	0.24	0.24	0.55	0.54	1.93	1.92
		5	-	-	0.12	0.12	0.47	0.47	1.53	1.53
		Total	0.11	0.15	2.19	2.08	3.57	3.42	9.54	9.39
	Total	1	0.70	0.95	0.86	0.16	1.24	0.29	4.88	3.93
		2	1.50	1.75	1.91	0.41	2.55	0.80	5.02	3.27
		3	-	-	0.16	0.16	0.29	0.29	3.71	3.71
		4	-	0.25	0.61	0.61	1.39	1.14	5.75	5.50
		5	-	-	0.23	0.23	1.00	1.00	4.73	4.73
		Total	2.20	2.95	3.76	1.56	6.46	3.51	24.10	21.15
Total		1	0.70	1.30	1.89	1.19	2.68	1.38	9.46	8.16
		2	4.20	4.80	3.10	(1.10)	4.14	(0.66)	9.40	4.60
		3	-	-	0.51	0.51	0.75	0.75	8.34	8.34
		4	-	0.60	1.24	1.24	2.86	2.26	12.02	11.42
		5	-	-	1.01	1.01	2.73	2.73	10.87	10.87
		Total	4.90	6.70	7.74	2.84	13.15	6.45	50.11	43.41

Table A: Staffing Gaps by Classification and Region.

In addition to this quantitative analysis, surveys were used to qualitatively assess how competent ODOT staff believes it is to maintain existing and planned ITS technologies. This examination showed that organizational expertise exists on essentially every device ODOT currently has; however, regional gaps in knowledge do exist. These training gaps may be readily addressed through the use of cross-training between senior and junior ODOT staff.

One potential alternative for dealing with future staffing gaps is to use contract maintenance. While many agencies are increasingly relying on contracting for ITS maintenance, it should not be viewed as a certain solution for ODOT's ITS maintenance difficulties. Contracting should be targeted toward activities where response time is not as critical, where the device deployment on a statewide basis is fairly extensive, and where clear lines of responsibility between contractors and ODOT may be defined. Activities that were identified as good candidates, either now or in the future, for contracting include:

- weigh-in-motion systems,
- kiosks,
- preventative maintenance on closed-circuit TV cameras and permanent variable message signs (VMS),
- road and weather information system field units,
- travel time estimation,
- automatic vehicle location in-vehicle sensors,
- all maintenance activities on portable VMS, and
- fiber optic communications.

Budget

As a final element in the maintenance plan, a maintenance budget needed to be developed. The budget, shown in Table B, reflects that all maintenance activities are performed as recommended, with contracting applied on a time-and-materials basis where appropriate. The budget includes costs for spare parts and emergency device replacement (such as due to lightning strikes), but excludes costs associated with operations, continued vendor support and routine device replacement. As can be seen, the estimated maintenance budget statewide under the existing deployment level is nearly $1.3 million. As deployment increases, however, the estimated budget increases as well, to a total of over $7.6 million per year by the time devices in the Strategic Plan have been deployed. The largest component of the maintenance budget is emergency device replacement.

	Region					State
Year	**1**	**2**	**3**	**4**	**5**	**Total**
Existing	$ 464,580	$ 408,959	$ 86,089	$ 167,446	$ 154,608	**$ 1,281,682**
STIP	$ 652,053	$ 583,194	$ 123,680	$ 356,406	$ 448,596	**$ 2,163,929**
Strategic Plan	$ 2,347,936	$ 1,417,132	$ 1,178,268	$ 1,267,177	$ 1,411,741	**$ 7,622,254**

Table B: Maintenance Budget by Region.

Strategic Maintenance Plan

This plan is intended as an evolving document that will serve primarily as a starting point for institutionalizing maintenance as a part of ITS devices. On that basis, and on the basis of work done in preparation of this plan, Table C presents recommendations for short-term, medium-term and long-term time frames.

Future Research and Evaluation

There are other activities not related directly to ITS maintenance which are recommended as potential research activities to build on promising areas identified in this research project, including:

- a before-and-after comparison to evaluate the effectiveness of implementing the two-tier maintenance model on ITS maintenance,
- a revision of future maintenance budgets based on cost data provided by the to-be-implemented logging and tracking system, and
- an investigation into contracting opportunities for non-ITS maintenance within ODOT.

Time Frame	Recommendations
Short-Term	1. Continue to develop an organizational consensus as to the importance of ITS in fulfilling ODOT's mission. 2. Continue to pursue implementation of the two-tier maintenance model, including identifying individuals who will fill the support coordinator role for each region. 3. Research and implement a statewide logging and tracking system for ITS maintenance activities. 4. Develop regional guidelines for prioritization of ITS repair maintenance activities. 5. Develop checklists for preventative maintenance tasks on each device. 6. List and quantity an appropriate spare parts inventory for each device. 7. Identify and procure equipment that may be needed in performing diagnostics on ITS field devices. 8. Schedule cross-training activities to improve the overall skill level of ODOT technicians. 9. Investigate contracting alternatives on non-mission-critical devices. 10. Disseminate this plan document to other agencies, to assist them in analyzing ITS maintenance alternatives.
Medium-Term	1. Develop process for on-going cross-training on new devices. 2. Improve the statewide logging and tracking system to minimize time on data entry. 3. Develop statewide, scalable standards for ITS devices, as well as a process for these standards to be developed and implemented in the future. 4. Investigate alternatives for competition between ODOT and contractors on ITS maintenance, in order to evaluate the benefits and consequences of contracting. 5. Research contracting alternatives that may be used in procurement of new devices to reduce maintenance costs.
Long-Term	1. Replace non-standardized devices with devices that are compatible with ODOT's standards. 2. Regularly evaluate ITS maintenance activities on a series of performance measures, including repair response time and the length of time a device is inoperable. 3. Pursue strategic planning efforts that incorporate maintenance planning as a key consideration.

Table C: Strategic Recommendations for ITS Maintenance.

1 INTRODUCTION

The mission statement of the Oregon Department of Transportation (ODOT) is “to provide safe and effective transportation systems that support economic opportunity and livable communities for Oregonians.” (1) One increasingly important part of fulfilling ODOT’s mission is the strategic deployment of Intelligent Transportation Systems (ITS). ITS integrates advanced technology into the transportation system for both users and operators, in order to enhance the safety and efficiency of the system.

To protect its investment in ITS, ODOT is endeavoring to ensure the proper and timely operation of all ITS deployments through appropriate maintenance activities. For this reason, ODOT has partnered with the Western Transportation Institute at Montana State University-Bozeman (WTI-MSU) to develop this statewide ITS maintenance plan. This plan is intended to provide five clear points of guidance for ODOT in relation to ITS maintenance:

- a model for processing ITS maintenance;
- a schedule for prioritizing ITS maintenance activities;
- a preventative maintenance schedule for all existing and planned devices;
- an assessment of training and contracting needs for ensuring that all maintenance activities are performed properly; and
- a comprehensive budget for ITS maintenance.

Chapter 2 of this document will describe the context of this plan with respect to other ODOT ITS efforts, and describe efforts that have been done by other public agencies and private sector firms. Subsequent chapters will address each of the bulleted points described above in an attempt to evaluate in a comprehensive fashion all of the issues associated with ITS maintenance in Oregon. This plan is accompanied by a volume of technical appendices that contain supporting information for the documentation provided in this plan.

2 BACKGROUND AND LITERATURE REVIEW

The purpose of this chapter is to provide a context for the need and purpose of this maintenance plan. First, ODOT's increasing reliance on intelligent transportation systems will be quantified. Second, comments collected from meetings with ODOT stakeholders will be used to identify the needs perceived by ODOT staff which may be address directly or indirectly through an ITS maintenance plan. Finally, this chapter will summarize findings from contacts with other transportation agencies and private sector firms to identify the potential availability and applicability of similar maintenance plans that may have been developed elsewhere.

2.1 Plan Context

Due to the increasing complexity and expense of adding to the capacity of the transportation system, transportation agencies are increasingly shifting from a construction focus to an operational focus. ODOT is no exception to this trend. In recent years, the Oregon Department of Transportation has begun to pursue a relatively aggressive program of ITS deployment in fulfilling the agency's mission. ODOT expects to continue in this direction in the future. ODOT's Statewide Transportation Improvement Program 2000-2003 (STIP) (2), which provides funding for transportation projects over the next four years, includes deployment of many ITS devices throughout the state. Moreover, the Oregon Intelligent Transportation Systems Strategic Plan: 1997-2017 (3), approved by the Oregon Transportation Commission in 1998, indicates that ODOT and other agencies throughout the state are planning to deploy an increasing number of devices in the future.

The extent of ODOT's existing and planned[1] ITS deployment is shown in Table 2-1. ODOT's statewide ITS inventory database was used as a starting point for determining existing deployment levels (4), with additional information gleaned from contacts with ODOT staff, including the ITS unit, and regional and district maintenance staff. Planned deployment quantities and locations[2] were based on a review of the STIP and the Strategic Plan, along with conversations with ODOT's ITS unit. While it is expected that the nature of ODOT's planned ITS infrastructure will change based on many factors, such as technological advancement, changing regional needs and fiscal constraints, the table nonetheless shows a clear trend for increased deployment of ITS devices.

2.2 Stakeholder Meetings

In Oregon, ITS devices have historically cut across jurisdiction lines for operations and maintenance. In order to ensure that this plan would satisfactorily identify and address the needs of the agency overall, the ODOT ITS unit scheduled a series of meetings with different stakeholder groups during late May 1999. The structure of each meeting varied slightly with the overall goal of answering a few broad questions for each group:

[1] While the California-Oregon Advanced Transportation System (COATS) Project between the California Department of Transportation (Caltrans) and ODOT has identified initial ITS deployment projects, for the purposes of this report they are not included.

[2] Where not explicitly indicated, locations where assumed based on device function and need.

Device	Region	Existing	Existing + STIP	Existing + STIP + Strategic Plan
Automatic Traffic Recorders	Region 1	26	27	29
	Region 2	26	30	46
	Region 3	26	28	31
	Region 4	23	24	26
	Region 5	26	26	29
	State Total	127	135	161
Speed Zone Monitoring Stations	Region 1	4	4	4
	Region 2	8	8	8
	Region 3	4	4	4
	Region 4	9	9	9
	Region 5	9	9	9
	State Total	34	34	34
Closed-Circuit Television (CCTV) Surveillance	Region 1	39	46	119
	Region 2	5	7	45
	Region 3	1	1	41
	Region 4	10	15	40
	Region 5	1	18	31
	State Total	56	87	276
Video Detectors	Region 1	-	-	100
	Region 2	4	5	5
	Region 4	-	1	1
	State Total	4	6	106
Road and Weather Information System (RWIS)	Region 1	6	9	14
	Region 2	4	9	24
	Region 3	1	4	24
	Region 4	8	15	37
	Region 5	1	20	29
	State Total	20	57	128
Travel Time Estimation	Region 1	-	-	80
	State Total	-	-	80
Automatic Vehicle Location (AVL)	Region 1	7	7	107
	Region 2	-	4	104
	Region 3	-	-	100
	Region 4	-	40	100
	Region 5	-	-	100
	State Total	7	51	511
Ramp Metering	Region 1	64	90	150
	Region 2	-	-	65
	Region 3	-	-	35
	State Total	64	90	250

Table 2-1: Statewide ITS Inventory Assumptions.

Device	Region	Existing	Existing + STIP	Existing + STIP + Strategic Plan
Emergency Signal Preemption	Region 1	206	206	206
	Region 2	104	104	104
	Region 3	59	59	59
	Region 4	51	51	51
	Region 5	23	23	23
	State Total	443	443	443
Transit Signal Prioritization	Region 1	17	17	17
	Region 2	-	-	100
	State Total	17	17	117
Advanced Traffic Management System	Region 1	1	1	1
	Region 2	-	-	1
	Region 3	-	-	1
	Region 4	-	-	1
	Region 5	-	-	1
	State Total	1	1	5
Callboxes	Region 3	4	4	4
	State Total	4	4	4
Cellular Call-In	Region 2	-	-	1
	State Total	-	-	1
Regional Incident Detection System	Region 1	-	1	1
	State Total	-	1	1
Intersection-Based Incident Detection System	Region 2	-	1	1
	Region 4	-	1	1
	State Total	-	2	2
Computer-Aided Dispatch	Region 2	5	5	5
	Region 3	2	2	2
	Region 4	2	2	2
	State Total	9	9	9
Incident Response Vehicles	Region 1	7	7	7
	Region 2	-	4	4
	State Total	4	-	-
Pre-planned Detour Routes	Region 1	-	-	500
	Region 2	-	-	100
	Region 3	-	-	100
	Region 4	-	-	50
	State Total	-	-	750
Hazardous Material Response	Region 2	-	-	1
	State Total	-	-	1
Alphanumeric Paging	Region 1	1	1	1
	State Total	1	1	1
Highway Travel Conditions Reporting System	Region 2	-	1	1
	State Total	-	1	1

Table 2-1: Statewide ITS Inventory Assumptions. (cont.)

Device	Region	Existing	Existing + STIP	Existing + STIP + Strategic Plan
800-number Information	Region 2	1	1	1
	State Total	1	1	1
Internet Access	Region 2	1	1	1
	State Total	1	1	1
Kiosks	Region 1	-	-	117
	Region 2	-	-	30
	Region 3	-	-	30
	Region 4	-	-	30
	Region 5	-	-	30
	State Total	-	-	237
Icy Bridge Warning CMS	Region 3	1	1	1
	State Total	1	1	1
Tunnel Lane Closure CMS	Region 1	1	1	1
	State Total	1	1	1
Radio-Controlled Snow Zone CMS	Region 4	4	4	4
	State Total	4	4	4
Telephone-Activated Snow Zone CMS	Region 5	8	8	8
	State Total	8	8	8
Oversize Vehicle Restriction CMS	Region 2	1	1	1
	State Total	1	1	1
Permanent Variable Message Signs	Region 1	12	16	32
	Region 2	5	9	9
	Region 3	2	2	2
	Region 4	1	1	1
	Region 5	5	10	18
	State Total	25	38	62
Portable Variable Message Signs	Region 1	1	1	61
	Region 2	19	19	99
	Region 3	-	-	100
	Region 4	3	5	102
	Region 5	-	-	100
	State Total	23	25	462
Highway Advisory Radio (HAR)	Region 3	1	1	1
	State Total	1	1	1
Icy Bridge Detectors	Region 1	1	1	5
	Region 2	-	-	4
	Region 3	-	-	4
	Region 4	-	-	4
	Region 5	-	-	4
	State Total	1	1	21

Table 2-1: Statewide ITS Inventory Assumptions. (cont.)

Device	Region	Existing	Existing + STIP	Existing + STIP + Strategic Plan
Oversize Load Detectors	Region 4	-	5	5
	State Total	-	5	5
Variable Speed Limit Signs	Region 1	-	-	2
	Region 2	-	-	3
	Region 3	-	-	5
	Region 4	-	-	5
	Region 5	-	-	5
	State Total	-	-	20
Queue Detection System	Region 2	1	1	1
	State Total	1	1	1
Weigh-in-Motion (WIM) Stations	Region 1	-	5	5
	Region 2	2	3	3
	Region 3	4	4	4
	Region 4	-	4	4
	Region 5	5	5	5
	State Total	11	21	21
Downhill Speed Advisory Systems	Region 2	-	-	4
	Region 3	-	1	8
	Region 4	-	-	7
	Region 5	1	1	7
	State Total	1	2	26
Fiber Optic Networks	Region 1	-	80	80
	State Total	-	80	80
Radio Communications	Region 1	4	4	4
	Region 2	5	5	5
	Region 3	2	2	2
	Region 4	2	2	2
	Region 5	-	-	2
	State Total	13	13	15
Maintenance Coordination	Region 1	-	1	1
	Region 2	-	1	1
	Region 3	-	1	1
	Region 4	-	1	1
	Region 5	-	1	1
	State Total	-	5	5

Table 2-1: Statewide ITS Inventory Assumptions. (cont.)

- What should the maintenance model look like? This question was broken up into several smaller questions to get at specific issues such as tracking, prioritization, and budgeting.

- Where do you perceive your responsibilities for ITS maintenance beginning and ending? Because ITS devices tend to cut across organizational lines in their operations and maintenance, it was important to determine how stakeholders thought lines of responsibility should fall.

- What are your top three ITS maintenance priorities?

- What would you hope for the ITS maintenance plan to accomplish?

These questions were presented in a matrix format to each stakeholder group as shown in Table 2-2. Meetings were held with eight different groups of stakeholders, as shown in Figure 2-1. Each of the stakeholder groups was selected to represent a unique perspective on ITS maintenance within ODOT.

- The ITS Executive Steering Committee is a high-level, policy-oriented committee which sets the direction for ODOT's ITS efforts. Its membership includes key leaders from several planning and operational units. The committee has many broad roles, including maintaining oversight of staff working on ITS issues, assisting with statewide coordination of ITS efforts, and setting prioritization of ITS initiatives and funding.

- The District Managers are responsible for day-to-day maintenance operations in each of ODOT's districts. Their maintenance responsibilities include not only ITS devices but also traditional highway maintenance, such as pavement and structures. They are responsible for budgeting and scheduling maintenance activities at the district level.

- The Transportation Operation Center (TOC) Managers are responsible for day-to-day operations of the state's four TOCs, which are located in Portland, Salem, Medford and Bend. The TOCs are generally "consumers" of ITS device data outputs, as these devices help the TOCs to better manage traffic congestion, report on traffic conditions, and coordinate incident response and management.

- Information Services has oversight responsibility over ITS hardware and software installations. They provide data storage for ITS databases, provide computer hardware and software support, and manage communications links and networks.

- The Regional Electricians are tasked to perform day-to-day ITS maintenance. They are generally the first line of defense for maintenance of many ITS devices, including ramp meters, variable message signs (VMS) and cameras.

- The Traffic Signals Services Unit (TSSU), based in Salem, is responsible for testing of traffic control devices as well as higher-level maintenance. If electricians are not

		Stakeholder "Clusters"					
What should the maintenance model look like?	Problem identification and verification						
	Problem reporting and assigning						
	Problem logging and tracking						
	Resource allocation: equipment, staff, training, spare parts, etc.						
	Centralized or distributed?						
	Vendor or in-house?						
	Prioritization (preventative vs repair)						
Where does your responsibility for ITS maintenance begin and end?							
What are the top three ITS maintenance priorities?	1						
	2						
	3						
What do you hope the ITS Maintenance Plan will be able to accomplish?							

Table 2-2: Questions for Stakeholder Meetings.

able to successfully resolve a problem with an ITS device, TSSU is often used as the next line of help.

- The Motor Carrier Transportation Division has statewide responsibility for transportation issues related to the motor carrier industry. They are responsible for maintaining ITS installations related to trucks, such as weigh stations with weigh-in-motion technology.

- The Transportation Data Section (TDS) is responsible for both operating and maintaining automatic traffic recorders (ATR) throughout Oregon, which are used primarily in statewide planning efforts.

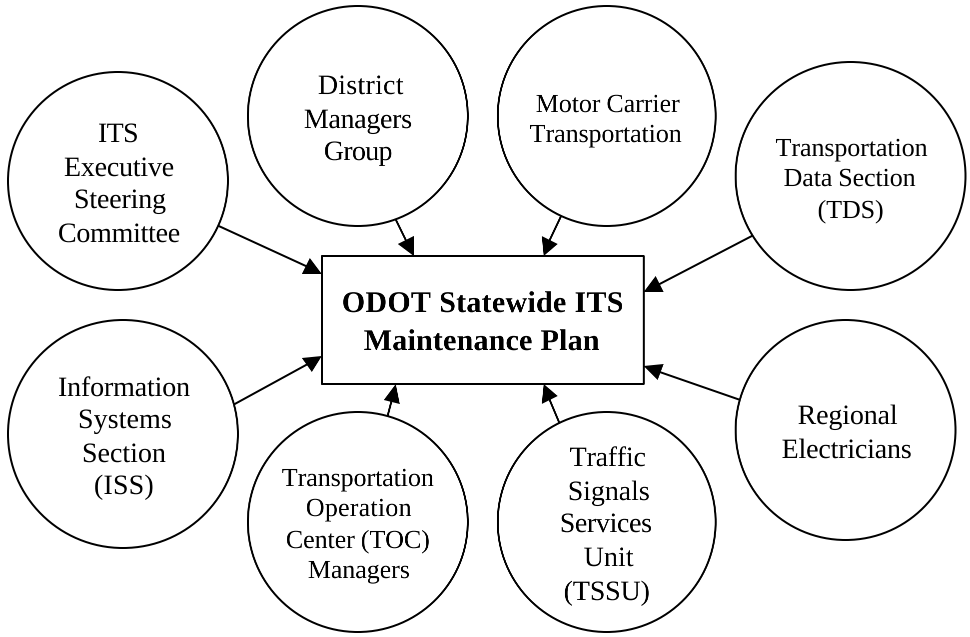

Figure 2-1: Stakeholder Groups.

A list of participants attending each of the stakeholder meetings is in Appendix A.

Several common themes emerged from these stakeholder meetings in answer to the four broad questions introduced earlier. This section will summarize the stakeholders' responses to these questions.

2.2.1 Maintenance Model

In defining existing and desired maintenance models, stakeholders were asked to consider several different aspects:

- Problem identification and verification. How are problems typically identified? How are problems normally diagnosed?
- Problem reporting and assigning. What is the process for problems to get reported and assigned to the right people?
- Problem logging and tracking. What processes exist for logging maintenance activities? How are problems tracked from identification through resolution?
- Resource allocation. What are current issues with resource allocation in terms of staffing, training, equipment and spare parts?
- Centralized or distributed. Would a centralized or distributed maintenance model work better?

- Vendor or in-house. Under what conditions should vendors be brought in to perform maintenance?

- Prioritization. How are repairs prioritized? Where does preventative maintenance rank among maintenance priorities?

2.2.1.1 Identification and Verification

For the majority of ITS devices that are currently in the field, device malfunctions are reported either through individuals reporting problems or through querying processes run by ODOT staff. When "pull technology" such as this is used as the primary method of problem identification, problems will be remedied only as quickly as they are made known. Relying on "pull technology" to report problems is effective in a sense, then, since it allows ODOT to focus its maintenance efforts on devices that are being used regularly by the public or by ODOT operators.

There are a couple of problems with "pull technology" however, which were brought out in the stakeholder meetings.

- Devices located in rural areas, such as some closed-circuit television (CCTV) cameras and VMS, may be left inoperable for long periods of time unless a problem is reported. These locations may be strategically important for safety and/or liability reasons. Consequently, ODOT will not be getting the maximum potential use out of its ITS investment.

- Pull technology requires additional effort by maintenance staff in terms of querying existing devices. Significant time savings could result if expert systems were used which allowed devices to initiate reports whenever a malfunction occurred.

Some devices, such as road and weather information systems (RWIS) stations, have the capability to report to an operator through e-mail that there is a device malfunction. Some devices that already have such self-diagnostic capabilities, such as ramp meters and traffic signal controllers, are not being presently utilized. Stakeholders agreed that future systems would likely need a greater degree of self-diagnosing capability.

Problem verification or troubleshooting is a concern for many ITS devices, due to both a lack of adequate training for maintenance personnel and a lack of 24-hour, 7-day support.

2.2.1.2 Reporting and Assigning

The stakeholder meetings revealed that there are varying practices for the reporting and assigning of maintenance needs, with there being no statewide reporting model. There are instances of reporting and assigning practices that have been established and are adhered to with good results. TDS, for example, is able to maintain over 90 percent of its ATRs working at any given time due to an established problem identification and assignment process. The Motor Carrier Transportation Division, through the use of contracting, has a process for automatically reporting and assigning maintenance needs so that they will be resolved in a predetermined time. For many other devices, however, there is no similar procedure. It was learned that there is generally no single point of contact for ITS maintenance needs and no common procedure for assigning the repairs to the appropriate individual.

In assigning ITS maintenance, one problem that was brought up during several meetings was the lack of training to handle ITS maintenance. Traditional channels that would be used for maintenance of other systems within ODOT are currently not adequate for handling current maintenance needs. Information Services, for example, would traditionally be a point of contact for software and hardware maintenance issues related to ITS devices. However, their desktop support is trained primarily on traditional desktop applications rather than very specific, localized software packages associated with individual devices. Electricians would normally be the first line for electrical devices in the field, but in many cases lack the training to be able to properly diagnose and remedy malfunctioning ITS field devices.

Another concern raised was the lack of consistent 24-hour, 7-day support for ITS devices. For many deployments, it is critical that the devices be operational on a continual basis, even during weekends and overnight. However, many support services within ODOT are not currently equipped to be able to provide comparable support. In the desire to expedite repairs, operators and managers have learned to do some repair work outside of normal channels in order to improve operations of the transportation system for both operators and users.

2.2.1.3 Logging and Tracking

When stakeholders were asked about the logging and tracking of maintenance on ITS devices, it was discovered that there is no common form of logging and tracking problems; it varies by groups and regions. TSSU, for example, has established a paper logging system, which is later entered into a central computerized database, which tracks maintenance performed on all state-maintained traffic signals. TDS uses a similar system for tracking the maintenance history of its ATR equipment. These databases, however, are still primarily paper-based and are limited to only a few types of ITS devices. For most devices, little or no tracking is done. In addition, these databases are typically not accessible across different ODOT units, which many stakeholders cited as a problem.

Many stakeholders expressed a desire to see a common automated means of logging and tracking maintenance that could be commonly accessed between stakeholders. It was hoped that such a system could be used to track costs by specific field devices, which could help to develop better estimates of budgeting based on features.

In reviewing this process of logging and tracking, it was found in summary that there is no collective oversight for problem management, hand-offs, tracking and coordination.

2.2.1.4 Resource Allocation

The common perception from stakeholders is that ODOT is moderately to severely understaffed to handle current ITS maintenance needs, depending on location and activity. District managers, for example, reported that ITS devices have been added to their district's maintenance needs without the additional resources to maintain them. Consequently, the focus is primarily on reactive maintenance or "putting out fires" rather than proactive or preventative maintenance. Logging and tracking activities are also underemphasized.

Moreover, in some instances, such as the more rural regions, there is a single individual who has broad-based maintenance knowledge and institutional memory. In the event that these key individuals leave the organization, all the institutional memory would go with them, leaving broad sections of the ITS infrastructure without anyone who knows how to maintain or even operate them.

As was discussed in how problems are assigned, there was a concern that staffing decisions did not reflect the need for a 24-hour, 7-day operational focus. Personnel qualified to do maintenance, in many cases, still work traditional weekday, daytime hours, which may not be adequate to support the operations of the TOCs, which operate on a 24-hour, 7-day basis.

There appears to be a universal need for improved training for maintenance personnel. Devices are often deployed without adequate training of the staff who would maintain them, and without sufficient documentation for basic troubleshooting tasks. Stakeholders felt that training needs should be included in both the design specification and procurement processes. There was also a desire for cross-functional training that would enable maintenance staff to be more effective in troubleshooting and isolating faults in ITS devices, even if they were not ultimately responsible for performing the maintenance item in question.

In addition to concerns about general understaffing, it was suggested that existing staffing could be more effectively utilized if there were greater standardization of ITS devices. Standardization has been introduced in other departments of transportation through tight specification processes and standard vendor or parts lists for purchasing. Increased standardization of devices improves the familiarity of maintenance staff with their operations, reducing the average time it takes to repair devices.

Standardization would have the added benefit of reducing the amount of spare parts needing to be kept on-hand to respond to repairs in a timely fashion. One success story with standardization is TSSU, which has had oversight over the Type 170 traffic signal controller becoming the statewide standard for signal control. Prior to this, field technicians had to maintain over a dozen different types of controllers in their central Salem warehouse; now they only need to keep a handful in stock, greatly saving in both space and the cost of special orders.

It was perceived that improved planning would help to improve the operations and maintenance of ITS installations. First, changes should be considered to the procurement process that would allow the procurement decision to reflect life cycle costs rather than just initial capital costs. Often it is found that low initial item cost is associated with higher maintenance cost and shorter operational life; life cycle cost analysis data could be used to create a “standard device list” from which items for purchase could be selected. There may be devices where a scaleable standard design has been found that will work well with all the regions. This would perhaps result in higher capital costs than a non-standardized device, but would have lower maintenance costs that could result in cost savings over the life of the device. Until these changes are implemented, tighter specifications could be drafted in order to ensure standardization is obtained. Second, some parts of the state, specifically Regions 2 and 3, expressed interest in having a strategic or implementation plan for ITS devices. A greater understanding of how these devices are to integrate into the broader transportation system to meet user needs may help to improve how resources are allocated to maintain the devices.

2.2.1.5 Centralized vs. Distributed System

Stakeholders were also asked their perspectives on resource allocation in terms of whether they thought resources would be better to be centralized statewide or distributed regionally. The responses across groups reflect the different priorities and responsibilities each group has for ITS maintenance.

- The electricians wished to have a centralized budget to handle major ITS repairs. They were concerned about the potential high cost of repairing an ITS device that has a catastrophic failure.
- The TOC managers preferred to have local ITS maintenance budgets, so they could have greater flexibility in addressing their needs, but a centralized budget for larger capital expenditures.
- The Motor Carrier Transportation Division perceives itself as having an independent, centralized maintenance model through contracting. They budget $1.2 million per year which covers all of their ITS maintenance needs statewide.
- Information Services preferred a certain degree of centralization in order to ensure standardization of equipment.
- TDS suggested that there should be a centralized budget for major parts, but that technician time should be charged on regional budgets as utilized.
- TSSU favored a tiered approach, with centralized core capabilities and distributed trouble shooting and diagnostics. They believe that the budgeting should follow a similar structure.

Several groups suggested that a good model for centralization would be the state's fleet management model.

2.2.1.6 Vendor vs. In-house

Stakeholders were asked to identify which factors do or should determine whether contractors are utilized to perform maintenance on ITS devices. Responses indicated that there were five primary factors that would influence this decision.

1. In-house capability is generally desired for mission-critical business, such as safety. Wherever expedited response time is an important concern, stakeholders expressed reluctance on utilizing contractors.
2. Contractors would be preferred if significant technical ability is required or if there is a deficiency in training. Some ITS devices may require significant amounts of training or higher education to be able to properly maintain. It may be more cost-effective in these cases to use contractors. In other cases, the training required might not be that substantial, but maintenance personnel do not have adequate time to take

training classes. Contractors could be used for stopgap maintenance until in-house support could get up to speed.

3. Support service may not be available. Contract maintenance may be desirable in some rural areas, where limited applications of ITS devices do not warrant significant amounts of training. However, because of the remote location of these devices with respect to contractor offices, companies may not be willing to contract to maintain these devices, or they may demand a premium fee to do so.

4. Contractors may be more appropriate for non-standardized equipment. Stakeholders from several groups suggested that a tiered approach should be used in maintenance of ITS devices. Each device has a testing or early deployment stage when small amounts of different technologies are being tested at different locations. In this stage, it is probably not economical to have in-house training for each of these different types of devices. As equipment becomes more standardized, training of maintenance personnel could begin to focus on one or two specific models of each device, making it more effective to handle maintenance in-house.

5. There may be inadequate numbers of staff to handle maintenance. Understaffing in many districts and divisions, due to legislative caps on total ODOT staffing levels, may force them to outsource maintenance, as opposed to the alternative of having devices which either operate inadequately (CCTV cameras which cannot pan or tilt, for example) or remain inoperative altogether.

The different factors involved in the decision whether to use contractors or in-house resources for ITS maintenance suggested that there should be some flexibility in how a maintenance plan addresses this part of the maintenance model.

2.2.1.7 Prioritization

There was a common theme from many of the groups that preventative maintenance was difficult to perform due to a lack of continuing resources. There were a couple of exceptions, such as TDS, which performs annual inspections of each of its ATR installations and does some routine replacement of parts. Given the choice between performing preventative maintenance or repair maintenance, stakeholders always favored performing repair maintenance.

Given constraints on resources, however, there is the question as to how repairs should be prioritized. There was no unanimous consensus on which factors are the overriding factors in determining what gets fixed first, but several factors were brought up repeatedly as playing into the prioritization decision.

- Safety. According to its mission statement, ODOT's mission is "to provide *safe* and effective transportation systems that support economic opportunity and livable communities for Oregonians." (1) Stakeholders expressed unanimous consent that the safety of the driving public was a dominant concern in deciding how device repair is prioritized. Stakeholders had different viewpoints, however, based on their own operational experience, of which ITS devices were most critical for safety.

- Traffic control devices. Urban TOC managers perceived that traffic control devices would be a top maintenance priority, because successful traffic control has a clear relationship to safety in congested urban roadway networks.

- Liability. Many devices need to be properly maintained for legislative and liability reasons. ATRs, for example, are required to be operational as a part of federal legislation, so TDS has a preventative maintenance program as well as a reporting and tracking system to help ensure compliance.

- Advisory or information devices. These devices may be necessary to report road closures or hazardous conditions to motorists in order that they may take appropriate actions. If these devices are inoperative, especially in more rural areas during hazardous weather conditions, the safety consequences can be severe.

- Public perception / level of service. The use of ITS devices is increasing the visibility of ODOT to the public. When ITS devices are operational, motorists appreciate the additional information and have commended stakeholders through various means to continue similar efforts. However, the public will likely be disposed against continued investment in new or expanded ITS deployments if it sees that efforts are not made to maintain devices once they are deployed. Stakeholders expressed an interest in prioritizing maintenance on devices that the public is more apt to notice.

- Geography. One clear finding out of meeting with the different stakeholder groups is that there is no obvious scheme that could be implemented statewide dictating how repairs should be prioritized. Operators and managers desired to have some local flexibility to be able to prioritize maintenance needs according to user needs.

2.2.2 Perceived Responsibilities

Stakeholders were asked to identify where they perceived their responsibilities beginning and ending for ITS maintenance. It was intended that this question would be a diagnostic tool, identifying areas of either overlapping responsibility between different groups, or areas of lapsed responsibility, with no one believing they were responsible for maintenance. As shown in Table 2-3, there seems to be overlap in perceived maintenance responsibilities between stakeholder groups. This chart highlights several issues when it comes to responsibility for ITS maintenance.

There are differences of opinion between repair and oversight responsibility, or between the perspective of maintenance providers and maintenance consumers. TOC managers, Information Services and TSSU each perceived that they had essentially "end-to-end" responsibility for maintaining certain ITS devices, but that means different things to each group. The TOC managers perceive themselves as primarily users of the devices, so it is their ultimate responsibility to ensure that the devices are working satisfactorily, although they may not necessarily make physical repairs to fix a device. Information Services believed their responsibility as a maintenance provider was to provide support at every level to ensure that the device users would be satisfied. TSSU perceived that they had responsibility over the electromechanical aspects of each of the devices, and have worked on modems and communications support for some devices previously. These conflicting understandings of

X - Active responsibility
C - Contracted responsibility

Stakeholders	Sensors	Communications	Field Controller / Processor	Software	Center Sub-System	Information Delivery
Regional Electricians	X	X	X			X
Transportation Data Section	X	X	X			
TOC Managers	X	X	X	X	X	X
Information Services		X	X	X	X	X
Motor Carrier Transportation Division	C	C	C	C	C	C
Traffic Signals Services Unit	X	X	X	X		

Table 2-3: Perceived ITS Maintenance Responsibilities.

responsibility illustrate that there are no clear guidelines for delineation of responsibilities. Most stakeholder groups perceive they are responsible for several elements of the system.

One important point to emphasize is that the lines of perceived responsibility vary by region. In rural areas, where it may be more difficult to obtain appropriate support from Information Services, managers perceive they have a greater repair responsibility over even the computer and communications elements.

2.2.3 Top ITS Maintenance Priorities

Stakeholders were asked, without referring to any pre-determined list of factors, to prioritize their top concerns for ITS maintenance. The most common answers, in no particular order, are as follows:

- Implement and increase consistent training and technical support. Stakeholders were concerned about gaps in training and support, especially in order to sustain 24-hour, 7-day operations.

- Address staffing needs. Stakeholders were concerned not only with the number of staff that could be dispatched to repair problems, but also their capabilities. It was believed that staffing and training levels ought to keep pace with the deployment of devices.

- Introduce standardization of ITS devices, systems and software. Stakeholders perceived standardization as having many benefits to ODOT, such as reducing spare parts inventories and staffing needs, improving the ability to troubleshoot and provide technical support, and reducing long-term maintenance costs. Successful standardization, it was believed, was going to depend upon determining who would be responsible for developing standard specifications, identifying standards which could be scaleable for different regions and needs, and enforcing standards to ensure that they are heeded in procurement decisions.

- Clearly define processes, procedures and budgets. The absence of logging and tracking of ITS maintenance, the absence of a single point of contact for device failure, and a lack of features-based budgeting for ITS devices were among many concerns cited in this area.

- Provide a clarification of roles and responsibilities for ITS maintenance. Table 2-3 indicated the overlapping and misunderstood roles and responsibilities that different stakeholders have. Stakeholders desired that this inefficiency should be resolved.

- Establish prioritization to accomplish tasks. Given scarce resources, there was a desire for a more universal understanding of what is most important for ITS maintenance. Stakeholders at the operations level are looking for increased guidance in this area.

- Create strategic implementation plans. There was a perception in some more rural areas that improved strategic planning of ITS devices would help to better define maintenance needs and strategies.

- Introduce redundancy in personnel, equipment and knowledge. Better logging and tracking of device maintenance history, improved training, and increased dissemination of knowledge among staff were commonly expressed goals. People who by their unique knowledge and skills could present a "single point of failure" desired that others would have the time to increase their respective knowledge and skills as well.

- Focus on pre-deployment testing of equipment. Devices deployed without proper testing can yield significant maintenance headaches in the future. Stakeholders expressed the desire to see devices tested before they were put into the field to reduce the frequency and severity of failure.

2.2.4 Desired Plan Accomplishments

The ITS maintenance plan, because it will cut across so many jurisdictions, requires a significant degree of consensus from the various stakeholder groups if it is to be effective. Therefore, as a final question, stakeholders were asked to define what they desired the plan to accomplish. In addition to the priorities discussed in the last section, four major points came out:

- The plan should serve as a foundation for addressing all issues and regions. Stakeholders wanted this to be a comprehensive yet simple plan for addressing ITS maintenance throughout the state. Because of the many differences between regions that have been discussed, stakeholders felt that the plan should be flexible to regional needs.

- The plan should develop a process for new technology implementation. Stakeholders desired that the plan should not be static, limiting itself only to those devices that are currently deployed or included in the strategic plan. The plan should recommend procurement and deployment strategies for new devices and technologies which reflects upcoming maintenance needs, and delineate a process for determining how maintenance for these devices will be funded and performed.

- The plan should raise awareness of staffing, training, maintenance, and standardization needs. Stakeholders were appreciative of the chance to offer input into the maintenance plan with the hope that it will help them to do their job better. They hoped, therefore, that the plan would help to highlight deficiencies in the existing system in order to provide for improved allocation of resources, especially as additional ITS devices continue to be deployed.

- The plan should clearly define organizational responsibilities. Stakeholders desired greater clarity in the boundary lines for not only their unit's responsibilities, but for other units as well. It was hoped that any organizational responsibilities presented in the plan would be flexible enough to adapt to changes in technology in the future.

The key findings of the stakeholder meetings are summarized in Table 2-4.

2.3 Literature Review

One early task in this project was to research and benchmark other maintenance plans from within and outside of the transportation industry. The first aspect of this research effort focused specifically on maintenance plans developed by other transportation agencies. It was learned that, in general, there are few published plans detailing maintenance of Intelligent Transportation Systems relative to the number of devices employed nationwide. Most plans that have been developed for ITS to date are strategic plans relating to deployment. These plans often have very broad estimates of maintenance costs, with little or no consideration of organizational structure, prioritization, tracking, maintenance procedures and other issues that ODOT has identified as being of critical importance.

Some plans were identified that examine maintenance in greater detail. Table 2-5 provides a detailed tabular summary of each of these maintenance plans[3]. In reviewing these plans, several key points may be made.

- Several metropolitan areas have developed models for maintenance plans. However, during the literature search, however, no statewide maintenance plan was identified. This suggests that ODOT is at the forefront of transportation agencies by attempting to document ITS maintenance needs on a statewide basis.

- Some, but not all, maintenance plans make a connection between device deployment and the resources needed to maintain them. During meetings with stakeholders, it was

[3] More detail on each of these maintenance plans is provided in Appendix B.

Identification and Verification	• Problems traditionally identified via individuals reporting or querying ("pull technology") • Some effective self-diagnosing systems are in use; some available but not presently being utilized (e.g. signal controllers & ramp meters) • Future systems will need greater self-diagnosing capability (e.g. RWIS) • Lack of 24 hour / 7 day support common • Rural applications more challenging to detect than urban
Reporting and Assigning	• No statewide reporting model • No single point of contact • No common procedure (i.e. one-stop shopping) • Information Services Help Desk is trained for traditional desktop PC applications, not ITS applications • Lack of consistent 24 hour / 7 day support
Logging and tracking	• No common form of logging and tracking problems; it varies by groups and regions • Logging and tracking is generally not done, or is done on paper. No common automated means is presently used • No shared logging/tracking database between stakeholders • No collective oversight for problem management, hand-off, tracking and coordination • Desire by stakeholders to track all costs by device (e.g. feature)
Resource Allocation	• Levels of standardization in part determines required levels of staffing, spare parts • Moderate to severe understaffing, depending on location and activity • In some severe cases there is a single individual (single point failure) for maintenance and institutional memory • Current focus is on reactive vs. proactive maintenance; ("fire drills") • There is a need for 24 hour / 7 day focus • Need to consider life-cycle costing (low bid item may mean higher maintenance costs) • Strategic / implementation plans needed (Regions 2 and 3) • Training is universally needed; should be included in specifications and purchasing • Cross-functional training needed for effective fault isolation and troubleshooting

Centralized vs. Distributed System	• Diverse perspectives depending upon group
	  • Electricians: desire centralized budgeting to handle major ITS repairs.
	  • TOC Managers: prefer local ITS maintenance budgets.
	  • Motor Carrier: implementing independent, centralized model through contracting
	  • Information Services: centralization preferred for control of standardized equipment
	  • TDS: suggest central budget for major parts, but charge technician time on regional budgets as utilized.
	  • TSSU: tiered approach – centralized core capabilities with distributed trouble shooting and diagnostics, with similar budgeting.
	• Several groups suggested investigate fleet management model

Table 2-4: Summary of Stakeholder Meetings.

Vendor vs. In-house	• Depends upon several factors • In-house capability generally desired for mission-critical business (e.g. safety) • Technical ability required or training deficiency (vendor) • Depends on availability of support service and willingness to pay? • Contractor more appropriate for non-standardized equipment (tiered approach) • Vendors may fill in gaps left by understaffing
Prioritization	• Diversity of opinion on prioritization, depending upon many factors: • Safety • Traffic control • Liability • Advisory / information devices • Public perception / level of service • Geography
Perceived Responsibilities	• No clear guidelines for delineation of responsibilities • Most stakeholder groups claim responsibility for several elements of the system • Differences in opinion between repair vs. oversight responsibility • There is a difference in perspective of maintenance providers (e.g. Information Services) vs. maintenance consumers (e.g. TOCs) • Boundaries vary by region (rural vs. urban)
Top ITS Maintenance Priorities	• Desire increased and consistent training and technical support (24 hour / 7 day) • Address staffing needs • Implement standardization of ITS devices, systems and software • Clearly define processes, procedures and budgets • Provide a clarification of roles • Establish prioritization to accomplish task • Create strategic implementation plan • Redundancy in personnel, equipment and knowledge • Focus on pre-deployment testing
Desired Plan Accomplishments	• Foundation for addressing all issues and regions • Develop process for new technology implementation • Raise awareness of staffing, training, maintenance, and standardization needs • Define organizational responsibilities

Table 2-4: Summary of Stakeholder Meetings. (cont.)

Categories	Metropolitan Area Plans				State Plans	
	Caltrans District 7 (6)	**Washington St. DOT SC&DI / Seattle (7)**	**Minnesota DOT I-494 ICTM (5)**	**National ITS Architecture (8)**	**Arizona DOT PECOS (9)**	**Texas DOT (10)**
Maintenance Model						
How are problems identified?	1. System operators report system errors to system administrator 2. Reported by system users through cellular phone 3. Network Management System will automatically detect Transportation Operations System communications	Flow engineer monitors for malfunctions	Problems detected by system software and reviewed daily by system operator	Not provided	Not provided	Not provided
How are problems verified?	Detected problems are verified by appropriate support group: • Field Support Engineers • System Engineers • TMC User/ Operator • Technicians • Contract Staff	Radio dispatch assigns the appropriate maintenance personnel to verify the problem and make repairs. The radio dispatcher is given permission by the on-call supervisor	Appropriate agency notified by operator	Not provided	Not provided	Not provided
What is the repair process?	A support group is dispatched (based on prioritization) to repair the equipment.	Maintenance personnel dispatched by SC&DI or FLOW engineer	Notified agency dispatches a technician to repair failed system	Not provided	Not provided	Not provided
What is the logging and tracking procedure?	All repair times and equipment recorded by “trouble-ticket”	Fundamental tracking procedure provided: 1. Reporting the problem (usually by operators) 2. Verification and repair 3. Logging activities through Access database for forecasting purposes	1. Repair activities are logged along with future repair requirements 2. Log is faxed back to operator for tracking of future activities 3. Final log kept on file	Not provided	Problems detected and recorded on PECOS computer system. Inventory, labor, equipment, material recorded via dial-up link for forecasting purposes	Not provided

Table 2-5: Comparison of ITS Maintenance Plans.

	Metropolitan Area Plans				State Plans	
Categories	**Caltrans District 7 (6)**	**Washington St. DOT SC&DI / Seattle (7)**	**Minnesota DOT I-494 ICTM (5)**	**National ITS Architecture (8)**	**Arizona DOT PECOS (9)**	**Texas DOT (10)**
Maintenance Model (continued)						
How are roles and responsibilities defined?	The support staff are listed above. All roles and responsibilities of staff are described within the document.	Responsible parties are as follows: 1. Engineers (Freeway Operators, SC&DI Operators, Flow, Software) 2. Flow Operators 3. Computer Programmers 4. Traffic System Operations Specialists	Based on agency or jurisdiction Agency is responsible for equipment within its jurisdiction. Roles of ICTM staff described, and existing staff for each jurisdiction briefly described.	Not provided	Not provided	Not provided
Repair Prioritization						
What factors determine how repairs are prioritized?	Tasks prioritized on basis of: • Public Safety • Traffic Service • Preservation of facility/operational integrity • Appearance	Response times based on repair time and importance of the equipment in SC&DI system	ITS elements prioritized and activities identified as Critical or Non-critical based on overall system importance Minimal repairs made on low priority equipment until time allows further repairs	Not provided	Not provided	Not provided
Resource Needs						
How are needs estimated?	Labor requirements and maintenance support costs predicted for 10 yr. period Maintenance divided into scheduled and unscheduled tasks Assumed O&M costs stabilize after five years	Maintenance divided into preventative and repair of malfunction categories	Maintenance separated into preventative, critical, and non-critical maintenance tasks based on manufacturer suggestion Limited tasks listed	Maintenance divided into recurring and non-recurring tasks per ITS element tabulated Maintenance provided for various geographical regions	Based on previous year's maintenance costs	Maintenance costs provided for system to maintain system at "tolerable" levels
How are changing needs addressed over time?	First 5 years of plan costs are assumed to rise with additional devices	Costs are expected to rise with preventative maintenance plan	Costs expected to rise following operational test and warranty expiration	Needs assessed for 1996	Costs expected to rise with additional deployment and device replacement	Recommends aggressive upgrading and replacement, but doesn't provide costs

Table 2-5: Comparison of ITS Maintenance Plans. (cont.)

	Metropolitan Area Plans				State Plans	
Categories	**Caltrans District 7 (6)**	**Washington St. DOT SC&DI / Seattle (7)**	**Minnesota DOT I-494 ICTM (5)**	**National ITS Architecture (8)**	**Arizona DOT PECOS (9)**	**Texas DOT (10)**
Resource Needs (continued)						
How does the plan address preventative maintenance?	Specific requirements listed for each piece of equipment	Preventative maintenance performed at same time as repairs Suggested preventative maintenance tasks are provided	Preventative maintenance guidelines not provided but recommended	No schedule is provided Preventative maintenance is included in recurring operations and maintenance costs	No schedule is provided Preventative maintenance is a separate cost item	No schedule is provided Preventative and repair maintenance are combined in cost analysis
Resource Availability						
What are staffing levels?	Person-hours required for maintenance tasks provided	Staffing levels provided, but relationship to maintenance unclear	Person-hour requirements listed to perform tasks	Not provided	Staffing requirements listed in terms of man-hours per equipment	Estimated cost per employee provided
How are staffing levels determined?	Contract support provided for man-power limitations, and specialized sub-systems	Maintenance training for software and equipment	Outside support used for expensive-to-stock equipment	Not provided	Not provided	Not provided
Budgeting						
For what years is a budget developed?	Budget provided 1996-2006	Budget provided 1996 All improvements to be online by 2000	Budget provided 1995	O&M costs provided per system element 1996	Budget provided 1998-2012 Costs provided for next fiscal year based on present year & assumptions	O&M costs provided per system element 1996
How much money is predicted for maintenance?	Funding range $2,941,587 -$6,220,989 per year for operations and maintenance	Maintenance Costs $115,000 per month or $1,380,000 per year	Replacements and services $90,955 annually	Variable budget, depending upon number of devices	Funding range $2,871,376 - $11,177,513 per year for operations and maintenance (includes replacement costs)	Variable budget, depending upon number of devices
What factors determine budget levels?	Quantity of equipment Cost (spare parts, training, tools, test equipment) Person-years to perform tasks	Determined by parts, labor, equipment Personnel costs determined by average hourly income. Final costs determined for maintenance costs, personnel costs, and power, phone, & vehicle costs	Maintenance costs provided for a fully operational system along with person-hour requirements Cost of maintenance based on manufacturer reliability predictions and assumptions made in analysis	Operations and maintenance costs provided for each geographical region based on individual equipment requirements and quantity Tasks and staffing requirements combined in cost analysis.	Preventative (labor, equipment, materials, man-hours) Demand (labor, equipment, materials, man-hours) Replacement Operations	Costs estimates provided per element on a per unit basis. Maintenance (both preventative & repair tasks) Operations

Table 2-5: Comparison of ITS Maintenance Plans. (cont.)

made clear by regional and district maintenance staff that the lack of such a linkage now is hampering current maintenance efforts. ODOT should, therefore, seek to develop such a linkage in its maintenance planning.

- Most maintenance models, except the Integrated Corridor Traffic Management (ICTM) project in Minnesota (6), have been developed for a single, centralized organization. While several organizations were involved in that ITS deployment, however, they were concentrated in a relatively small geographic area. Because ITS technology extends across several ODOT business units, ODOT's maintenance plan will need to have a maintenance model that provides for clear coordination of resources across different units.

- Preventative maintenance is acknowledged as critical to successful ITS maintenance. However, due to a shortage of resources, preventative maintenance tasks are often performed concurrently with repair maintenance tasks.

- Budgeting is normally a major, if not the primary, emphasis in maintenance plans. This is also true for ODOT's maintenance plan, which has as its final step the development of a comprehensive ITS maintenance budget.

The second part of the benchmarking effort focused on making contacts with the private sector. Many companies were contacted in an effort to compile data on representative maintenance plans and procedures from private industry. Company selection was intentionally limited to corporations with far-flung networks of devices similar in scope to a DOT-administered statewide ITS network. An effort was made to focus on companies that are in the midst of a technology leap from traditional infrastructure to more advanced technology systems and communications such as fiber optic communications. Companies contacted included:

- large and small telecommunications companies, such as MCI, AT&T, Bell Canada, Bend Cable, and U.S. West;
- power companies, including Pacific Gas & Electric and Montana Power;
- ITS contractors, such as 3M and International Road Dynamics; and
- many other suppliers of ITS-related components.

Additionally, organizations such as Access ITS, ITS America, the Society of Automotive Engineers, and government sources like the Federal Highway Administration were queried for contact information.

The investigation into private industry plans was less fruitful than the public maintenance planning documentation search, with regards to obtaining actual printed plans. Many working contacts were made with various private industry representatives, but little hard data was forthcoming. Reasons for the lack of success in obtaining plans include corporate guarding of "proprietary" data, lack of private industry incentive to respond to requests for information from a third party, inability to contact and interview busy corporate executives having authority to divulge planning documentation, and simply a lack of any available corporate planning documents.

Despite the lack of specific private industry maintenance planning documentation, some generalizations can be drawn regarding private industry implementation of new technology.

- When considering a new system or component involving advances in technology, a "test bed" approach is typically used to proof items prior to general implementation. This test stage helps determine whether the sensors and other intelligent systems can improve quality of service and also what maintenance and repair equipment and procedures would be needed for implementation.

- Some companies do in-house environmental testing in addition to service-based tests, to help determine life cycle costs and component reliability. Others use vendor data and warranties to supplement in-service testing for selection of components that will become the new standard. In any case, there is typically a service-based trial period prior to system-wide implementation of next-generation hardware.

- More expert systems, using artificial intelligence, are generally desired; testing is planned or under way to determine effectiveness of selected devices and systems. This is being driven by cost and manpower limitations and also by the availability of self-diagnostic capabilities in newer devices and systems.

- Regarding planning and prioritization of maintenance activities, it is currently based on human interpretation and intervention at some state of the process. One source from TCI, regarding the means of prioritizing maintenance activities, said, "His name is Bob!" In other words, an active human presence in the maintenance loop is required to correctly process diverse inputs and to determine a logical and effective course of action. This comment also points to the flexibility needed when processing and prioritizing maintenance activities. Software and hardware advances are helping to limit involvement but a human presence is still mandatory in the decision loop.

- Federal and state organizations may be ahead of many private industries in development of a comprehensive maintenance plan for this type of technology. The private sector's integration of new technology is a sequence of discovery, development, testing and implementation in order to keep a competitive advantage. The creation of a long-term maintenance plan seems in some cases to be a "luxury" that many private companies do not pursue. The philosophy differences between profit-driven private entities opposed to service-driven government agencies should be recognized.

2.4 Summary

From the stakeholder meetings and a review of public and private sector maintenance plans, the following observations maybe made.

- There is consensus at ODOT at many levels that there is a clear need for a maintenance plan.

- The scope of this project reflects the desires of ODOT stakeholders, indicating that this plan should be at least a useful starting point for ODOT's ITS maintenance.
- Plans from other transportation agencies offer some guidance in developing a plan that will meet ODOT's needs, but are often of smaller geographic scale and scope.

3 MAINTENANCE MODEL

As was discussed in last chapter, ODOT stakeholders often mentioned the lack of a clear set of procedures and guidelines to direct how ITS maintenance activities are performed. Such a set of procedures, which will be referred to as a maintenance model, is intended to describe how problems are reported and verified, who is responsible for tracking the maintenance process, and what roles and responsibilities ODOT staff have throughout the process.

A Technical Memorandum from this project (11) presented four maintenance model concepts. Development of each of these concepts was guided by the following assumptions.

1. Each alternative should build upon the existing ODOT organizational structure.

2. Each alternative should include systematic logging and tracking of maintenance.

3. Additional staff will be available for ITS maintenance, although the maintenance model will be used to help identify how these staff should fit into ODOT's organizational structure.

These concepts were subsequently revised for presentation to ODOT in a series of stakeholder meetings that were conducted in August 1999, and are discussed in greater detail in Appendix C. Based on these stakeholder meetings, the two-tier maintenance model was selected as the preferred alternative. This chapter will describe how repair maintenance activities are processed under this model, the roles and responsibilities for various ODOT staff, and recommendations for further action.

3.1 Description of Process

The philosophy behind the two-tier model, as shown in Figure 3-1, is to classify each ITS device into one of two tiers. One tier would consist of "mainstream devices" – i.e. devices which have become standardized within ODOT and for which repair training is adequate for ODOT to be capable of handling nearly all diagnostic and repair capabilities in-house. This would include devices such as traffic signals, ramp meters, and road and weather information systems (RWIS). In some cases, a device may be mainstream in one region but not in another due to broader deployment experience. For example, closed-circuit television (CCTV) cameras would likely be mainstream in Region 1, but they may not be mainstream yet in some of the rural regions. The second tier would be comprised of what are termed "emerging technologies" – i.e. devices which may be limited or non-standardized in deployment. Emerging technologies would be classified not necessarily as technologically new technologies, but technologies that are relatively new to ODOT. Therefore, this would include new technologies such as travel time estimation and automatic incident detection systems, as well as older but non-standardized technologies such as variable message signs (VMS). Over time, perhaps as long as five to ten years, it is hoped that emerging technologies would become "mainstreamed."

One significant feature of this model is the creation of a regional ITS support coordinator position to be on the front line for ITS maintenance. The support coordinator would be expected

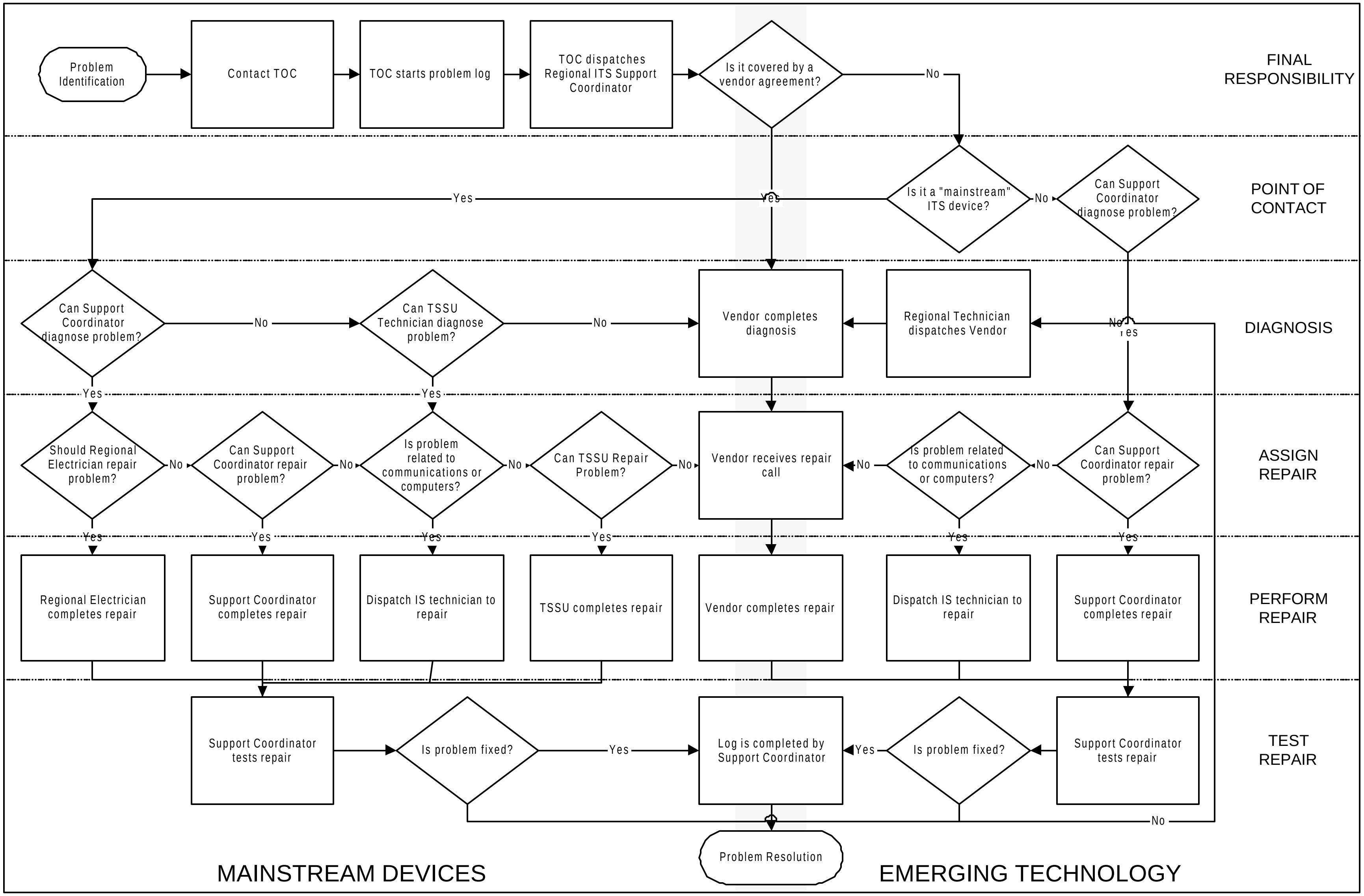

Figure 3-1: Repair Process for Two-Tier Maintenance Model.

to be capable of performing most device diagnostics, some device repairs, post-repair testing and logging. More importantly, however, the support coordinator is expected to be able to identify individuals with the appropriate skills to handle maintenance needs when they occur, and to track the repair until it has been successfully remedied.

The order of the repair process itself differs depending upon which of the two tiers the particular device falls under. For mainstream devices, the process is organized as follows.

- Problem diagnosis. Once a problem is reported, the support coordinator dispatches a regional electrician to diagnose the problem. It is assumed that the electrician will have adequate training to be able to successfully diagnose, if not repair, most ITS problems. If the electrician is unable to diagnose the problem, the electrician will report it to a TSSU technician. If the TSSU technician is unable to diagnose the problem, the TOC is notified and dispatches vendor service to perform a diagnosis.

- Problem repair. Whoever is able to diagnose the problem has significant responsibility in determining how the problem will get resolved. If the electrician diagnoses it and is able to fix it, the repair will be made as soon as possible. If the electrician has diagnosed the problem but is not technically competent to fix the problem, the electrician will contact the next appropriate level of support. If the problem is identified as occurring in the field device, a TSSU technician would be dispatched to complete the repair. For other problems, such as network connections, communications support, and computers for back-end ITS support, an Information Services technician would be assigned. If ODOT staff is unable to repair the problem, the vendor is dispatched.

- Solution testing. After the repair has been completed, the next step is to confirm that the repair has been successful. This requires testing the ITS device to ensure that it is working properly. The regional electrician would be in the field to ensure the device is working properly, although they may need to coordinate with others to perform testing (such as sending test messages to a VMS).

- Logging and tracking. Documentation is needed to track the problem from the beginning of the repair process to repair completion. A paper tracking system may be used, where the paper is handed off from one technician to the other during the process, noting all maintenance tasks performed, until the repair is completed. In the long-term, this system may be supplemented or replaced with a purely computerized system, perhaps using personal digital assistants (PDA) to enter and receive data.

For emerging technologies, the repair process is as follows.

- Problem diagnosis. Once a problem is reported, the support coordinator will make the first effort at diagnosing the problem. If necessary, the regional support coordinator may seek TSSU support to help diagnose the problem. If the regional ITS support coordinator cannot diagnose the problem, the support coordinator would contact the vendor.

- Problem repair. The support coordinator will fix the device to the extent they are capable. In some cases, they may make simple repairs for which a vendor could be called but is unnecessary to do so, such as re-booting a server. It is not expected that the support coordinator will be capable of resolving all ITS problems, but this individual should be able to readily identify who needs to be brought in to fix problems. Information Services would be brought in for communications and computer-related issues outside of the field device, while TSSU would be dispatched for problems at the field device level.

- Solution testing. After the repair is completed, the support coordinator is responsible for verifying that the repair has been successful.

- Logging and tracking. The regional support coordinator is responsible for logging and tracking maintenance activities upon being contacted by the TOC. It is the support coordinator's responsibility to complete the maintenance record, identifying actions taken, individuals contacted, and the corrections made.

3.2 Roles and Responsibilities

Table 3-1 highlights the roles and responsibilities of ODOT staff under the two-tiered model. The TOC is responsible for initiating requests for maintenance, but the problem is then handed off to the support coordinator for resolution. The regional support coordinator would be the single point-of-contact for maintenance, and would have a role in training the regional electricians, but they would also be responsible for handling the maintenance of emerging technologies. The support coordinators will need to be in a continual learning mode in order to stay abreast of current and future ITS deployment technologies. At the district or regional maintenance level, electricians will likewise need to be in a continual learning mode in order to become increasingly familiar with more technologies as they are mainstreamed. Information Services would have maintenance responsibility for ITS components beyond the field device, including back-end computer support and communications linkages between the field devices and the TOC.

3.3 Remaining Issues

Stakeholders agreed that the two-tier model was philosophically preferable, but there was some concern about some of the details. This section highlights the major issues stakeholders raised in connection with the two-tier model. These issues have been, or are in the process of being, addressed as ODOT works on implementing the preferred model alternative. Issues are divided into three broad categories: organizational issues, technological evolution, and staffing and training. Although some preliminary recommendations are provided in some instances, it is beyond the scope of this maintenance plan to fully address these questions.

3.3.1 Organizational Issues

Where does the ITS support coordinator reside? Based on input collected from the stakeholder meetings, it was preferred, if possible, to locate the support coordinators at a regional level in the same building as the TOC. This would improve coordination activities.

ODOT Organizational Unit / Title	Primary Role	Primary Maintenance Responsibilities
TOC	Oversight for ITS maintenance	• Initiates the maintenance process • Initiates the maintenance record
Regional ITS Support Coordinators	First line of ITS maintenance	• Determine if vendor should be first point of contact for a particular repair • Coordinate repair activities • Track entire maintenance process Mainstream Devices • Lead field repair efforts after unsuccessful repair Emerging Technologies • Diagnose most ITS problems • Repair problems to the extent they are capable • Test repairs • Complete repair log
District/Regional Maintenance Staff	First line of ITS maintenance for mainstream devices; no responsibility for emerging technologies	Mainstream Devices • Perform initial diagnosis • Repair problems to the extent they are capable • Test repairs • Complete repair log Emerging Technologies • No ITS maintenance responsibilities
Information Services	Second line of ITS maintenance	• Repair problems related to communications and computers for back-end ITS equipment including network connections to roadside devices
TSSU	Third line of ITS maintenance for mainstream devices; no responsibility for emerging technologies	Mainstream Devices • Diagnose and repair problems beyond capability of regional electricians for roadside devices and sensors Emerging Technologies • No maintenance repair responsibilities
Vendors / Contractors	Last line of ITS maintenance for mainstream devices and emerging technologies	• Fulfill vendor maintenance agreements • Diagnose and repair problems beyond ODOT capabilities

Table 3-1: Maintenance Roles and Responsibilities.

Who does the support coordinator report to? It is envisioned that the support coordinator would report to different individuals for different duties. The support coordinator would report to the regional TOC for billing purposes and for learning of current maintenance issues. It is also envisioned that each support coordinator would report to the recently created ITS standards engineer position in Salem. This would promote information sharing across regions and to allow the support coordinators to cover for each other during vacations or evening and weekend hours.

How does the support coordinator manage maintenance once it goes into other business units, such as Information Services and TSSU? One concern raised by many stakeholders is that the support coordinator would lose some control in problem resolution once they had to hand it off to a different business unit. In some cases, moreover, these business units are not necessarily homogeneous, one-stop entities. If a device is malfunctioning due to what has been identified as an area Information Services is responsible for, there could still be many individuals within Information Services who need to be contacted, depending if it's a hardware, software, server, network, communications or other issue. In order to avoid this, it is recommended that each unit that is involved in ITS maintenance, including Information Services, TSSU and the maintenance districts, identify a single point-of-contact who could shepherd maintenance through that unit. These contact people need to work with each region's support coordinator to develop an understanding of the role of ITS in ODOT's mission and an understanding of which maintenance activities are of highest priority in fulfilling the mission.

Who decides that contract maintenance support needs to be brought in? It is recommended that this decision be made at a local level and that it be coordinated at a statewide level. This may improve the ability to acquire more favorable contractor relationships.

Who manages maintenance support contracts? Maintenance support contracts should similarly be managed at a local level, with a statewide perspective in mind.

3.3.2 Technological Evolution

Who makes the decision about what is mainstream technology versus what is emerging technology? The ITS Technical Working Group likely represents the best forum for appreciating when a technology may be considered mainstream. They have the best statewide perspective within ODOT about the pace of technological innovation with respect to ITS.

Can the evolution decision be made at a local level? Yes; however, this decision ought to be coordinated through the ITS Technical Working Group to promote the coordination of ITS activities throughout the state.

3.3.3 Resources and Training

What is the skill set for the support coordinator? The following are recommended skills that the support coordinator should have.

- Contract administration. The support coordinator will have significant interaction with vendors and contractors, and needs to be able to administer these contracts appropriately.

- First-level diagnostic capabilities. The two-tier model places the support coordinator at the front line for diagnosing emerging technologies. Since emerging technologies are more likely to have self-diagnostic capabilities or rely on solid-state "black box" technology, diagnostics may require less technical skill in the future.

- Some electrical knowledge. If the support coordinator has some electrical knowledge, this may reduce the need for electricians to travel to remote locations to address simple electrical repair needs.

- Some systems/networking knowledge. Similarly, the support coordinator should have some elementary computer knowledge in order to be able to repair simple problems on their own, such as re-booting a server, testing network connectivity, etc.

- Licensing. While licensing may be valuable for repairs involving electrical or communication systems, a licensing requirement would tend to make this skills set practically impossible to fulfill. Therefore, it is recommended that this position not require any special licensing or certification. The support coordinator should learn what types of repairs require licensing or certification to complete, and which ODOT technicians have the appropriate background to do those repairs.

Can people with these skills be recruited and retained? This rhetorical question is a natural outcome of examining the desired skill level for the support coordinator position.

Does an appropriate job classification exist? In the positions approved for the Traffic Management Section, the support coordinator position was designated as Traffic Signal Technician-2 (TS-2). Based on the skill set, it may be necessary to classify the position as a level 5 Information Services technician (IS-5), or perhaps create a new classification.

How do you balance the recently approved additional ITS unit FTEs versus the number of needed support coordinators? The three approved support coordinator positions would not allow there to be one support coordinator for each of the four existing TOCs, or for the fifth planned TOC. There are a few potential solutions to this problem, each of which has some disadvantages.

- Use a contractor. Contract support could provide a fairly immediate method for staffing each of the TOCs with a support coordinator. The principal drawback in using contract support for this position is that the position will be most effective when the support coordinator can establish long-term relationships throughout ODOT to expedite maintenance activities. Furthermore, it would be philosophically preferable to have the support coordinator positions filled by ODOT staff in order to foster a sense of organizational "ownership" of ODOT's ITS infrastructure and to allow it to become integrated into ODOT's mission alongside more traditional maintenance activities.

- Have support coordinators centrally located (in Salem) until a sufficient number of coordinators can be obtained to staff each of the regions. An arrangement like this would encourage the support coordinators to work together as a team. This solution has the disadvantage of preserving a separation between operations and maintenance functions in each of the regions. Once additional positions are obtained, would ODOT be able to keep these individuals in those positions and yet move them to different regions of the state? Moreover, it would become increasingly complicated for the support coordinators to perform first-line diagnostics and basic repairs when they may be several hours distance from malfunctioning devices.

- Allocate the three support coordinators over the entire state. Under this concept, one support coordinator might be responsible for northwest Oregon including Region 1 and northern Region 2, another support coordinator would be responsible for southwest Oregon (Region 3 and the remainder of Region 2), and the third coordinator would be responsible for Regions 4 and 5. This would allow ODOT to implement the two-tier model, with a single point-of-contact, on a statewide level while allowing for room to grow as additional support coordinator positions are obtained. One question with this possible solution is whether the three support coordinators could adequately handle the workloads without suffering professional burnout.

- Postpone implementation of the two-tier model until additional positions are obtained. This solution looks at implementing the two-tier model as an "all-or-nothing" proposition. Due to the time lag that exists between realization of a staffing need and ODOT's ability to procure an FTE, this solution would likely promote inertia and reduce the likelihood of many of ODOT's current ITS maintenance problems being remedied in the near future.

How do you cover 24-hour/7-day operations with one FTE per region? ITS devices may not always malfunction during regular business hours. Accordingly, the support coordinator role needs to be provided in some capacity to match the 24-hour/7-day operational needs of many ITS devices. One potential solution is to have the support coordinators work as a coordinated team, with them rotating to take turns being on-call during evening and weekend hours. This will succeed only if two things occur. First, the TOCs must prioritize when maintenance issues warrant after-hours support. This relates to the regional prioritization of ITS maintenance, which was discussed in the first technical memorandum. Second, the workload of the support coordinators must be manageable enough during business hours that on-call duty will not be perceived as a time-consuming burden. Otherwise, this will increase the difficulty of recruiting qualified people for these positions.

How do you provide training for emerging technologies? It is likely that basic maintenance training would be provided for support coordinators (and perhaps a couple of maintenance staff) upon device deployment[4]. The challenge for ODOT will be to ensure that there is a technology transfer from the few who learn the maintenance procedures initially to the many who will need to know it upon large-scale device deployment.

[4] See Chapter 6 for a more in-depth exploration into training issues.

4 REPAIR PRIORITIZATION

One critical part of the daily maintenance operations of an organization is the determination of how repairs should be prioritized. This chapter will examine existing procedures for prioritizing repairs within the Oregon Department of Transportation (ODOT) and in other transportation agencies, as well as stakeholder perspectives on the key factors that should influence repair prioritization for Intelligent Transportation Systems (ITS) devices. This chapter will culminate in recommendations for a set of guidelines for prioritization of repairs of ITS devices.

4.1 Review of Existing Prioritization

In order to develop reasonable guidelines for prioritizing maintenance, research was done into procedures in place at ODOT and other transportation agencies. This section highlights the findings from these efforts.

4.1.1 Oregon Department of Transportation

In the ODOT Maintenance Guide (12) a prioritization order has been developed for the repair of electrical work, as shown in Table 4-1. In reviewing these guidelines, several features in the current prioritization scheme should be emphasized:

- The existing guidelines place top priority on safety and legislative mandates. Of particular interest is the priority placed on draw bridges and bridge navigation lights. According to ODOT staff, the maritime system has a higher maintenance priority than the highway system because it was established earlier so marine vessels have

Type of Electrical Repair (in order of decreasing priority)	Priority
Emergency services (includes improper signal operation, signal red-out, electrical knockdowns, and any other instance where electrical safety is of concern)	24 hr / 7 day service
Draw bridges and bridge navigation lights	24 hr / 7 day service
Traffic signal repair	24 hr / 7 day service
ODOT radio communications sites	24 hr / 7 day service
Rest areas, ports of entry, scale sites	24 hr / 7 day service
Traffic signal construction and change-out projects	no priority given
Scheduled traffic signal maintenance	no priority given
Scheduled street lighting maintenance	no priority given
Scheduled maintenance for tunnels, rest areas, ports of entry, and scale sites	no priority given
ODOT buildings (construction or maintenance)	no priority given
Outside agency electrical work (non-signal)	no priority given

Table 4-1: Existing Prioritization of Electrical Repair Work.

(Source: 12)

ultimate right-of-way.

- The top electrical maintenance priorities are expected to have 24 hour / 7 day support. For the top five types of electrical repair, it is anticipated that support will be available around-the-clock. The Maintenance Guide adds that emergency electrical services require personnel to be “on call and prepared to respond” for these requests. In other words, when an electrician, with proper licenses and certification, is contacted, they have the responsibility to respond and correct the problem.

- Repair maintenance takes precedence over preventative (scheduled) maintenance activities.

- The existing guidelines do not include most Intelligent Transportation Systems (ITS) devices. Traffic signals, radio communications sites, ports of entry and scale sites are probably the types of repair most similar to ITS repair.

Not indicated on the chart is an additional level of prioritization for traffic signal repair. ODOT employs a three-tier system for assigning repairs to traffic signals (12).

- Category 1 – Intersections operating at level of service (LOS) F when in flash condition during the 8th highest traffic volume hour of the day.

- Category 2 – Intersections operating at LOS F when in flash condition during the peak traffic hour, but not during the 8th highest hour of the day.

- Category 3 – Intersections operating at LOS E or better in flash condition during the peak traffic hour of the day.

According to ODOT’s guidelines, all Category 1 signals must be repaired before Category 2 signals are repaired, and all Category 2 signals must be repaired prior to repairs on Category 3 signals.

4.1.2 Other Transportation Agencies

Some of the maintenance plans discussed in Chapter 2, along with other documents identified by WTI staff, include guidance for prioritizing ITS maintenance. These prioritization guidelines are summarized in tables in Appendix D. The following two observations may be made about prioritization guidelines presented in these documents.

- Devices are typically prioritized according to their relative necessity to the daily operation or integrity of the system.

- Safety-related or traffic control devices tend to have a higher priority than traveler information devices.

4.2 Review of Stakeholder Input

As was shown in reviewing ODOT's existing prioritization guidelines, most ITS devices are currently not considered as a part of repair prioritization decisions. Consequently, surveys were distributed in June 1999 to the ITS Executive Steering Committee, the TOC Managers and the District Managers in order to determine how ODOT stakeholders perceive the repair priority of different ITS deployments (13). The survey forms are included as Appendix E, and the results of these surveys are detailed in Appendix F.

In summary, stakeholders indicated that prioritizing ITS device repair is going to be highly dependent on several factors, including:

- device type,
- device location within region,
- device function,
- region, and
- time of year.

There were different responses between district managers and TOC managers in different geographical areas, which highlights the need for some flexibility in prioritization, in order to allow local decision-makers to develop guidelines which best meet their needs.

4.3 Guidelines for Prioritizing Repair

Based on ODOT's existing prioritization schedule, stakeholder input, and a review of repair prioritization guidelines developed by other agencies, this section will give broad guidelines for how ITS maintenance can be prioritized across the state. These guidelines are intended to be flexible according to local needs. Because of the differences in priorities that exist across regions, this section will also examine how the priority scheme may be implemented on a regional basis to reflect local conditions.

4.3.1 General Guidelines

Figure 4-1 presents a suggested model for deciding how ITS maintenance should be prioritized across the state. The model is a broad flow chart, describing maintenance problems not by device specifically but by device function and problem type. Response times are listed as recommendations only; specific response times may be shorter for critical deployment locations. The ability to meet response times depends primarily on the availability and flexibility of staff and other resources. Actual response times should be used primarily as performance criteria for evaluation of the adequacy of maintenance resources to meet regional needs.

Each portion of the model in Figure 4-1 will be discussed in greater detail in this section.

4.3.1.1 Fulfill Legal Mandates

The first priority for ODOT in ITS maintenance should be to satisfy legislative mandates or legal requirements. Currently, few of ODOT's ITS devices could be classified as necessary to

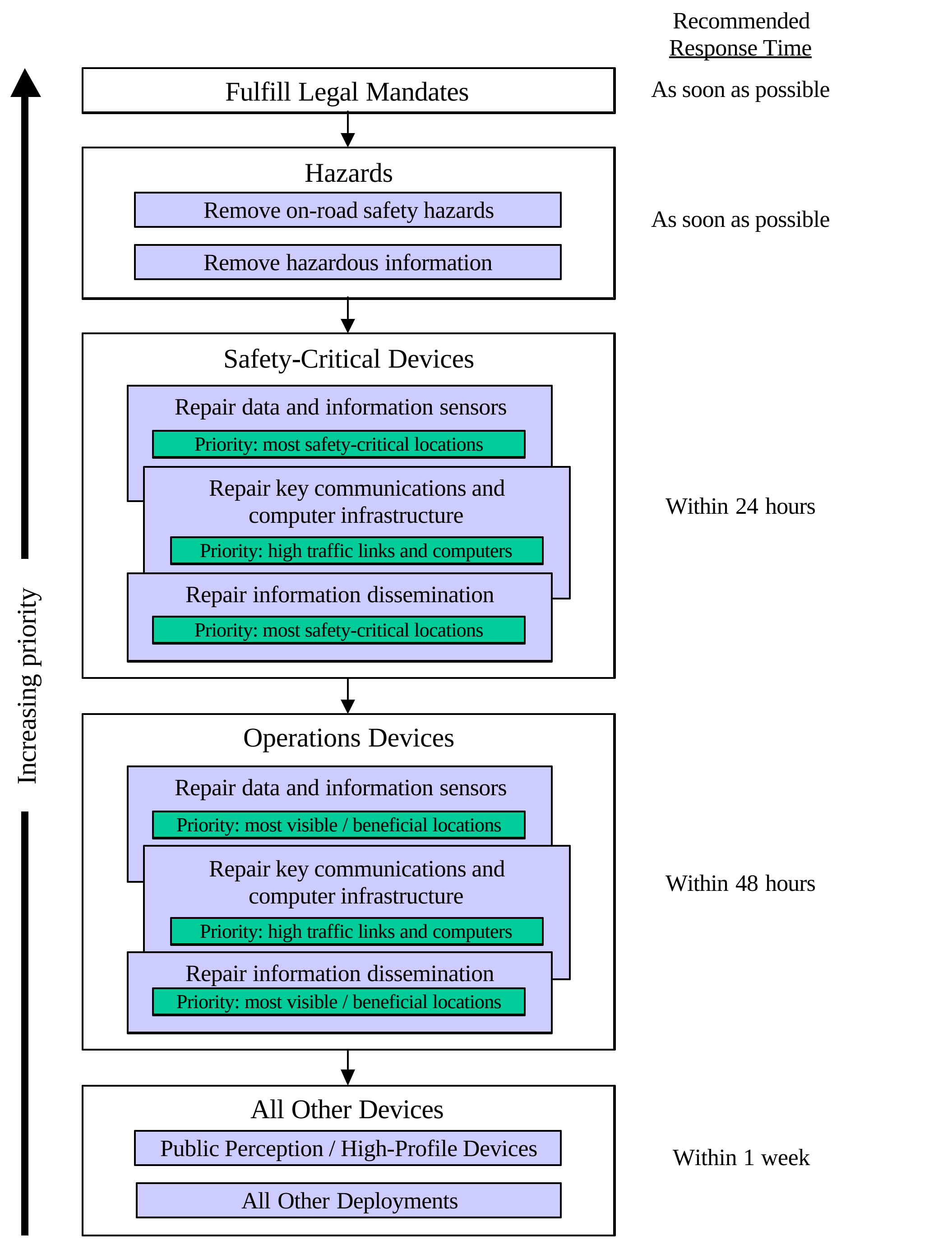

Figure 4-1: Prioritization for ITS Maintenance.

fulfill specific legislative mandates. One exception is ATRs which, according to ODOT staff, are required by federal mandates. Some other devices, such as traffic signals, may have liability implications if they are non-operational, but there is not necessarily a liability concern if they are not operational.

4.3.1.2 Hazards

The second priority level for ITS maintenance is to address safety hazards caused by ITS devices. Safety is considered to be critical to ODOT, as illustrated not only by the survey responses of various ODOT stakeholders but also in the agency's mission statement: "to provide *safe* and effective transportation systems that support economic opportunity and livable communities for Oregonians." (emphasis added) (1) When they are maintained well, ITS devices may provide significant safety benefits.

Poorly maintained or non-operational ITS devices can have one of two adverse safety consequences. First, at a minimum, non-operational devices will have no net safety benefit and will have essentially diverted capital dollars from programs where they may have been a better safety benefit, such as improving guardrails or roadway reflectors. At worst, a non-operational device could create a greater hazard by its presence than if it were not there at all. Examples of this could include ITS devices that fall off of their support structures and into the roadway, or exposed electrical wiring which could result in electrical shock. In addition, as the public places greater trust in en-route information systems, non-operational devices could result in significant additional safety problems. For example, truck drivers may get used to relying on signs associated with a downhill speed advisory system rather than their own judgment for determining their vehicle speed. As a result, if the system is not functioning properly, drivers may exceed safe speeds, resulting in potential injuries or fatalities.

Consequently, after fulfilling any legislative mandates, ODOT should address present electrical and physical safety hazards introduced by malfunctioning devices. As soon as ODOT is made aware of these kinds of problems, ODOT should dispatch repair services to provide emergency clearance of the problem, not necessarily to restore the device to normal operation. For example, if a variable message sign was disconnected from its canopy and fell to the roadway, maintenance personnel should remove the sign from the roadway first as an emergency precaution. Restoring the sign to useful operation would fall further down the prioritization list, based on other factors.

After this, the next priority is to make sure that there are no information dissemination devices that are giving bad and potentially harmful information to users. Incorrect information may increase risks for drivers depending upon the information provided. For example, an outdated VMS message encouraging drivers to take a detour route to avoid an incident on the freeway may direct them into worse conditions as conditions have changed, with potential safety problems. ODOT should focus on information dissemination devices, such as VMS, the 800-telephone numbers, and information kiosks, which are reported to be providing potentially hazardous information. The goal of repairing these devices is not necessarily to restore the device to operations, but to stop the flow of erroneous information.

4.3.1.3 Safety-Critical Devices

Because of the high priority placed on safety not only throughout ODOT but also in other transportation agencies, devices that have a high impact on motorist safety should have a high repair priority. Therefore, after addressing safety hazards, the next level of priority shown in

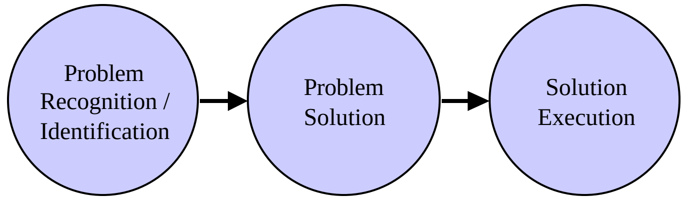

Figure 4-2: Information Flow for ITS Devices.

Figure 4-1 are safety-critical devices. "Safety-critical" is a broad term that may include various types of ITS devices, depending upon the region, the time of year, and other factors.

For every ITS device that provides a safety benefit to the motoring public, there are three stages involved in the device's operation, as shown in Figure 4-2.

1. Problem recognition or identification. The device must first recognize there is some sort of existing or potential problem. This may be accomplished through human recognition of a problem (through surveillance cameras or other observations) or through automated recognition of a problem (through inductive loops, for example).

2. Problem solution. After recognizing the problem, an appropriate solution must be developed. This may be done through human intervention or an automated procedure.

3. Solution execution. Once the solution to the problem is developed, the solution is executed and users/operators are appropriately informed.

The integrity of the entire process, therefore, hinges on accurate information. Without accurate information, problems cannot be properly recognized, or the solutions to problems cannot be properly executed and acted upon by users and operators. Since the first step in the process is the recognition of problems, maintenance efforts should focus first on those devices that, when operational, could identify when problems have occurred. Emphasis should be particularly placed on locations where the greatest number of safety problems may occur.

Once it is assured that accurate information is available, the next priority is to assure that this information can get to the TOC operators. This includes the entire communications and computer network that goes between field devices and the TOC. The level of priority for this indicates that maintenance support for communications and computer equipment needs to parallel the operations of the transportation operation centers. If a TOC is operating on a 24-hour-a-day, 7-day-a-week basis, maintenance support for communications and computer equipment needs to be available at the same level. The greatest emphasis should be placed on the portions of the information network receiving the most traffic, including critical servers.

Once communications links have been addressed, the next step is to have decisions made at the TOC level communicated to users. This will involve not only the communications network between the TOC and any field devices providing information, such as VMS, but also operations of field devices which provide information.

As Figure 4-1 shows, there may be some overlap between these priorities. Decisions to prioritize should have some flexibility within this framework to address unusual repair circumstances. In cases of catastrophic failure with the communications or computer systems, for example, these problems would likely take precedence since other maintenance concerns would be unable to be identified or addressed.

It should be the responsibility of TOC managers and district managers to identify the most critical, safety-oriented aspects of their respective jurisdictions, and place appropriate emphasis on their maintenance.

4.3.1.4 Operations-Critical Devices

After safety-critical maintenance has been taken care of, the next step would be to perform maintenance on ITS devices that enhance and improve the operational efficiency of the transportation system. This would include a variety of systems, such as ramp meters, some VMS deployments, and weigh-in-motion systems.

At this point, prioritization may reflect more economic issues: the number of users who would benefit, the amount of time which could be saved, or the amount of inconvenience that could be avoided. Repair should be prioritized to maximize the amount of benefit that can be yielded. As was done with the safety-related devices, precedence should be placed first on ensuring that information provided from the field is correct, then on repairing the communications network, and finally on the information dissemination component to the public.

4.3.1.5 All Other Devices

There are many devices that may have no direct safety benefits and very limited operational benefit but are perceived as very valuable by the traveling public for the information they provide. These devices would be considered next in the priority list. Examples of these might include kiosks, as well as Internet pictures from ODOT's field cameras during non-winter travel. These devices will be often be used for pre-trip planning, and may improve the travel experience for travelers in the state, especially recreational travelers and tourists.

4.3.1.6 Comparison to Existing Guidelines

Figure 4-3 presents a comparison between these guidelines and ODOT's existing prioritization scheme. There are several pertinent observations that can be made from this comparison.

- Both prioritization schemes emphasize liability, safety and high profile maintenance. In this way, the proposed prioritization scheme does not represent a radical restructuring of existing ODOT procedures.

- The existing prioritization scheme assumes a degree of separation between electrical components which does not exist under ITS. For example, the current prioritization scheme delineates traffic control and communication components as separate priorities. Consequently, the proposed prioritization scheme indicates some overlap between traffic control and communications elements, based on device function.

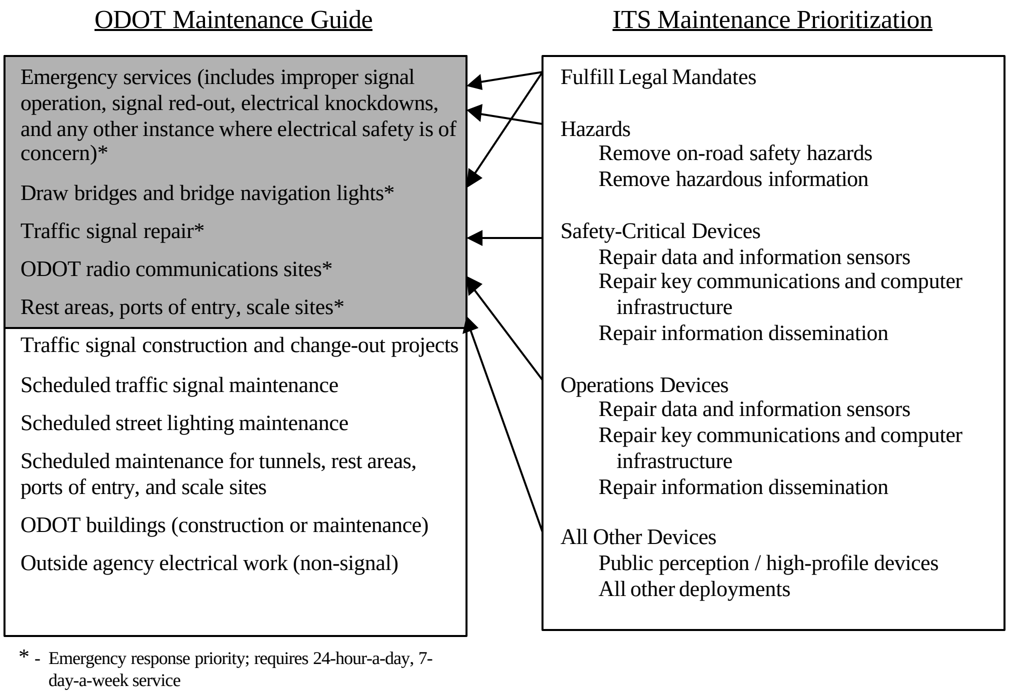

Figure 4-3: Comparison Between Proposed ITS and Existing Prioritization Schemes.

- ITS maintenance logically falls toward the upper end of maintenance priorities according to ODOT standards. According to the existing ODOT maintenance procedures, all of these types of devices are classified as emergency response priorities, with on-call service available on a 24-hour, 7-day-a-week basis. This is consistent with the trend toward continuous operations at the TOCs.

- The proposed guidelines have greater flexibility than the existing guidelines. This flexibility is largely due to the nature of ITS devices, and is necessary for managers and operators to identify priorities based on regional needs. It should be noted that, without proper documentation of priorities by TOC staff, this has the potential to increase the single-point-failure concept that was a concern of stakeholders. Regions would be encouraged to document lists of device priorities, by time of year as appropriate, to not increase the likelihood of single-point-failure.

4.3.2 Regional-Specific Guidelines

It has been emphasized throughout this chapter that prioritizing repairs is a decision that is best left to individuals who are closest to each of the regions and their unique travel needs. However, since this chapter has been primarily abstract and theoretical, it may be helpful to show how priorities might work out in different environments. Table 4-2 provides a broad categorization of how priorities may work out in different environments. Four different combinations of geography and weather are considered, based on an urban or a rural TOC, under

Device		Safety-Critical				Operations-Critical				Other			
	Response Time	24 hours				48 hours				1 week			
		Location		Weather		Location		Weather		Location		Weather	
Data Collection	Automatic Traffic Recorders									Urban	Rural	Hazardous	Good
	Speed Zone Monitoring Stations									Urban	Rural	Hazardous	Good
	Closed-Circuit Television (CCTV)	Urban (some)	Rural (some)	Hazardous		Urban (some)			Good		Rural (some)		Good
	Video Detection Systems					Urban	Rural	Hazardous	Good				
	Road and Weather Information System (RWIS)	Urban (some)	Rural (some)	Hazardous						Urban (some)	Rural (some)		Good
	Travel Time Estimation					Urban	Rural	Hazardous	Good				
	Automatic Vehicle Location (AVL)	Urban (some)	Rural (some)	Hazardous		Urban (some)	Rural (some)		Good				
Traffic Management	Traffic Signals	Urban	Rural	Hazardous	Good								
	Ramp Metering Systems					Urban	Rural	Hazardous	Good				
	Emergency Signal Preemption	Urban	Rural	Hazardous	Good								
	Transit Signal Prioritization					Urban	Rural	Hazardous	Good				
	Advanced Traffic Management System	Urban	Rural	Hazardous	Good								
Incident Detection	Mayday Callboxes	not applicable											
	Cellular Call-In	not applicable											
	Urban Automatic Incident Detection System	Urban		Hazardous	Good								
	Intersection-Based Incident Detection System	Urban	Rural	Hazardous	Good								
Incident Management and Response	Computer-Aided Dispatch					Urban	Rural	Hazardous	Good				
	Incident Response Vehicles	Urban	Rural	Hazardous	Good								
	Pre-Planned Detour Routes	not applicable											
	Hazardous Materials Response	Urban	Rural	Hazardous	Good								
Pre-Trip Traveler Information	Alpha-Numeric Paging	not applicable											
	Highway Travel Conditions Reporting System	Urban	Rural	Hazardous	Good								
	800-number information	Urban (some)	Rural (some)	Hazardous		Urban (some)	Rural (some)		Good				
	Internet access	Urban (some)	Rural (some)	Hazardous						Urban (some)	Rural (some)		Good
	Kiosks	Urban (some)	Rural (some)	Hazardous						Urban (some)	Rural (some)		Good
En-Route Traveler Information	Icy Bridge Warning System (Low-Tech)	Urban (some)	Rural (some)	Hazardous						Urban (some)	Rural (some)		Good
	Tunnel lane closure advisory	Urban	Rural	Hazardous	Good								
	Snow Zone Advisory	Urban (some)	Rural (some)	Hazardous						Urban (some)	Rural (some)		Good
	Snow Zone Changeable Message Sign	Urban (some)	Rural (some)	Hazardous						Urban (some)	Rural (some)		Good
	Oversize Vehicle Closure CMS	Urban (some)	Rural (some)	Hazardous		Urban (some)	Rural (some)		Good				
	Bridge CMS	Urban	Rural	Hazardous	Good								
	Permanent Variable Message Signs (VMS)	Urban (some)	Rural (some)	Hazardous		Urban (some)	Rural (some)		Good				
	Portable Variable Message Signs (VMS)	Urban (some)	Rural (some)	Hazardous		Urban (some)	Rural (some)		Good				
	Highway Advisory Radio (HAR)	Urban (some)	Rural (some)	Hazardous		Urban (some)	Rural (some)		Good				
	Icy Bridge Detectors	Urban (some)	Rural (some)	Hazardous		Urban (some)	Rural (some)		Good				
	Oversize load detectors	Urban (some)	Rural (some)	Hazardous						Urban (some)	Rural (some)		Good
	Variable speed limit signs	Urban	Rural	Hazardous	Good								
	Queue Detection System	Urban	Rural	Hazardous	Good								
Commercial Vehicle Operations	Weigh-in-Motion (WIM) Stations					Urban	Rural	Hazardous	Good				
	Downhill Speed Advisory Systems	Urban	Rural	Hazardous	Good								
Communication Systems	Fiber optic networks	Urban	Rural	Hazardous	Good								
	Radio Communications	Urban	Rural	Hazardous	Good								
	Maintenance Coordination	Urban	Rural	Hazardous	Good								

LEGEND				
Some	All		All	
Urban (some)	Urban	Urban Deployment	Hazardous	Hazardous Weather
Rural (some)	Rural	Rural Deployment	Good	Good Weather

Table 4-2: Regional Repair Prioritization Guidelines.

good or bad weather conditions. The gray boxes indicate devices in which some but not all locations would be classified at the indicated priority level.

These guidelines place high statewide priority on devices that have clear safety implications, such as traffic signals and variable speed limit signs. Emphasis is also given to devices or systems that help to reduce the time between incident occurrence and the deployment of an appropriate response. This includes the advanced traffic management system, the hazardous materials response system, fiber optic communication systems and incident response vehicles.

Many ODOT's ITS field devices in Table 4-2 are depicted with gray boxes, indicating the need for regional input in identifying the most critical device locations. Because incidents are more likely to occur under inclement weather, the repair priority of most ITS devices is elevated when the weather turns bad.

4.4 Recommendations

In order to implement the repair prioritization guidelines depicted in Figure 4-1, there are at least three actions which need to be undertaken in order to ensure these guidelines will be both usable and useful.

- Communicate throughout ODOT the importance of ITS to fulfilling ODOT's mission. Figure 4-3 showed clearly how ITS maintenance should rank as a high-priority maintenance item under ODOT's prioritization schedule for electrical maintenance. This fact should be communicated through the agency.

- Each region should develop and publish guidelines for identifying specific high-priority maintenance items. These guidelines should be coordinated at a statewide level, to improve identifying when staffing resources should be shared across regions.

- ODOT should identify and locate resources to meet response time goals. This is especially critical because some ITS devices that have high public visibility, such as kiosks, are ranked as lower in priority than other devices. ODOT may require a combination of in-house staff and contract maintenance to meet its response time goals. This topic will be discussed further in Chapter 6.

5 PREVENTATIVE MAINTENANCE

Preventative maintenance is a critical maintenance activity that may be used in order to delay or reduce the need for repair maintenance, as well as increasing the useful life of field devices. Based on the stakeholder meetings described in Chapter 2, however, preventative maintenance is generally underperformed or neglected by ODOT because of inadequate knowledge of the frequency and nature of required preventative maintenance tasks as well as inadequate staffing levels. This chapter will focus on the first of these causes by delineating appropriate preventative maintenance tasks for each device in ODOT's existing and planned ITS infrastructure. This will be followed by a brief discussion of roles and responsibilities relating to preventative maintenance, and recommendations for actions with respect to pursing preventative maintenance more consistently.

5.1 Recommended Practices

Because preventative maintenance is sometimes considered to be a "luxury" when resources are constrained, there is often not a consensus on what the best preventative maintenance practices for each device should be. Table 5-1 shows a summary of recommended preventative maintenance tasks and frequencies for the various elements of ODOT's existing and planned ITS infrastructure. Recommended frequencies are based on a review of guidelines developed by Caltrans and the Washington State Department of Transportation (WSDOT) in conjunction with the ITS maintenance plans they developed (6, 7), as well as conversations with product vendors and ODOT personnel.

5.2 Roles and Responsibilities

Because of the time-insensitive nature of many preventative maintenance activities, they could be performed in a "vacuum" – i.e. independent of the two-tier maintenance model presented in Chapter 3. For example, electricians may develop a regular rotation schedule to address preventative maintenance needs in a particular region without the explicit knowledge of the support coordinator. While this approach helps to shift some coordination work away from the support coordinator, it has the drawback of discouraging economy in trips to field devices. For example, if a repair visit occurs a couple of days before a scheduled preventative maintenance activity, the technician could do both the repair and preventative maintenance in one trip, providing savings in travel time. Therefore, preventative maintenance activities should be coordinated through the support coordinator, similar to repair maintenance activities.

5.3 Recommendations

In order to implement an effective preventative maintenance schedule, the following actions are recommended.

- Document required preventative maintenance tasks for each device. A detailed checklist should be developed for field personnel that would list all tasks that are to be performed on each preventative maintenance visit. This checklist would help to guide training of new maintenance personnel, as well as provide a way of ensuring

Device	Component	Maintenance Procedure	Frequency
Data Collection			
Automatic Traffic Recorders (1)	Controller	Check batteries; visual inspection and cleaning; check connections	Every 12 months
	Loops	Visual inspection and testing	Every 12 months
	Cabinet	Visual inspection and cleaning	Every 12 months
Speed Zone Monitoring Stations (1)	Controller	Check batteries; visual inspection and cleaning; check connections	Every 12 months
	Loops	Visual inspection and testing	Every 12 months
	Cabinet	Visual inspection and cleaning	Every 12 months
Closed-Circuit TV (CCTV) Surveillance	Support Structure	Visual inspection	Every 12 months
	Pan-Tilt-Zoom Units	Visual inspection and testing	Every 6 months
	Camera / Lens / Filter	Clean lens; visual inspection; check enclosure pressure	Every 6 months
	Camera Housing / Cables	Cleaning and visual inspection; check connections	Every 6 months
	Camera Control Receiver	Check pan-tilt-zoom capability using laptop; check connections	Every 6 months
	Camera Servers and Modems	Visual inspection and check connections	Every 12 months
	Weather Equipment	Visual inspection and calibration	Every 12 months
	Surge Protection / Power	Visual inspection and testing	Every 6 months
	Video switching equipment (Region 1)	Visual inspection and testing; check connections	Every 6 months
	Video rack equipment (Region 4)	Visual inspection and testing; check connections	Every 6 months
	Camera Server Software	Install manufacturer upgrade	As available
	Camera Server	Database and server management activities	Every week
Video Detectors	Support Structure	Visual inspection	Every 12 months
	Video Detector	Clean lens; visual inspection; calibration	Every 12 months
	Controller	Check batteries; visual inspection and cleaning; check connections	Every 12 months
	Surge Protection / Power	Visual inspection and testing	Every 12 months
Road and Weather Information System (RWIS)	Sensors	Visual inspection; cleaning and calibration	Every 12 months
	Local cable and wiring	Visual inspection	Every 12 months
	RPU	Re-boot and visual inspection	Every 2 months
	Modems / Routers	Visual inspection; check connections	Every 12 months
	Software (SCAN & Database)	Install upgrades as available	As available
	Surge Protection / Power	Visual inspection and testing	Every 6 months
	Servers (Regional / Statewide)	Database and server management activities	Every week

(see last page of table for legend)

Table 5-1: Preventative Maintenance Schedule.

Device	Component	Maintenance Procedure	Frequency
Data Collection (cont.)			
Travel Time Estimation	Camera	Visual inspection; clean lens; test alignment	Every 6 months
	Light Source	Visual inspection and testing	Every 6 months
	Modems	Visual inspection; check connections	Every 12 months
	Controller / RPU	Re-boot and visual inspection	Every 2 months
	Software (RPU)	Install upgrades	As available
	Cabinet	Visual inspection and cleaning	Every 12 months
	Travel Time Server	Database and server management activities	Every week
	Software (Server)	Install upgrades	As available
Automatic Vehicle Location (AVL)	Vehicle sensors	Inspection, calibration and cleaning	Every 12 months
	AVL Software	Install upgrades	As available
	AVL Server	Database and server management activities	Every week
Traffic Management			
Ramp Metering (1)	Loops and Detectors	Visual inspection and testing	Every 3 months
	Signal Heads	Check bulbs and alignment	Every 3 months
	Signal Controller	Visual inspection; cleaning and testing	Every 3 months
	Controller cabinet	Visual inspection and cleaning	Every 3 months
Signal Preemption for Emergency Vehicles (1)	In-vehicle unit	Testing	Every 12 months
	Optical reader	Visual inspection and testing	Every 12 months
	Controller	Visual inspection and cleaning	Every 12 months
Preferential Signal Treatment for Transit (1)	In-vehicle unit	Testing	Every 12 months
	Optical reader	Visual inspection and testing	Every 12 months
	Controller	Visual inspection and cleaning	Every 12 months
Advanced Traffic Management System (ATMS)	Operator workstations	Re-booting, testing and upgrades	Every month
	Communications within TOC	Visual inspection; check connections and cabling	Every 12 months
	Software	Upgrades and enhancements	As available
	ATMS Database	Database pruning and management	Every week
	Servers	Server management activities	Every week
Incident Detection			
Callboxes	Telephone handsets	Test equipment	Every month
Cellular Call-in	Roadside signs (1)	Prune vegetation	Every 12 months
Regional Incident Detection System	Server	Database and server management activities	Every week
	Software	Install upgrades	As available
Intersection-Based Incident Detection System	Controller / RPU	Re-boot; visual inspection	Every 2 months
	Software / firmware	Install upgrades	As available

(see last page of table for legend)

Table 5-1: Preventative Maintenance Schedule. (cont.)

Device	Component	Maintenance Procedure	Frequency
Incident Management and Response			
Computer-Aided Dispatch (CAD)	CAD Server	Various computer maintenance activities	(2)
	CAD workstations	Re-booting, testing and upgrades	Every month
	Communications within TOC	Inspect, check connections and cabling	Every 12 months
	Software	Install upgrades	As available
	Database management	Various database management activities	(2)
Incident Response Vehicles	On-board VMS	Visual inspection and cleaning; testing	Every 6 months
	Vehicle maintenance	Based on mileage, manufacturer's recommendations	(1)
Pre-planned Detour Routes	Route selection	Test route selection algorithms in each region	Every 12 months
Hazardous Material Response	Modems / routers	Visual inspection, check connections	Every 12 months
	Software (database)	Install upgrades	As available
	HazMat Server	Server and database management activities	Every week
Pre-Trip Traveler Information			
Alphanumeric Paging	Software	Install upgrades	As available
Highway Travel Conditions Reporting System (HTCRS)	Database management	Pruning and database management	Every week
800-number Information	Communications in WRDC	Inspect, check connections and cabling	Every 12 months
	Software (voice generation)	Install upgrades	As available
	Software (phone server)	Upgrades and enhancements	As available
	Servers	Re-boot; server management activities	Every week
Internet Access	Web server	Re-boot; server management activities	Every week
Kiosks	Terminals	Inspect; clean monitors and cabinets	Every month
	Network connections	Check connections, replace cabling	Every 12 months
	Thermal printers	Check print quality; replace paper	Every month
	Software (Kiosk-level)	Install upgrades	As available
	Software (Server-level)	Install upgrades	As available
En-Route Traveler Information			
Changeable Message Signs (CMS) (1)	Controller / motor	Visual inspection and testing	Every 12 months
	Sign Display	Testing, cleaning; check illumination	Every 12 months
	Sign Housing	Visual inspection and check communications	Every 12 months
	Communications	Check modems and hardwire connections; check radio-activated connections	Every 12 months
	Surge Protection / Power	Visual inspection and testing	Every 12 months

(see last page of table for legend)

Table 5-1: Preventative Maintenance Schedule. (cont.)

Device	Component	Maintenance Procedure	Frequency
En-Route Traveler Information (cont.)			
Permanent Variable Message Signs	Controller / Internal Wiring	Visual inspection and testing	Every 6 months
	Sign Matrix, Panels, Modules	Testing and cleaning; replace bulbs and pixels as necessary	Every 6 months
	Display	Cleaning and visual inspection	Every 6 months
	Sign Housing	Visual inspection and check connections; clean filters	Every 6 months
	Modem / Communications	Visual inspection; check connections; test messages	Every 12 months
	Software	Install upgrades	As available
	Surge Protection / Power	Visual inspection and testing	Every 6 months
Portable Variable Message Signs	Controller / Internal Wiring	Visual inspection and testing	Every 3 months
	Sign Matrix, Panels, Modules	Testing and cleaning; replace bulbs and pixels as necessary	Every 3 months
	Display	Test messages	Every week
	Sign Housing	Visual inspection and check connections; clean filters	Every 3 months
	Software	Install upgrades	As available
	Power	Visual inspection and testing; check and replace batteries as necessary	Every 3 months
Highway Advisory Radio (HAR) (3)	Antenna Assembly	Visual inspection	Every 12 months
	Transmitter	Check power and range and frequency	Every 12 months
	Beacon equipment	Visual inspection and testing	Every 12 months
	Recorder / player unit	Testing; check connections	Every 12 months
	Operator workstation	Basic computer maintenance; test messages	Every 12 months
	Power supply	Check power level and connections	Every 12 months
Icy Bridge Detectors and Oversize Load Detectors	Sensors	Visual inspection; cleaning and calibration	Every 12 months
	Flashing beacon and sign	Visual inspection and testing	Every 12 months
	Field controller (4)	Visual inspection and testing	Every 2 months
	Controller cabinet	Visual inspection and cleaning	Every 12 months
	Software	Install upgrades	As available
	Communications equipment	Visual inspection; check connections	Every 12 months
Variable Speed Limit Signs (VSLS)	Sensors	Visual inspection; cleaning and calibration	Every 12 months
	Flashing beacon and sign	Visual inspection and testing	Every 12 months
	Field controller	Visual inspection and testing	Every 2 months
	Controller cabinet	Visual inspection and cleaning	Every 12 months
	Software	Install upgrades	As available
	Communications equipment	Visual inspection; check connections	Every 12 months

(see last page of table for legend)

Table 5-1: Preventative Maintenance Schedule. (cont.)

Device	Component	Maintenance Procedure	Frequency
En-Route Traveler Information (cont.)			
Queue Detection System	Controller / Timer	Check batteries, test induction, check connections	Every 12 months
	Loops	Visual inspection and testing	Every 12 months
	Flashing beacon / sign	Visual inspection and testing	Every 12 months
	Cabinet	Visual inspection and cleaning	Every 12 months
Commercial Vehicle Operations			
Weigh-in-Motion (WIM) Stations (5)	Sensors (axle, AVC, AVL, loops)	Test signal level and lead cable; calibrate	Every 6 months
	Single load cell scales	Test signal level and lead cable; calibrate	Every 6 months
	Piezoelectric sensors	Test signal level and lead cable; calibrate	Every 6 months
	Grout and sealant	Visual inspection	Every 6 months
	Detector housings and cabinets	Visual inspection; test ventilation	Every 6 months
	WIM electronics, power supplies and modems	Visual inspection; cleaning; testing	Every 6 months
	Modems / routers	Visual inspection; check connections	Every 12 months
	Cables and connectors	Visual inspection and testing	Every 12 months
	Red light / green light	Visual inspection and testing	Every 12 months
Downhill Speed Advisory System	WIM equipment (5)	See guidelines under Weigh-in-Motion systems	
	VMS equipment	See guidelines under Permanent Variable Message Signs	
Communications Systems			
Fiber Optics Networks	Landline cable	Perform optical time domain reflectometer tests	Every 24 months
Radio Communications	Hand-held units	Visual inspection; testing	Every 12 months
	Radio consoles	Visual inspection; testing	Every 12 months
	In-vehicle communications	Visual inspection; testing	Every 12 months
Maintenance Coordination			
Maintenance Coordination	Laptop computers	Visual inspection; re-boot and diagnostics	Every month
	Tracking software	Install upgrades	As available

Notes
(1) Maintenance procedures are already in place.
(2) Maintenance responsibility is outside of ODOT responsibility.
(3) More frequent maintenance would be recommended for year-round operations.
(4) Ice bridge warning system field controllers would need maintenance for only six months out of the year.
(5) WIM maintenance responsibility is currently provided by vendors.

Table 5-1: Preventative Maintenance Schedule. (cont.)

that no tasks as neglected. The checklist could be based on Table 5-1, but would likely need to have greater detail to be of value to field personnel.

- Establish point-of-contact for coordinating and tracking preventative maintenance activities. The support coordinator role would be ideal for this, although record-keeping of preventative maintenance activities in some regions may become time-consuming enough that it should be delegated to individuals performing preventative maintenance.

- Incorporate preventative maintenance activities into centralized tracking system. This would enable preventative maintenance activities to be performed concurrently with repair maintenance, resulting in savings in travel time.

- Identify staffing resources to perform preventative maintenance. Preventative maintenance is often underemphasized because maintenance personnel's schedules are filled with "putting out fires." As is true for repair maintenance, a combination of in-house and contractor resources may be required to fulfill this maintenance.

- Order spare parts necessary for preventative maintenance in advance. Some preventative maintenance activities will involve replacement of parts that frequently fail, such as light bulbs. These parts should be kept in stock so that preventative maintenance is not hindered by delays caused by the procurement process. This will require identifying which spare parts are necessary for each device, and the appropriate quantity of each part.

6 RESOURCE ANALYSIS

The previous three chapters addressed some theoretical or idealized perspectives on how ITS maintenance should be performed within ODOT. They described how maintenance requests should be processed through ODOT, what activities should have the highest priority, and what preventative maintenance activities would be desirable for each part of ODOT's ITS infrastructure. To keep this maintenance plan practical, however, it is important to be able to address the following questions.

- What resources are needed to make this happen?
- What resources does ODOT currently have?
- Where are there shortfalls or surpluses in resources?
- How should these gaps be addressed?

This chapter seeks to answer each of these questions, and is organized in four sections accordingly. The first three sections of this chapter relate as shown in Figure 6-1: resource needs, available resources and resource gaps. Resource needs refer to the number of full-time employees (FTEs) required for a given skill set in each region of the state in order to perform appropriate and adequate preventative and repair maintenance on all of the existing and proposed ITS infrastructure. The available resources refer to the number of FTE equivalents ODOT is currently devoting to ITS maintenance activities. The difference between these two matrices indicates where resource gaps or surpluses may exist. The fourth section of this chapter examines alternatives that may be used to resolve any gaps that may exist.

6.1 Resource Needs

There is a relationship between the number and type of ITS devices that ODOT deploys and the amount of resources that must be devoted to ITS maintenance. As was discussed in Chapter 2, however, few maintenance plans have attempted to quantify this relationship. This section seeks to develop estimates, on a per-device basis, of the staffing resources required to maintain ODOT's existing and planned infrastructure.

6.1.1 Key Assumptions

Several simplifying assumptions were applied in order to estimate the resources needed for

$$\underbrace{\begin{pmatrix}\text{resource}\\ \text{needs}\end{pmatrix}_{ijk}}_{\text{Section 6.1}} - \underbrace{\begin{pmatrix}\text{available}\\ \text{resources}\end{pmatrix}_{ijk}}_{\text{Section 6.2}} = \underbrace{\begin{pmatrix}\text{resource}\\ \text{gap}\end{pmatrix}_{ijk}}_{\text{Section 6.3}}$$

where i = region (1, 2, 3, 4 or 5)
j = job classification
k = analysis year (existing, existing + STIP or strategic plan build-out)

Figure 6-1: Resource Model Formula.

ITS maintenance. These assumptions are as follows.

1. Multiple sources of information were required to reliably quantify resource needs. The best source of information on identifying the resources needed to maintain the ITS infrastructure would be historical cost data either from internal experience or from other agencies. Conversations with ODOT stakeholders indicate, however, that there is inadequate data within ODOT by which resource needs could be estimated. Consequently, the following sources of information were used.

    - Vendors. With the exception of a few devices, ODOT has purchased or will purchase its ITS devices from vendors who have sold similar products to other departments of transportation or non-transportation entities. Because of their role in component design and their extensive experience, vendors may provide helpful insight on the typical maintenance needs associated with a given device.

    - Arizona Department of Transportation (ADOT). ADOT developed an in-house inventory and accounting system to track maintenance on its ITS infrastructure, and this has been used by ADOT to estimate future resource needs for ITS maintenance (9). This system has produced estimates for maintenance needs per device, divided into preventative and repair maintenance tasks.

    - Caltrans. Caltrans developed estimates for resource needs for preventative and repair maintenance for its ITS infrastructure in the greater Los Angeles area (6). Estimates are included for only a few of the devices which ODOT is deploying, but are very specific in terms of describing the maintenance tasks which are included.

    - Other agencies. In some cases, ODOT has identified individuals at other transportation agencies who have substantial experience with a given ITS device. These agencies may therefore be able to provide good information as to the maintenance needs of a device once all of the initial "bugs" have been resolved.

    - ODOT. ODOT's ITS Unit identified individuals throughout ODOT who have significant experience with specific devices. These individuals were contacted in order to describe the actual field maintenance experience.

    There are occasions when maintenance estimates provided by different sources were in conflict with each other. In these cases, best professional judgment was applied to determine the most appropriate estimate to be used. Resource needs estimates are intended to provide a "worst case" scenario, so that resource needs are not underestimated.

2. Resource needs must be estimated from a component level. To better clarify the maintenance needs of each ITS device, each device is characterized by up to six different types of components.

   - Sensors. This broadly refers to components that gather data about traffic or environmental conditions. These may include video sensors, audio sensors, pressure sensors, or environmental sensors.

   - Communications. This broad category includes communications from the device in the field to the operator. It could include wireline communications such as coaxial, telephone or fiber optic networks, as well as wireless communications like cellular telephone and radio communications. It also may include hardwire connections in the field between various device components.

   - Field Processors/Controllers. Many ITS devices will have a processor located in the field that analyzes sensor data and performs an appropriate response, or translates the sensor data in a more usable form to the operator. The processor may be a solid-state device with pre-programmed firmware, or it may be a full-fledged microcomputer.

   - Software. There may be specialized software for a given device that is installed onto the field processor, as well as software used by the operator to access or manage various field devices.

   - Center Subsystems. These are components in which data from various field controllers is pooled together and processed in order to make effective decisions or provide information regarding the transportation system. An example of this would be the Transportation Operation Centers (TOCs), which act as information clearinghouses for data collected through a variety of ITS devices and other data sources.

   - Information Delivery. This is the component of the ITS device that gives the right information to the right people at the right time. It includes information delivered to drivers in the field, such as through variable message signs or highway advisory radio, as well as information delivered to operators, through radio systems and computer screens.

   Appendix G describes each of the devices included in this analysis and the maintenance needs associated with each.

3. Staffing needs must be estimated by employee classification. Table 6-1 lists the ODOT staff classifications that were used in developing estimates of resource needs. Multiple classifications were used for the support coordinator position in order to reflect more accurately the desired skill set of individuals who would fill that role. Multiple classifications are also used within each Information Services classification

Title	Abbrev	Description / Explanation	DAS #
Support Coordinator / IS-Diagnostics	SC-I-D	Support Coordinator position is divided into seven categories to better understand the skill set required for the position in each region. IS - Information Services Elec - Electrician-type work Program Technician - work that doesn't require any special technical skill set	TBD
Support Coordinator / IS-Repair	SC-I-R		TBD
Support Coordinator / IS-Preventative Maintenance	SC-I-PM		TBD
Support Coordinator / Elec-Diagnostics	SC-E-D		TBD
Support Coordinator / Elec-Repair	SC-E-R		TBD
Support Coordinator / Elec-Preventative Maintenance	SC-E-PM		TBD
Support Coordinator / Program Technician	SC-P		TBD
Info Services - Kiosk Specialist	IS-K	There is currently no ODOT kiosk specialist; this is assumed to be an IS-4 level position.	1484
Info Services 5 - Radio Technician	IS-5R	Higher IS classifications are used to refer to specialized skill sets which may be needed for some device maintenance.	1485
Info Services 5 - Networks / Servers	IS-5N		1485
Info Services 5 - Software	IS-5S		1485
Info Services 6 - Radio Technician	IS-6R		1486
Info Services 6 - Networks / Servers	IS-6N		1486
Info Services 6 - Software	IS-6S		1486
Info Services 7 - Networks / Servers	IS-7N		1487
Info Services 7 - Software	IS-7S		1487
Fiber Optic Technician	IS-F	ODOT currently does not have any fiber optics technicians, so no DAS classification exists.	TBD
Electrician	ELEC		4213
Traffic Signal Technician 3	TS-3	For some devices, a Traffic Signal Technician 2 (DAS# 3410) may be dispatched. TS-3 is used in order to provide "worst-case" estimates.	3411

TBD - To be determined
DAS - Department of Administrative Services

Table 6-1: ODOT Staff Classifications.

to reflect specialization of skills into networks and servers, software, or radio communications.

Estimates for resource needs are based on the preferred maintenance model discussed in Chapter 3. Based on this model, the following assumptions were used.

- Support coordinators will perform all preventative maintenance, except for activities requiring specialized licensing, training or equipment (i.e. fiber optics training, bucket truck, etc.).
- The support coordinator will perform initial device diagnostics and will make initial attempts at device repair.

- Higher-level support (IS-6, IS-7 or TSSU) would be brought in only when initial attempts at diagnostics and repair are unsuccessful.

- The support coordinator is responsible for all logging and tracking activity.

These assumptions are clarified in greater detail in Appendix H.

4. Future resource needs estimates must reflect technological change. Intelligent transportation systems continue to be an evolving technology. This trend is expected to continue for the foreseeable future, and the rate and nature of technological change could be expected to have a significant impact on ODOT's ITS maintenance needs. Appendix I describes some assumptions about the anticipated direction and effects of technological change that were used in this analysis.

5. The extent of vendor support will affect resource needs. In order to provide a worst case scenario – i.e. maximizing the FTEs ODOT must provide to perform ITS maintenance – it is assumed that ODOT staff will be able to perform device maintenance effectively and efficiently wherever allowed to. In at least two cases vendor support would be utilized.

    - Specialized components. Some components, especially for newer technologies, will be so sophisticated that it may be impossible to diagnose or repair them without specialized equipment. In these cases, it is assumed that ODOT would have no maintenance responsibility. When repairs are needed, the malfunctioning components would be returned to the vendor or supplier for appropriate maintenance.

    - Warranty coverage. Some existing and planned devices will have vendor-provided warranty coverage which would relieve ODOT of significant maintenance responsibility for a period. However, to maintain consistency with a worst case scenario, it is assumed that no warranty coverage will be in effect.

6. FTE equivalents must include appropriate employee benefits and training. It is unreasonable to assume that each ODOT employee can devote 40 hours per week for 52 weeks per year to ITS maintenance. Figure 6-2 shows a series of equations that were used to develop an estimate of 1,627 hours as comprising a FTE equivalent year. This reflects reasonable assumptions in terms of vacation leave and time for training to enhance existing skills and learn new skills.

7. Travel time must be included to accurately reflect true resource needs. Because of uncertainty regarding locations of planned device deployments and the ability to schedule multiple repair activities on one trip, several simplifying assumptions about travel time were necessary. These assumptions are described in greater detail in Appendix J. Travel times that were assumed for this analysis are shown in Table 6-2.

		Region				
Location	**Type of Support**	**1**	**2**	**3**	**4**	**5**
Field Device	Regional	1	1 3/4	2	3 1/4	2 3/4
	Centralized in Salem	1	1 1/4	3 1/4	3 1/2	5 1/4
TOC	Regional	0	0	0	0	0
	Centralized in Salem	1 1/2	0	2	3	6

Table 6-2: Travel Time Assumptions.

Based on these assumptions, Appendix K provides tables for each device which indicate the maintenance needs of each ITS device under each of these six components. For each device, the following information is provided:

- a table indicating the device's existing and planned inventory, by region;
- brief descriptions of maintenance needs for each of the device's six components (where applicable), with tables identifying the anticipated frequency of preventative and repair maintenance, the average length of time required for maintenance, and the staff classifications involved in maintenance activity;
- a summary of the per-unit maintenance needs, summarized over the device's six components, by classification level; and
- a summary of the total maintenance obligation by classification by region in FTEs.

6.1.2 Electricians

Table 6-3 shows the number of electrician FTE equivalents that are required for ITS maintenance. As can be seen, it is estimated that ITS maintenance activities would require less than 1 FTE per region through the end of the STIP. As was stated earlier, it is assumed that electricians would perform few preventative maintenance activities. If they were to perform additional preventative maintenance activities, this would significantly increase the number of

$$52\frac{weeks}{year} - \underbrace{3\frac{weeks}{year}}_{\text{vacation}} - \underbrace{2\frac{weeks}{year}}_{\text{training}} - \underbrace{1\frac{week}{year}}_{\text{sick leave}} = 46\frac{weeks}{year}$$

$$46\frac{weeks}{year} \times 5\frac{days}{week} - \underbrace{13\frac{days}{year}}_{\text{holidays}} = 217\frac{days}{year}$$

$$217\frac{days}{year} \times \left(8\frac{hours}{day} - 2\frac{breaks}{day} \times 0.25\frac{hours}{break}\right) \approx 1{,}627\frac{hours}{year}$$

Figure 6-2: Number of Hours in an FTE Year.

(Source: 14)

FTE equivalents required. By the conclusion of the Strategic Plan, it is estimated that more than 1 FTE each would be required in Regions 1, 4 and 5, and that nearly 1 FTE would be required in Regions 2 and 3.

	Region					State
	1	2	3	4	5	Total
Existing	0.46	0.29	0.12	0.21	0.26	1.35
Existing + STIP	0.63	0.44	0.16	0.51	0.64	2.38
Existing + Strategic Plan	1.47	0.93	0.95	1.34	1.38	6.07

Table 6-3: Staffing Requirements for Electricians.

6.1.3 TSSU

According to the preferred maintenance model, TSSU is dispatched to perform maintenance activities when support coordinators and/or electricians are unable to successfully resolve a problem. In order to be consistent with other classifications, Table 6-4 divides maintenance activities for TSSU by region, although it is assumed that all TSSU staff would continue to be headquartered in Salem.

	Region					State
	1	2	3	4	5	Total
Existing	0.03	0.03	0.02	0.02	0.05	0.14
Existing + STIP	0.04	0.04	0.02	0.05	0.09	0.23
Existing + Strategic Plan	0.06	0.04	0.09	0.09	0.16	0.44

Table 6-4: Staffing Requirements for TSSU.

Table 6-4 indicates that limited involvement is anticipated from TSSU in ITS maintenance. This is based on assumptions regarding the percentage of repairs that support coordinators and/or electricians are able to successfully address. It is anticipated that, even with build-out of the Strategic Plan, only 0.44 FTEs would be required. However, if the first-line of diagnostic and repair capability is less effective in their work, much greater involvement from TSSU would be anticipated.

6.1.4 Information Services

For the purposes of estimating resource needs, Information Services has been sub-divided into three broad classifications based on type of skill set:

- networks and servers, which includes maintenance of desktop computers and workstations;
- software, which includes software installation and programming; and
- radio communications, which is focused on consoles and hand-held units, but not on towers and other supporting infrastructure.

Table 6-5 shows the network and server support that must be provided by Information Services, according to the resource needs estimates. It is estimated that there is need for some support at the IS-5 level, increasing as more devices are deployed. By the time the Strategic Plan is completely implemented, regional needs will vary between approximately 0.4 and 0.6 FTE equivalents at the IS-5 level. The need for IS-6 support for networks and servers is anticipated to be fairly minimal, based on assumptions regarding the percentage of problems which can be adequately addressed by IS-5 technicians.

Info Services 5 - Networks / Servers (IS-5N) - DAS #1485

	Region					State
	1	2	3	4	5	Total
Existing	0.08	0.14	0.01	0.08	0.03	0.34
Existing + STIP	0.10	0.17	0.03	0.16	0.13	0.58
Existing + Strategic Plan	0.39	0.35	0.38	0.61	0.51	2.24

Info Services 6 - Networks / Servers (IS-6N) - DAS #1486

	Region					State
	1	2	3	4	5	Total
Existing	0.02	0.03	0.00	0.02	0.01	0.07
Existing + STIP	0.02	0.03	0.01	0.03	0.03	0.11
Existing + Strategic Plan	0.06	0.05	0.06	0.09	0.08	0.33

Table 6-5: Staffing Requirements for Information Services Network and Server Specialists.

The resource needs for IS software support are shown in Table 6-6. It is assumed that support coordinators will be able to install off-the-shelf software upgrades with little difficulty, and that the software vendor would address any technical support issues. The primary software maintenance issues will be in the development and revision of ODOT-developed packages, such as the TripCheck Web site, as well as in the development of enhancements to packages developed by others, such as database queries developed on a vendor-provided RWIS database.

Info Services 6 - Software (IS-6S) - DAS #1486

	Region					State
	1	2	3	4	5	Total
Existing	0.00	1.06	0.00	0.00	0.00	1.06
Existing + STIP	0.00	1.40	0.00	0.00	0.00	1.40
Existing + Strategic Plan	0.00	1.40	0.00	0.00	0.00	1.40

Info Services 7 - Software (IS-7S) - DAS #1487

	Region					State
	1	2	3	4	5	Total
Existing	0.00	0.01	0.00	0.00	0.00	0.01
Existing + STIP	0.00	0.01	0.00	0.00	0.00	0.01
Existing + Strategic Plan	0.00	0.01	0.00	0.00	0.00	0.01

Table 6-6: Staffing Requirements for Information Services Software Specialists.

According to Table 6-6, more than 1 FTE at the IS-6 level will be required in Salem through the duration of the Strategic Plan. Resource needs are increased slightly when the STIP is in effect due to relative infancy of these computer applications. Limited IS-7 support would be necessary only to assist the IS-6 programmers in more challenging programming efforts.

Table 6-7 shows the estimated resource needs for Information Services' radio technicians. Because ITS maintenance excludes any maintenance performed on ODOT's radio infrastructure, maintenance needs will be fairly minimal. It is estimated that ITS maintenance will demand an average of 0.1 FTE equivalents at the IS-5 level in each of ODOT's regions by the end of the Strategic Plan. There is anticipated to be limited need for IS-6 radio technicians for ITS maintenance, to reflect special maintenance needs.

Info Services 5 - Radio Technician (IS-5R) - DAS #1485

	Region					State
	1	2	3	4	5	Total
Existing	0.02	0.02	0.01	0.02	0.00	0.07
Existing + STIP	0.02	0.02	0.01	0.08	0.00	0.13
Existing + Strategic Plan	0.08	0.10	0.09	0.11	0.10	0.48

Info Services 6 - Radio Technician (IS-6R) - DAS #1486

	Region					State
	1	2	3	4	5	Total
Existing	0.00	0.00	0.00	0.00	0.00	0.01
Existing + STIP	0.00	0.00	0.00	0.01	0.00	0.02
Existing + Strategic Plan	0.01	0.01	0.01	0.01	0.01	0.04

Table 6-7: Staffing Requirements for Information Services Radio Technicians.

There are two other types of maintenance that would likely fall under Information Services' responsibility: kiosk maintenance and fiber optics.

Kiosk maintenance would require regular, preventative inspections of kiosk cabinets and connections, paper levels and print quality. Because of the frequency of maintenance required for this task and the less advanced skill set, kiosk maintenance was treated as a separate IS classification. Table 6-8 shows the estimated resource needs for kiosk maintenance. As can be seen, nearly 4 FTE equivalents would be required for kiosk maintenance. This estimate assumes that ODOT would handle all preventative maintenance activities in-house. ODOT may be able to secure relationships with kiosk hosts such that they would be responsible for some or all preventative maintenance tasks, which may help to reduce this staffing burden.

	Region					State
	1	2	3	4	5	Total
Existing	0.00	0.00	0.00	0.00	0.00	0.00
Existing + STIP	0.00	0.00	0.00	0.00	0.00	0.00
Existing + Strategic Plan	1.42	0.49	0.53	0.74	0.65	3.83

Table 6-8: Staffing Requirements for Information Services Kiosk Specialists.

Fiber optics maintenance is another position that is currently not provided for in ODOT's classification system. Table 6-9 estimates the resources that would be required for

	Region					State
	1	2	3	4	5	Total
Existing	0.00	0.00	0.00	0.00	0.00	0.00
Existing + STIP	0.19	0.00	0.00	0.00	0.00	0.19
Existing + Strategic Plan	0.19	0.00	0.00	0.00	0.00	0.19

Table 6-9: Staffing Requirements for Information Services Fiber Optic Technicians.

maintenance of ODOT's Region 1 fiber optics system are less than 0.2 FTE equivalents, assuming that there is no more than 80 miles of fiber optic cable under ODOT's responsibility. As fiber optics is increasingly used for field communications between device components, this staffing burden will increase.

6.1.5 Support Coordinator

Table 6-10 summarizes the estimated FTE equivalent needs for the support coordinator position. As can be seen, there are extensive FTE needs associated with the support coordinator position both currently and into the future. Under the existing inventory deployment, it is estimated that there is enough maintenance activity to occupy more than 1 FTE in both Regions 1 and 2. After the STIP is complete, the FTE requirement in four of ODOT's regions would be for approximately 2 FTEs. By the time the Strategic Plan is fully implemented, the maintenance needs are estimated to increase to a total of over 35 FTEs statewide. Slightly more FTEs are allocated to Regions 4 and 5 under the Strategic Plan, which reflects in part the effect of increased travel times in those regions.

	Region					State
	1	2	3	4	5	Total
Existing	1.29	1.53	0.34	0.89	0.66	4.71
Existing + STIP	1.67	2.03	0.53	2.02	1.85	8.10
Existing + Strategic Plan	5.80	6.03	6.25	9.02	7.99	35.09

Table 6-10: Resource Needs for Support Coordinators.

Because of the significant number of FTEs devoted to the support coordinator position, it would be helpful to see how these FTEs are divided into different activities. Table 6-11 shows, for the existing inventory, the percentage of work for each of seven sub-classifications for support coordinators. As can be seen, the largest potion of time overall – 24 percent statewide, with 37 percent in Region 1 – is devoted to preventative maintenance tasks on computer and communications systems. Overall, support coordinators in Regions 1, 2 and 4 would devote more of their efforts to Information Systems maintenance activity than electrician-related activity, whereas the reverse is true in Regions 3 and 5.

	Region					
	1	2	3	4	5	Total
Coordination	8%	22%	12%	10%	7%	13%
Elec - Diag	14%	17%	21%	16%	29%	18%
Elec - Repair	14%	13%	21%	12%	26%	16%
Elec - PM	6%	6%	7%	8%	7%	7%
IS - Diag	15%	19%	9%	19%	8%	16%
IS - Repair	6%	9%	5%	11%	4%	8%
IS - PM	37%	14%	26%	25%	18%	24%
Total	100%	100%	100%	100%	100%	

Table 6-11: Percent Breakdown of Support Coordinator Time – Existing.

Across the five regions, support coordinators would spend an average of 13 percent of their time on coordination, logging and tracking of maintenance. Region 2 has a larger percentage of time devoted to coordination than other regions because of the statewide systems that are based in Region 2.

Table 6-12 shows that there is little change in the percentage allocation of support coordinator time once the STIP has been implemented. One significant change is that a smaller percentage of time is spent on coordination of maintenance activities.

	Region					
	1	2	3	4	5	Total
Coordination	8%	19%	10%	9%	7%	11%
Elec - Diag	15%	16%	18%	16%	21%	17%
Elec - Repair	16%	14%	18%	13%	19%	16%
Elec - PM	6%	6%	8%	7%	7%	7%
IS - Diag	14%	17%	11%	18%	13%	15%
IS - Repair	6%	9%	6%	11%	7%	8%
IS - PM	35%	19%	29%	26%	26%	26%
Total	100%	100%	100%	100%	100%	

Table 6-12: Percent Breakdown of Support Coordinator Time – STIP.

Once the Strategic Plan has been implemented, it is anticipated there would be significant changes in the support coordinator's role, as shown in Table 6-13. In all regions, the percent of time spent on maintenance coordination has increased, to an average of 19 percent of time statewide. For each of the regions, an increasing portion of time would be devoted to IS-related diagnostics and repair, indicating an increasing need for that skill set over time.

	Region					
	1	2	3	4	5	Total
Coordination	18%	23%	22%	17%	18%	19%
Elec - Diag	11%	11%	13%	14%	14%	13%
Elec - Repair	15%	13%	14%	14%	17%	15%
Elec - PM	9%	9%	9%	8%	8%	8%
IS - Diag	14%	16%	16%	17%	16%	16%
IS - Repair	9%	11%	12%	13%	12%	12%
IS - PM	24%	16%	15%	17%	14%	17%
Total	100%	100%	100%	100%	100%	

Table 6-13: Percent Breakdown of Support Coordinator Time – Strategic Plan.

Because of the significant increase in FTEs required from the existing deployment to the deployment under the Strategic Plan, it is important to note how many FTEs would be required for each of these roles in the future. Table 6-14 reflects the product of the percentages shown in Table 6-13 and the

	Region					
	1	2	3	4	5	Total
Coordination	1.04	1.40	1.37	1.55	1.48	6.83
Elec - Diag	0.62	0.68	0.79	1.27	1.13	4.49
Elec - Repair	0.88	0.81	0.86	1.30	1.37	5.23
Elec - PM	0.52	0.52	0.57	0.71	0.62	2.95
IS - Diag	0.81	0.95	0.99	1.50	1.27	5.53
IS - Repair	0.52	0.68	0.73	1.17	0.97	4.07
IS - PM	1.41	0.99	0.93	1.51	1.16	5.99
Total	5.80	6.03	6.25	9.02	7.99	35.09

Table 6-14: Number of Support Coordinator FTEs by Type of Work – Strategic Plan.

FTE requirements estimated under the Strategic Plan. It is estimated that each region would need at least one FTE devoted to maintenance coordination. At least 0.5 FTE would be required for each of the indicated skill sets in each region. Most activities in Region 4 and 5 would require at least 1.0 FTE each, indicating the effects of increased travel time on resource needs.

6.2 Available Resources

In addition to identifying what staffing resources are necessary for ODOT's ITS maintenance, it is important to identify what staffing resources ODOT currently has for performing ITS maintenance. Initially, telephone contacts were made with ODOT staff in the regional maintenance offices, Information Services and TSSU to discern how much time is currently being spent on ITS maintenance. In reviewing this data, it was determined that a lack of consistent record keeping across the organization made this data suspect. Therefore, job descriptions were reviewed for various ODOT positions to determine the percentage of time it was anticipated that each staff position should be spending on ITS maintenance.

6.2.1 Electricians

Based on telephone contacts with several ODOT electricians, it was determined that electricians are spending a small portion of their time on ITS maintenance (15, 16, 17). Based on review of job descriptions, however, it was determined that the time electricians currently spend on ITS maintenance is not a part of their job descriptions (18, 19, 20). Therefore, in terms of resource availability, it is assumed that there are zero electricians in any region available for ITS maintenance.

6.2.2 TSSU

There are three broad classifications of staff at TSSU: lead technician, journey level ITS technician, and journey level traffic signal technician (21). Job descriptions for each of these positions were reviewed to identify those duties that are most similar to the resource needs evaluated in Section 6.1. For this reason, the following types of duties identified in job descriptions were not included:

- any activities with traffic signals;
- providing training, since time was already allocated for training under the FTE formula developed in Section 6.1;
- construction turn-on inspection; and

Classification	No. of Staff	% of Time on ITS Maintenance	No. of FTEs
Lead Technician	1	65%	0.65
Journey Level ITS Technician	3	63%	1.89
Journey Level Traffic Signal Technician	4	4%	0.16
Total			**2.70**

Table 6-15: Available FTEs for TSSU Technicians.

- special projects.

On this basis, Table 6-15 provides estimates for the number of FTEs estimated to be available for ITS maintenance from TSSU. All TSSU staff are based in Salem, although they will be required to travel to service field devices.

6.2.3 Information Services

In ODOT, computer support for workstations, networks and servers is handled by Information Services both in Salem and through the Field Services unit. Table 6-16 shows the estimated FTE availability of network and server support from Information Services. It was determined that several field services technicians are currently providing ITS maintenance, although it is only explicitly in the job descriptions of technicians working in Regions 1 and 2 and not in those of technicians in other regions (27, 28, 29).

	Region					State
	1	2	3	4	5	Total
IS Field Services FTEs	0.70	1.30	0.00	0.00	0.00	2.00

Table 6-16: Available FTEs for Information Services Network and Server Support.
(Sources: 22, 23, 24, 25, 26)

There are currently three FTEs in Information Services devoted to ITS software applications, including development as well as maintenance (30); of these 3.0 FTEs, it is estimated that 0.2 FTEs are devoted to maintenance (20). Because of the difficulty in separating out software maintenance activity from other duties in application development, the number of actual FTEs may be somewhere in between these two values. For a worst-case scenario, it is assumed that only 0.2 FTEs are available.

Since the job descriptions for Information Services' radio technicians do not include ITS maintenance (31), it will be assumed that there are zero available FTEs for radio-related ITS maintenance. Technicians currently spend minimal time on applications directly related to ITS (32).

As was alluded to in the previous section, ODOT currently does not have any dedicated fiber optics technicians. Some TSSU technicians have obtained some training in fiber optics and the unit also possesses some testing equipment (21). The availability of these technicians was considered in Table 6-15. ODOT currently does not have any staff positions devoted to kiosk maintenance, either.

6.2.4 Support Coordinators

Currently, there are no support coordinator positions within ODOT. As a part of a program options package approved in 1999, however, three FTE positions were obtained for the support coordinator role. Based on subsequent discussions, it was agreed that one of these positions would be given to TSSU for support of ITS field devices in Region 1[5] (33). Based on position

[5] Because the TSSU position has not been filled as of yet, it is still included with the support coordinator positions.

descriptions prepared by ODOT's ITS Unit, it is estimated that these individuals would spend between 50 and 70 percent of their time in support or coordination of preventative and repair maintenance activities on ITS devices. Based on these assumptions, Table 6-17 provides estimates for resource availability of support coordinators in each ODOT region.

	Region					State
	1	2	3	4	5	Total
Support Coordinator FTEs	0.60	0.60	0.00	0.60	0.00	1.80

Table 6-17: Available FTEs for Support Coordinators.

6.3 Resource Gaps

This section will analyze the gaps in resources between what is needed to properly maintain ODOT's ITS infrastructure and what ODOT currently has devoted to ITS maintenance.

6.3.1 Staffing Gaps

The first type of gap to be analyzed is the gap in staffing as expressed in FTEs. Table 6-18 shows an initial assessment of staffing gaps. Estimates of available FTEs are provided in the leftmost column. Because it is unclear how staffing decisions will evolve in the future, it was assumed that no additional FTEs would be acquired by ODOT for ITS maintenance through the completion of the Strategic Plan. Estimates of FTE needs are presented under the existing, STIP and Strategic Plan build-out deployment levels, along with estimates of the staffing gaps or surpluses. Positive values for staffing resource differences represent gaps, whereas negative values represent apparent resource surpluses.

The most notable finding in Table 6-18 is that there is currently an overall shortage of staffing resources for performing ITS maintenance at acceptable levels. It is estimated that ODOT currently needs 7.74 FTEs for ITS maintenance, with only 4.9 FTEs available, for a gap of 2.84 FTEs. The addition of the support coordinator positions for the STIP increases resource availability to 6.7 FTEs; however, the resource gap increases to 6.45 FTEs because of the increase in the number of ITS devices deployed. This gap widens to 43.41 FTEs by the time the Strategic Plan is completed because it is assumed ODOT will not be able to add additional maintenance staff to keep pace with increasing levels of deployment. To put it differently, it is estimated that ODOT would need to be able to add about 2 FTEs per year for the next twenty years to have adequate staffing to perform all ITS maintenance in-house.

Gaps are not consistent across all staffing classifications, primarily because the staffing positions where resources are available are not necessarily the positions which will be performing ITS maintenance under the preferred maintenance model alternative. For example, TSSU has an apparent surplus of staffing through the end of the Strategic Plan. However, they are likely currently doing some of the diagnostic and repair work of both regional electricians and support coordinators. The same is likely true of Information Services' network and server support.

For this reason, resource gaps were also analyzed by skill set or maintenance activity. Maintenance activities were divided into seven categories: three for electrical maintenance

			FTEs					
Classification	Region	Avail.	Existing		STIP		Strategic Plan	
			Need	Gap*	Need	Gap**	Need	Gap**
Electricians	1	-	0.46	0.46	0.63	0.63	1.47	1.47
	2	-	0.29	0.29	0.44	0.44	0.93	0.93
	3	-	0.12	0.12	0.16	0.16	0.95	0.95
	4	-	0.21	0.21	0.51	0.51	1.34	1.34
	5	-	0.26	0.26	0.64	0.64	1.38	1.38
	Statewide	-	1.35	1.35	2.38	2.38	6.07	6.07
TSSU	Statewide	2.70	0.14	(2.57)	0.23	(2.47)	0.44	(2.26)
IS Networks / Servers (incl. Field Services)	1	0.70	0.10	(0.60)	0.12	(0.58)	0.44	(0.26)
	2	1.30	0.17	(1.14)	0.20	(1.10)	0.40	(0.90)
	3	-	0.02	0.02	0.03	0.03	0.44	0.44
	4	-	0.10	0.10	0.19	0.19	0.70	0.70
	5	-	0.03	0.03	0.15	0.15	0.59	0.59
	Statewide	2.00	0.41	(1.59)	0.70	(1.31)	2.57	0.57
Radio Communications	1	-	0.02	0.02	0.02	0.02	0.09	0.09
	2	-	0.02	0.02	0.03	0.03	0.10	0.10
	3	-	0.01	0.01	0.01	0.01	0.10	0.10
	4	-	0.03	0.03	0.09	0.09	0.12	0.12
	5	-	-	-	-	-	0.10	0.10
	Statewide	-	0.08	0.08	0.15	0.15	0.52	0.52
Software	Statewide	0.20	1.07	0.87	1.41	1.21	1.41	1.21
Fiber Optics	Statewide	-	-	-	0.19	0.19	0.19	0.19
Kiosks	Statewide	-	-	-	-	-	3.83	3.83
Support Coordinators	1	0.60	1.29	1.29	1.67	1.07	5.80	5.20
	2	0.60	1.53	1.53	2.03	1.43	6.03	5.43
	3	-	0.34	0.34	0.53	0.53	6.25	6.25
	4	0.60	0.89	0.89	2.02	1.42	9.02	8.42
	5	-	0.66	0.66	1.85	1.85	7.99	7.99
	Statewide	1.80	4.71	4.71	8.10	6.30	35.09	33.29
Total	Statewide	6.70	7.74	2.84	13.15	6.45	50.11	43.41

* - Does not include support coordinators.

** - Assumes that no additional FTEs are obtained.

Table 6-18: Staffing Gaps by Classification and Region.

(diagnostics, repair and preventative maintenance), three for Information Services-related maintenance (diagnostics, repair and preventative maintenance), and one for maintenance coordination. In order to establish a relationship between resource availability by staff classification and resource availability by maintenance activity, the following assumptions were made.

- For Information Services maintenance activities, 75 percent of time is spent on diagnostics, 20 percent on repair and 5 percent on preventative maintenance.

- For electrical maintenance activities, 50 percent of time is spent on diagnostics and 50 percent on repair. No time is allocated for preventative maintenance in order to reflect the perception that preventative maintenance is not being done.
- Support coordinators are assumed to spend 0.1 FTE of their time on maintenance coordination activities. The remainder of their time is split equally between Information Services and electrical maintenance activities.

Using these assumptions, Table 6-19 shows estimated staffing gaps for maintenance activities in each region. Based on this analysis, it is clear that there are staffing gaps in electrical maintenance, IS-related maintenance and maintenance coordination. The analysis shows that staffing gaps are currently greatest for preventative maintenance activities. On a regional basis, each of the regions shows staffing gaps for both electrical and IS-related maintenance, with the exception of electrical maintenance in Region 2 where resource availability is skewed by the allocation of all available TSSU staff time to that region.

6.3.2 Skills Gaps

While ODOT may have "warm bodies" to fill roles in maintenance, it is important to assess, on a broad level, the level of skills of these individuals with respect to their designated responsibility. For simplicity, skills gaps have been estimated in a broad sense for each of the major classification groups. Responses received from many ODOT stakeholders in June 1999 (13), as well as telephone conversations, were used to provide an assessment of existing skill levels.

Based on these forms of input, it seems as though the most significant skills gaps in ODOT are related to maintenance of field or electrical components. It does not appear as though skill gaps are caused by a lack of experience in the organization overall, as there seems to be some in-house expertise for each existing field device in ODOT's ITS infrastructure. Rather, skill gaps appear to exist at a regional level, based either on a lack of familiarity with a particular device or a lack of adequate support or training from the device vendor. Skill gaps exist on a variety of ITS devices throughout the state. Skills gaps do not seem to be as substantial in Region 1, where there is generally a greater deployment of ITS devices. This data suggests that ODOT may be able to resolve its own skills gaps through internal training efforts. For repair activities for which IS would be typically called, Field Services technicians report that they seldom if ever need to call on more specialized support from Salem to help resolve a problem.

6.4 Training and Contracting Alternatives

To resolve these resource gaps in staffing and training levels, ODOT has two broad options: enhance and develop resources within the organization in order to provide for adequate staffing and training, or rely on contract support. This chapter reviews potential alternatives for each option and then proposes recommendations for how gaps may best be resolved.

Type of Work		Region	FTEs							
			Available		Existing		STIP		Strategic Plan	
			Now	Future	Need	Gap	Need	Gap	Need	Gap
Coordination		1	-	0.10	0.10	0.10	0.14	0.04	1.04	0.94
		2	-	0.10	0.33	0.33	0.38	0.28	1.40	1.30
		3	-	-	0.04	0.04	0.05	0.05	1.37	1.37
		4	-	0.10	0.09	0.09	0.18	0.08	1.55	1.45
		5	-	-	0.05	0.05	0.13	0.13	1.48	1.48
		Total	-	0.30	0.61	0.61	0.88	0.58	6.83	6.53
Electrical / Electronic	Diagnostic	1	-	0.11	0.26	0.26	0.36	0.25	0.73	0.62
		2	1.35	1.46	0.31	(1.04)	0.41	(1.05)	0.76	(0.71)
		3	-	-	0.10	0.10	0.12	0.12	0.87	0.87
		4	-	0.11	0.18	0.18	0.41	0.30	1.38	1.27
		5	-	-	0.25	0.25	0.51	0.51	1.26	1.26
		Total	1.35	1.69	1.09	(0.26)	1.82	0.13	4.99	3.31
	Repair	1	-	0.11	0.38	0.38	0.52	0.41	1.48	1.37
		2	1.35	1.46	0.33	(1.02)	0.47	(1.00)	1.19	(0.27)
		3	-	-	0.13	0.13	0.17	0.17	1.29	1.29
		4	-	0.11	0.20	0.20	0.49	0.37	1.88	1.77
		5	-	-	0.31	0.31	0.64	0.64	2.02	2.02
		Total	1.35	1.69	1.34	(0.01)	2.28	0.59	7.86	6.17
	Preventative Maintenance	1	-	0.03	0.30	0.30	0.42	0.39	1.34	1.32
		2	-	0.03	0.23	0.23	0.33	0.31	1.04	1.01
		3	-	-	0.08	0.08	0.12	0.12	1.10	1.10
		4	-	0.03	0.17	0.17	0.39	0.36	1.46	1.44
		5	-	-	0.17	0.17	0.45	0.45	1.39	1.39
		Total	-	0.08	0.94	0.94	1.71	1.64	6.33	6.25
	Total	1	-	0.25	0.93	0.93	1.30	1.05	3.55	3.30
		2	2.70	2.95	0.86	(1.84)	1.21	(1.74)	2.99	0.04
		3	-	-	0.31	0.31	0.41	0.41	3.26	3.26
		4	-	0.25	0.55	0.55	1.29	1.04	4.72	4.47
		5	-	-	0.73	0.73	1.60	1.60	4.66	4.66
		Total	2.70	3.45	3.37	0.67	5.81	2.36	19.18	15.73
Information Services	Diagnostic	1	0.53	0.71	0.24	(0.29)	0.34	(0.37)	1.40	0.68
		2	1.13	1.31	0.38	(0.74)	0.48	(0.84)	1.23	(0.08)
		3	-	-	0.04	0.04	0.07	0.07	1.26	1.26
		4	-	0.19	0.21	0.21	0.45	0.26	1.89	1.71
		5	-	-	0.07	0.07	0.30	0.30	1.60	1.60
		Total	1.65	2.21	0.93	(0.72)	1.64	(0.57)	7.38	5.17
	Repair	1	0.14	0.19	0.14	0.00	0.26	0.07	1.27	1.08
		2	0.30	0.35	0.26	(0.04)	0.33	(0.02)	1.15	0.80
		3	-	-	0.03	0.03	0.05	0.05	1.22	1.22
		4	-	0.05	0.16	0.16	0.39	0.34	1.93	1.88
		5	-	-	0.05	0.05	0.22	0.22	1.60	1.60
		Total	0.44	0.59	0.64	0.20	1.25	0.66	7.18	6.59
	Preventative Maintenance	1	0.04	0.05	0.48	0.44	0.64	0.59	2.21	2.17
		2	0.08	0.09	1.26	1.19	1.75	1.66	2.63	2.55
		3	-	-	0.09	0.09	0.16	0.16	1.23	1.23
		4	-	0.01	0.24	0.24	0.55	0.54	1.93	1.92
		5	-	-	0.12	0.12	0.47	0.47	1.53	1.53
		Total	0.11	0.15	2.19	2.08	3.57	3.42	9.54	9.39
	Total	1	0.70	0.95	0.86	0.16	1.24	0.29	4.88	3.93
		2	1.50	1.75	1.91	0.41	2.55	0.80	5.02	3.27
		3	-	-	0.16	0.16	0.29	0.29	3.71	3.71
		4	-	0.25	0.61	0.61	1.39	1.14	5.75	5.50
		5	-	-	0.23	0.23	1.00	1.00	4.73	4.73
		Total	2.20	2.95	3.76	1.56	6.46	3.51	24.10	21.15
Total		1	0.70	1.30	1.89	1.19	2.68	1.38	9.46	8.16
		2	4.20	4.80	3.10	(1.10)	4.14	(0.66)	9.40	4.60
		3	-	-	0.51	0.51	0.75	0.75	8.34	8.34
		4	-	0.60	1.24	1.24	2.86	2.26	12.02	11.42
		5	-	-	1.01	1.01	2.73	2.73	10.87	10.87
		Total	4.90	6.70	7.74	2.84	13.15	6.45	50.11	43.41

Table 6-19: Staffing Gaps by Maintenance Activity by Region.

6.4.1 Staffing Development Alternatives

There are two broad classes of staffing development alternatives: increasing maintenance staff size, and increasing skills levels.

6.4.1.1 Staffing

To enhance resources within ODOT for staffing levels would require the addition of new FTE positions or the reassignment of existing FTE positions. As was demonstrated by the program options package this summer, it is feasible for ODOT to add new FTE positions. Under continued pressure from the state legislature to restrain hiring levels, however, it may be difficult for ODOT to continue this course in the future, especially at a rate to meet planned deployment levels.

Alternatively, ODOT may choose to reassign existing FTEs from other divisions into ITS maintenance, and then use contract support to address maintenance needs elsewhere. The advantage of juggling staff like this is that it may be easier to contract some ODOT functions than it would be to contract ITS maintenance. It is beyond the scope of this plan to identify other activities within ODOT that would be better candidates for contracting than ITS maintenance.

6.4.1.2 Training

Five different training concepts were identified as possibilities for addressing training gaps:

- contractual training, where training is included as a part of device procurement;
- remedial training, which is provided by the vendor under a separate contract after the device has been deployed;
- development training, which is provided by colleges or technical schools and may provide theoretical understanding that may be applicable to multiple devices;
- training from other agencies, which involves taking advantage of contractual training received at other transportation agencies when they receive a new device deployment; and
- internal training, where senior ODOT maintenance technicians train junior technicians on maintenance activities.

The main characteristics of each of these training methods are outlined in Table 6-20 and are described in detail in Appendix L.

6.4.1.3 Staff Enhancement Guidelines

Based on this evaluation, the following guidelines are recommended for staffing and training enhancement.

- ODOT should require a training component in all new device procurements. Contractual training should not only include operations training, but also maintenance. It is critical that multiple technicians who would be involved in

	Type of Training				
	Contractual	**Remedial**	**Development**	**Other Agencies**	**Internal**
Description	Obtain training through initial procurement contract	Obtain training from vendor after deployment	Take professional development or continuing education classes	Obtain training in conjunction with other agencies' deployments	ODOT trains itself
Areas of Training					
Field components	All	All (provided vendor is still in business)	Theoretical training	Some (based on deployment)	Some (based on experience)
IS components	Custom applications	Custom applications	All	Custom applications	All
Characteristics					
Schedule availability	Only on deployment	On demand	Subject to course providers	Subject to their deployment	Subject to staff availability
Duration of training	Short course	Short course	Short or long course	Short course	Short course
Cost per staff	Negligible	Negligible	Full	Some	Negligible
Vendor cost	Time	Time, travel, lodging	Included in tuition	Time, partially borne by other agency	None
Advantages	• Reduces vendor cost • Minimizes down time after installation	• If training is not included in procurement it may reduce deployment cost • Fills existing training gaps	• Theoretical training may apply to many devices • May assist in recruiting and retention	• Reduces ODOT cost	• No additional vendor or class cost • Builds upon unique local experience • Builds camaraderie • Ensures all staff are expanding skills
Disadvantages	• Training gap until legacy devices are replaced • Training gap if people leave ODOT	• Vendor cost is high • Device-specific training: little "bang for the buck"	• Time to acquire theoretical training may be significant • May hurt in retention	• Subject to schedules and manufacturers selected by other agencies	• Useless without existing skills base • Requires ODOT staff to be available to teach

Table 6-20: Training Alternatives.

maintenance attend, so that there is no single point-of-failure. The maintenance training should include demonstrations of recommended preventative maintenance activities, and instructions on basic diagnostics and repairs.

- ODOT should strive to have basic troubleshooting skills on all ITS devices in-house. As ODOT's diagnostic capability increases, this will reduce the amount of time and expense that must be committed to device repair.

- ODOT should have extensive repair capabilities in-house on high-priority devices. To maintain leverage with contractors as well as to minimize response time, ODOT should preserve the ability to perform all diagnostic and most repair functions on its high-priority devices.

- ODOT should minimize the use of remedial training. Remedial training will be more expensive and less convenient than cross-training and will typically be applicable to only a specific manufacturer of a specific device. Based on the analysis of skills gaps, Table 6-21 shows that for only two devices – weigh-in-motion systems and fiber optics communication systems – would it be advisable for ODOT consider relying on remedial training.

- ODOT should pursue greater cross-training to improve overall staff skill levels. Surveys conducted throughout ODOT reveal that there is, in-house, basic knowledge adequate for troubleshooting on nearly every ITS device ODOT has deployed. However, there has not been adequate knowledge dissemination across regions to improve the overall skills base. Improving the overall level of training will, at a minimum, give ODOT leverage in negotiating contracts with vendors. It would also help to improve the efficiency at which ODOT performs maintenance activities.

- ODOT should allocate time for staff to participate in training activities. The benefits of training staff on ITS maintenance (e.g. reducing device down-time, improving staff morale, increasing device longevity, decreasing maintenance cost) are significant, and should not be ignored in maintenance planning. These training activities must be planned to maximize the benefit of cross-training workshops and to ensure that they may occur when ITS maintenance needs are less time-sensitive.

- Staff should have the opportunity to use training. Staff will perceive training programs to be a waste of time unless they have the opportunity to apply their training to real-world maintenance needs.

6.4.2 Contracting Alternatives

As an alternative or supplement to enhancing and developing ODOT's staffing resources, ODOT may decide to utilize contracts to fulfill ITS maintenance needs. The trend for using contractors to perform highway maintenance activities is on the increase. Table 6-22 lists those factors most frequently cited in a survey of transportation agencies as reasons which contracting is used. Based on anecdotal evidence, ITS maintenance is also following this trend. Table 6-23

	No Training Necessary	Cross-Training	Training by Procurement	Remedial Training
Automatic Traffic Recorders	✓			
Speed Zone Monitoring Stations	✓			
Closed-Circuit Television (CCTV) Surveillance		✓		
Video Detectors			✓	
Road and Weather Information System (RWIS)		✓		
Travel Time Estimation			✓	
Automatic Vehicle Location (AVL)			✓	
Traffic Signals	✓			
Ramp Metering	✓			
Emergency Signal Preemption	✓			
Transit Signal Prioritization	✓			
Advanced Traffic Management System		✓		
Callboxes	✓			
Cellular Call-In	✓			
Regional Incident Detection System	✓			
Intersection-Based Incident Detection System	✓			
Computer-Aided Dispatch		✓		
Incident Response Vehicles		✓		
Pre-planned Detour Routes	✓			
Hazardous Material Response	✓			
Alphanumeric Paging	✓			
Highway Travel Conditions Reporting System	✓			
800-number Information	✓			
Internet Access	✓			
Kiosks			✓	
Icy Bridge Warning CMS	✓			
Tunnel Lane Closure CMS	✓			
Radio-Controlled Snow Zone CMS	✓			
Telephone-Activated Snow Zone CMS	✓			
Oversize Vehicle Restriction CMS	✓			
Permanent Variable Message Signs		✓		
Portable Variable Message Signs		✓		
Highway Advisory Radio (HAR)	✓			
Icy Bridge Detectors		✓		
Oversize Load Detectors		✓		
Variable Speed Limit Systems		✓		
Queue Detection System	✓			
Weigh-in-Motion (WIM) Systems		✓		✓
Downhill Speed Advisory Systems		✓		
Fiber Optic Networks				✓
Radio Communications	✓			
Maintenance Coordination	✓			

Table 6-21: Training Recommendations for Closing Skills Gaps.

lists some agencies that are relying almost exclusively on contracting for maintenance of ITS deployments.

Reason	Respondents	
	No.	%
Limitations on in-house staff	51	96%
The need for specialized equipment	50	94%
The need for specialized personnel	44	83%
To cover peak work loads	42	79%
To obtain services at lower cost	38	72%
Executive policy	37	70%
Emergency work	35	66%
To improve responsiveness	31	58%
Legal restrictions on the amount of work performed by agency forces	16	30%
Legal restrictions on contracting	16	30%
Employee contract restrictions	11	21%

Table 6-22: Top Reasons for Contracting Highway Maintenance.

(Source: 34)

Agency / Facility	Location	Types of Devices
Florida DOT (35, 36)	Orlando Tampa (Sunshine Skyway Bridge)	CCTV, VMS, loop detectors CCTV, wind sensors, callboxes
Indiana DOT (37)	Indianapolis	*CCTV, VMS, detectors
Kentucky Transportation Cabinet (38, 39, 40)	Statewide Cincinnati Cumberland Gap Tunnel	RWIS CCTV, VMS, detectors CCTV, VMS, CMS
Michigan DOT (41)	Detroit	CCTV, VMS, detectors
Missouri DOT (42)	St. Louis	*CCTV, VMS, microwave detectors
New York State DOT (43, 44)	Buffalo Long Island	CCTV, VMS, HAR CCTV, VMS, ramp meters, traffic signals, loop detectors
North Carolina DOT (45)	Greensboro	CCTV, VMS
Pennsylvania DOT (46, 47)	Philadelphia Scranton/Wilkes-Barre	CCTV, VMS, ramp meters, loop detectors CCTV, VMS
Pennsylvania Turnpike (48)	Systemwide	CCTV, VMS, HAR, queue detection stations, electronic toll collection
Wisconsin DOT (49)	Milwaukee	CCTV, VMS, ramp meters, loop detectors, microwave detectors

* - Planned deployment

Table 6-23: Selected Agencies Relying on Contracting for ITS Maintenance.

	Enhance Existing Staff	Contracting
Advantages	• Promotes ownership of system, which may improve maintenance quality and responsiveness • Potentially less expensive for frequent maintenance activities • Promotes organizational autonomy	• Politically simpler than trying to get additional FTEs • Potentially less expensive to contract infrequent or high-skill maintenance activities than to develop in-house expertise • Reduces need to continually train staff as new devices are implemented • Expedites acquisition of spare parts
Disadvantages	• Staff expansion may be constrained by legislation • Staff expansion requires additional support infrastructure (i.e. building space, etc.) • Difficult to cost-effectively acquire additional staff • Staff turnover can mean loss of skills base • Need to continually train staff as new devices or technologies are implemented • Inefficient to have many staff trained on infrequent maintenance problems	• Hard to develop sense of ownership for new contractor relationship • Difficult to obtain for some regions and devices • 24-hour, 7-day-a-week support may be prohibitively expensive • Quality and responsiveness of contractor maintenance is somewhat out of ODOT control • Hard to control costs

Table 6-24: Advantages and Disadvantages of Contracting for Maintenance

Table 6-24 summarizes some of the advantages and disadvantages of contracting for maintenance relative to enhancing and developing in-house capabilities. The trend of agencies toward using contracting is motivated primarily by the difficulty of hiring additional FTEs or giving staff adequate training. Many agencies have used contracts only out of necessity, however, and would rather use in-house support because of the perceived value of staff having a sense of ownership.

6.4.2.1 Contracting Methods

If ODOT elects to use contracting for some or all ITS maintenance activities, it is important to decide which contracting methods would best meet their needs. ODOT may elect to use traditional contracting methods or more innovative contracting practices.

Traditional Contracting. According to the 1997 Oregon Revised Statutes (ORS) 279.029, after a decision has been made that a contract is to be awarded, the contract is awarded to the lowest responsible bidder. The lowest responsible bidder is further defined as the lowest price, responsive bidder who has complied with all prescribed public bidding procedures and requirements, and who is not disqualified for any of the following reasons specified in ORS 279.037[6]:

- it does not have sufficient financial ability to perform the contract,
- it does not have equipment available to perform the contract,
- it does not have key personnel available of sufficient experience to perform the contract, or
- it has repeatedly breached contractual obligations to public and private contracting agencies (50).

The purpose of using a low-bid method for procuring maintenance has the benefit of encouraging competition. ORS 279.005 states, however, that price does not have to be the only grounds of comparison for ensuring competition in a bidding process, but that performance evaluations and evaluations of capabilities may be taken into consideration as well (50).

Assuming that price is the only criteria that ODOT uses for selecting a contractor, there are many potential types of low-bid contracts that may be pursued (51):

- fixed-price contracts, which establish a ceiling price for all prescribed maintenance activities;
- cost-reimbursement contracts, which pay for allowable incurred costs up to an estimated cap, which may be exceeded on the authority of the contracting agency;
- incentive contracts, which use various types of incentives or disincentives to motivate the contractor to perform in a way that may not be likely or possible under a fixed-price contract;
- indefinite-delivery contracts, which limit the agency's obligation to a minimum amount of maintenance as specified in the contract but use work orders to obtain services on an "as-needed" basis; and
- time-and-materials (T&M) contracts, which provide for acquiring service on the basis of direct labor hours at specific hourly rates (including overhead costs) and materials at cost.

Table 6-25 compares how these contracts may be structured for various types of ITS maintenance activities and highlights some of their relative strengths and weaknesses.

[6] ORS 279.015 allows several exemptions from the competitive bidding process (described in ORS 279.005 and ORS 279.007), including but not limited to:

- the contract value is less than $5,000;
- such an exemption is unlikely to encourage favoritism in the awarding of contracts or substantially diminish competition for contracts;
- using the exemption for a contract award will result in substantial cost savings to the public agency; or
- emergency conditions require prompt execution of the contract, and the contract value is less than $50,000.

ORS 366.445 specifies an additional exemption for ODOT to repair "at once any state highway which has been damaged by slides, flood or other catastrophe" such that it must be closed to traffic. This could include, for example, an overhead VMS structure falling onto a roadway.

	Fixed-price	Cost-reimbursement	Incentive	Indefinite-delivery	Time-and-materials
Description	Establish a ceiling price for all prescribed maintenance activities	Pay for costs up to an estimated cap, which may be exceeded on the authority of the contracting agency	Use incentives or disincentives to motivate the contractor	Obtain services on an "as-needed" basis	Acquire services based on specific hourly labor rates (with overhead) and materials at cost.
Example 1: VMS maintenance	Perform preventative and repair maintenance on VMS statewide for $900,000 per year	Pay contractor based on incurred costs to repair VMS (spare parts, labor)	Contractor pays $5,000 / day penalty for an urban VMS being down	Pay contractor only when VMS breaks $1,000 per visit (pre-determined in contract)	VMS technician bills at $50 / hour (including overhead) for repair activities
Example 2: RWIS server maintenance	Perform preventative and repair maintenance on RWIS regional servers for $10,000 per year	Pay contractor for each visit that is required and any hardware replacement costs	Contractor gets $500 / day for number of days where server operates acceptably	Call technician whenever server isn't functioning properly	Information technology specialist bills at $100 / hour (including overhead) for repair visits
Advantages	• Agency has fixed budget commitment • Good for preventative maintenance	• Works well when uncertainties in cost estimates do not allow for a fixed-price contract	• Rewards contractor for exceptional service	• Good when frequency of repair activity is unknown	• Good when it is difficult to accurately estimate the extent or duration of the work
Disadvantages	• Not good for repair maintenance unless frequency and severity of repairs can be reasonably predicted	• Requires contractor to have adequate accounting system • Requires appropriate monitoring to provide reasonable assurance that there are efficient cost controls	• Difficult to quantify incentives appropriate for ITS maintenance	• Different service calls may require different amounts of repair effort • Not appropriate for preventative maintenance	• Requires appropriate monitoring, because there is no incentive for labor efficiency

Table 6-25: Comparison of Traditional Contracting Methods.

In contracts specifically focused on maintenance activities, ORS 646.265 and ORS 646.267 define three broad classes of contracts that the State of Oregon will allow:

- maintenance agreements, which are contracts of limited duration that provide for scheduled (i.e. preventative) maintenance only;
- service contracts, which are contracts to perform "the repair, replacement or maintenance of property for operational or structural failure due to a defect in materials, workmanship or normal wear and tear" or due to damage "resulting from lightning, power surges or accidental damage from handling"; and
- warranties, which are given solely by the manufacturer as a part of a purchase agreement, without being negotiated as a part of the sale of the product, to cover defective parts and mechanical or electrical breakdowns (50).

These contracts would be able to, if desired by ODOT, cover ITS maintenance from the time a device is put into the field until it is replaced. On a preliminary analysis, there does not appear to be restrictions that these maintenance agreements and service contracts must be developed independently of each other.

Innovative Contracting. ORS 279.015 subsection (6)(a) calls for the agency director to, where appropriate, "direct the use of alternative contracting and purchasing practices that take account of market realities and modern or innovative contracting and purchasing methods." (50) Many innovative contracting methods have been developed in associated with highway construction projects as well as some ITS deployments. Some of the more commonly used innovative contracting methods for highway construction projects include the following.

- A+B Bidding (also known as cost plus time). A low-bidder is selected based on a combination of the contract bid items (A) and the time (B) needed to complete the project (52). Because the time frame involved in ITS maintenance activities is short, this method appears to have little applicability.

- Design-Build. According to the Utah Technology Transfer Center, design-build (DB) is a process "by which a single entity provides both the design and construction through the use of a single contract between the agency and the contractor" (53). By itself, DB has little applicability to ITS maintenance. Variations of DB, such as design-build-maintain (DBM) or design-build-warrant (DBW), may have some applicability for ITS maintenance after vendor warranties on field components have expired. Design-build contracts would have no applicability for existing ITS devices.

- Lane Rental. This type of contract assesses the contractor daily or hourly "rental fees" for each lane, shoulder or combination of lanes and shoulders that are taken out of service to perform contracted activities (54). This provides the contractor with an incentive to minimize the disruption that maintenance activities may cause on traffic flow. ODOT has used this method for two reconstruction projects on U.S. 26 in Portland (55). This type of contract may have applicability for maintenance activities which require lane closures, such as some overhead VMS maintenance, some CCTV maintenance activities, and replacement of loop detectors. It is important to note, however, that the time involved in lane closures for ITS maintenance will be minimal compared to that for traditional highway construction projects.

- Warranty. For highway projects, these are generally provided for a two- to five-year period after construction and are limited to items over which the contractor has full control (56). The purpose of this contract is to force the contractor to stand behind its work. A warranty may have applicability for repair of ITS field devices to a certain extent. For ITS devices, however, a warranty of this duration on device maintenance would not be practical; a shorter warranty, such as six months to one year, may be more appropriate.

- Job Order Contracting. Contractors will bid by submitting on a proposed contract with a factor that includes overhead, profit, and similar costs. The factor is multiplied by unit prices developed by the agency in order to determine the total contract amount (57). This is readily applicable to highway construction projects where many unit prices have been clearly established. Because reliable unit prices have not been developed for ITS maintenance, this would not appear to be viable at this time.

- Life Cycle Cost Procurement. The state of Missouri has used this approach for selecting bridge seismic retrofit systems, so that initial fabrication costs are included along with installation, inspection and maintenance costs (58). This type of procurement has potential application for new deployments in ODOT's ITS infrastructure, and would require the vendor to stand behind its product. This would not be applicable for legacy ITS devices.

6.4.2.2 Contracting Activities

ODOT must also decide which, if any, portions of its ITS maintenance activities should be contracted. There are several different classes of maintenance activities that may be contracted either independently of one another or in combination. These alternatives include the following:

- preventative maintenance, which may also be called a maintenance agreement;
- repair maintenance, which may also be called a service contract;
- low-level maintenance, which refers to lower skill level maintenance activities;
- high-level maintenance, where more sophisticated or specialized maintenance activities are contracted; and
- select devices, where certain devices are contracted for end-to-end maintenance.

These alternatives are summarized in Table 6-26, and are discussed in greater detail in Appendix M.

6.4.2.3 Contract Guidelines

When contract maintenance is used, the following guidelines should be kept in mind.

	Staffing Alternatives			Training Alternatives	
Name	**Preventative**	**Repair**	**Low-Level**	**High-Level**	**Select Devices**
Description	Use contractors to perform preventative maintenance	Use contractors for addressing repair or response maintenance	Use contractors for low skill-level maintenance activities	Use contractors for high skill-level maintenance activities	Use contractors for all maintenance (preventative and repair) on select devices
Advantages	• Ensures preventative maintenance will not be neglected • Potential for greater competition in more regions and on more devices	• Provides guarantee for response time • Eliminates need for ODOT to acquire expensive equipment for infrequent repairs	• Potential for greater competition in more regions and on more devices • Maintenance staff may continue to gain expertise	• Potential for savings in training and salary costs for staff • Consistent with organizational philosophy	• Allows ODOT to focus its maintenance activities on areas where its skills are strongest • Can contract for devices only where it may be cost-effective • Compatible with procurement schedules
Disadvantages	• Quality control is hard to enforce • Contractor will have no incentive to make repairs not in contract • Requires larger deployment to be cost-effective for vendors	• 24-hour, 7-day support is expensive • Lack of perceived ownership may limit willingness to make off-hour repairs	• Response time suffers, because these tasks may be handled more quickly by ODOT • May require multiple repair visits to restore operations	• Few contractors would be able to provide high-level maintenance in rural regions • Limits career path for field technicians	• Ties ODOT to vendor • Does not develop in-house expertise on these devices • Requires larger deployment to be cost-effective for vendors

Table 6-26: Contracting Alternatives.

- <u>Maintenance contracts should provide performance specifications for maintenance</u>. The contract should provide guidelines for emergency versus non-emergency repairs, with appropriate response times for each type. The contract should be very clear on how the contractor is notified of problems, how response time is defined, and how repairs are tested to ensure that they are adequate. In addition, the stringency of performance specifications should affect the decision about whether or not to contract. A Transportation Research Board report on maintenance contracting recommends that activities requiring fairly short response times and less than full-time contractor commitments should normally not be contracted (<u>34</u>).

- <u>Contract maintenance has a mixed track record for responsiveness to repair needs</u>. Simply specifying a response time in the contract does not guarantee contractor responsiveness. Moreover, depending upon how contracts are administered, response time may not be enforceable. At one agency contacted in this study, the maintenance contract serves the needs of the traffic division, but the contract was administered through the construction division because they have more experience with contract administration. The construction division has not been willing to enforce response time provisions to the level that the traffic division would like (<u>46</u>). Other agencies have had more favorable contractor experiences.

- <u>The vendor may not always be the best party to perform contract maintenance</u>. There are several advantages to retaining the original vendor for contract maintenance, such as expedience in acquiring spare parts, greater device-specific knowledge and good familiarity with local applications. If a vendor uses some non-standardized components in its devices, however, such an arrangement may leave ODOT vulnerable to contract price escalation.

- <u>Multiple, concurrent contracts may lead to "finger pointing"</u>. In some agencies where multiple concurrent contracts have been issued for a specific region, contractors may tend to blame each other for device malfunctions (<u>49</u>). This may increase response time and decrease system performance.

- <u>Maintenance contracts should be fairly short in duration, with renewal options</u>. In order to avoid getting saddled with an ineffective contractor for an extended period of time, ODOT should not allow maintenance contracts to be too lengthy in duration. This is especially appropriate in ITS maintenance, where technology upgrades may significantly affect maintenance needs. In conversations with other agencies, most maintenance contracts seem to run between one and two years. In order to reward contractor performance, however, ODOT should seek to include contract renewal options. This will encourage contractors to develop a long-term relationship with the agency, and will increase the contractor's sense of ownership.

- <u>Cost of specialized equipment should be considered in contracting</u>. If there are significant equipment costs involved in a maintenance contract, such as fiber optic test equipment or bucket trucks, a short-term contract may end up discouraging bid competition (<u>34</u>). One alternative that ODOT may consider, when equipment costs are significant, is to provide the specialized equipment to whichever contractor has been selected. Alternatively, ODOT may elect to develop a longer term contract, which would allow the contractor to fully depreciate the cost of the specialized equipment.

- Price contracts may hinder developing long-term maintenance relationships. In some instances where the agency is required to select the lowest price bid on a contract, there have been some bad experiences with underqualified entities winning maintenance contracts and satisfactory entities losing contracts.

- Contracts should be administered in a way that does not restrain competition. Options include cost competition between ODOT and a contractor on given maintenance activities, or subdividing a maintenance activity (such as preventative maintenance on VMS) between multiple contractors (34).

- A new maintenance contractor may require some in-house expertise. New contractors, especially if they did not perform the initial system installation, may be unfamiliar with many specific aspects about the ITS infrastructure, such as communications interfaces. Some in-house expertise may be necessary to provide a new contractor with enough initial knowledge to be able to effectively maintain the system.

6.4.3 Recommendations

In order to successfully meet its ITS maintenance needs, ODOT must select some combination of training and contracting alternatives. Table 6-27 provides some recommendations for where ODOT should use in-house expertise versus using contract support for maintenance. There were three primary determinants for whether or not maintenance activities should be contracted out.

- Is a particular device especially critical to how ODOT plans to fulfill its mission to the traveling public? The more critical a device is to ODOT's daily operations, then the better it is to have resources in-house available to minimize response time.

- Does a particular device have a broad enough deployment around the state to make a contract economically viable? As was shown in Table 6-23, it is not uncommon for a metropolitan area within a state Department of Transportation to decide to contract for ITS maintenance independent of other regions in the state. While ODOT may try that with deployments in Region 1, this would likely hinder the ability of ODOT to contract much other maintenance around the state. Therefore, ODOT should seek to – where possible – use statewide maintenance contracts for activities that are deemed appropriate for contracting.

- Could clear lines of responsibility between ODOT and the contractor be readily established? The absence of a clear demarcation between where the contractor's responsibility ends and ODOT's responsibility begins creates the potential for conflict and finger-pointing during times when critical repairs are needed.

		Existing		STIP		Strategic	
Device	**Activity**	**PM**	**Rep**	**PM**	**Rep**	**PM**	**Rep**
Automatic Traffic Recorders	All						
Speed Zone Monitoring Stations	All						
Closed-Circuit Television (CCTV)	Prev. Maint.					C	C
	Repair Maint.						
Video Detectors	All	W	W	W	W		
Road and Weather Information System (RWIS)	Field Units					C	C
	Servers						
Travel Time Estimation	All	W	W	W	W	C	C
Automatic Vehicle Location (AVL)	Repair of Sensors					C	C
	All other maint.						
Traffic Signals	All						
Ramp Metering	All						
Emergency Signal Preemption	All						
Transit Signal Prioritization	All						
Advanced Traffic Management System	All						
Callboxes	All						
Cellular Call-In	All	no maintenance necessary					
Regional Incident Detection System	All						
Intersection-Based Incident Detection System	All						
Computer-Aided Dispatch	All						
Incident Response Vehicles	All						
Pre-planned Detour Routes	All						
Hazardous Material Response	All						
Alphanumeric Paging	All						
Highway Travel Conditions Reporting System	All						
800-number Information	All						
Internet Access	All						
Kiosks	All	W	W	W	W	C	C
Icy Bridge Warning CMS	All						
Tunnel Lane Closure CMS	All						
Radio-Controlled Snow Zone CMS	All						
Telephone-Activated Snow Zone CMS	All						
Oversize Vehicle Restriction CMS	All						
Permanent Variable Message Signs (VMS)	Prev. Maint.					C	C
	Repair						
Portable Variable Message Signs (VMS)	All					C	C
Highway Advisory Radio (HAR)	All						
Icy Bridge Detectors	Field Units					C	C
Oversize Load Detectors	Field Units					C	C
Variable Speed Limit Systems	Field Units					C	C
Queue Detection System	All						
Weigh-in-Motion (WIM) Stations	All	C	C	C	C	C	C
Downhill Speed Advisory Systems	WIM components	C	C	C	C	C	C
	PM - VMS					C	C
	Repair - VMS						
Fiber Optic Networks	All	C	C	C	C	C	C
Radio Communications	All						
Maintenance Coordination	All						

(1) Responsibility may change hands in the future.

LEGEND

	- In-house (default)
	- In-house, currently outside of ITS maintenance
W	- Warranty coverage
C	- Contract coverage

Table 6-27: Contracting Recommendations by Device.

On that basis, the following devices were determined as most appropriate to contract.

- Weigh-in-motion (WIM) systems. These devices are ranked as the lowest repair priority among ITS devices. Moreover, contract maintenance has already been used successfully for these devices. The WIM component of the downhill speed advisory systems would also lend itself to contract maintenance.

- Kiosks. Contracting for kiosks would be favorable for many reasons, including the need for frequent preventative maintenance, the lower technical skill involved in maintenance, and the number of kiosks deployed statewide. While kiosks would be a high visibility item, they would not be the only way in which travelers in Oregon may receive pre-trip information, and would likely serve smaller volumes of user traffic than either the Internet or the 800-number.

- Preventative maintenance on CCTV and permanent VMS. The wide deployment of these devices favors contract maintenance. Due to the mission-critical nature of these systems, however, it is recommended that ODOT continue to do repair maintenance in-house.

- RWIS field units. Broader statewide distribution of RWIS systems should allow a contractor to economically perform preventative and repair maintenance on these devices. It is recommended that ODOT continue to maintain RWIS regional and statewide servers because of their integration in ODOT's wide-area network. On the same basis, the weather sensors and field units for icy bridge detectors, oversize load detectors and variable speed limit systems would be recommended for contracting as well. The field devices for these latter systems would have a higher priority than simple RWIS stations, however, because of the potential for liability exposure when they are non-operational in critical situations.

- Travel time estimation. This system does not seem to be as critical to traffic management in Region 1 as other ITS devices at this time; this may change once an operational system is deployed. Nevertheless, because this system has not been deployed, it may be an excellent candidate for a design-build-maintain procurement contract.

- Automatic vehicle location in-vehicle sensors. Because of the wide number of maintenance vehicles that will eventually have AVL equipment, this could be a cost-effective contracting arrangement.

- All maintenance activities on portable VMS. Contracting is only recommended under the Strategic Plan, when deployment of portable VMS statewide is planned to reach over 400. The number of portable VMS would likely allow individual units to be out of service for a couple of days in order to have maintenance performed, so response time may not be as critical.

- Fiber optics. Fiber optic communications is clearly an ITS support element that is critical to ITS operational success, especially in Region 1. However, the cost of test equipment for performing repair fiber optic maintenance may exceed $50,000 (6), and the frequency of maintenance tasks is limited. Unless ODOT significantly increases its fiber optics infrastructure, ODOT would likely have difficulty in recovering the cost of the test equipment. It should be emphasized, however, that ODOT does have adequate training and test equipment to be able to perform some localized fiber optics maintenance tasks.

Maintenance on all other ITS devices is recommended to be performed by ODOT staff. In order for ODOT to successfully maintain these items, it is critical that the training gaps mentioned previously in this chapter be addressed through cross-training.

7 MAINTENANCE BUDGET

A final critical element in the maintenance plan is the development of a comprehensive maintenance budget. The purpose of this budget is to quantify how much money should be devoted to ITS maintenance activities, not necessarily how much money is currently being spent on these activities throughout ODOT. The budget is developed at both regional and device levels by considering individually the following cost components:

- staffing,
- vendor/contractor costs,
- training,
- device replacement,
- spare parts, and
- test/specialized equipment.

After stating some general assumptions applied to developing the maintenance budget, this chapter will describe assumptions specific to each of these cost components. The chapter will conclude with some summary tables of a comprehensive maintenance budget for three forecast years – existing, STIP and Strategic Plan build-out – and recommendations for further courses of action.

7.1 General Assumptions

Given the lack of available data on actual, historical maintenance costs, developing a comprehensive statewide ITS maintenance budget requires several simplifying assumptions. These assumptions are described as follows.

- Indirect costs are excluded. There are many indirect costs associated with ITS maintenance activities, such as utilities to TOCs and vehicle costs for servicing field components. It is assumed that these costs would be included elsewhere in ODOT's budget.

- Operations costs are excluded. The cost of operating ITS devices, including the cost of supplying power and telephone service, is excluded from the budget. Salary costs for operators at the TOCs are also excluded. These costs would be encumbered elsewhere in ODOT's budget.

- All budgets are developed in current-year dollars. In order to simplify the analysis, no consideration will be made for the effect of salary inflation, change in costs for spare parts and device replacement, or other instances where the price of a resource may change over time.

- Each group of devices is considered homogeneous from a cost perspective. Conversations with ODOT stakeholders have revealed that there are variations in maintenance needs between manufacturers as well as deployment locations. It is assumed that improvements in manufacturing technology and maintenance practices will tend to dampen these variations over time.

- Costs reflect contracting recommendations described in Section 6.4. Different decisions on whether or not to contract specific maintenance activities may have significant effects on the maintenance budget.

7.2 Staffing

The most significant component of ODOT's maintenance budget will be the cost of personnel. In addition to the assumptions presented in Chapter 6 when estimates of staffing resource needs were developed, the following assumptions have been applied.

- Labor rates. Monthly salary estimates for ODOT staff classifications were estimated from tables published by the State of Oregon's Department of Administrative Services (DAS). These tables offer several cost levels for each classification (59, 60, 61, 62, 63). In order to provide a worst case scenario, it was assumed that all work done at each classification level would be charged at the highest labor cost for that classification. Table 7-1 shows the resulting estimates for ODOT employee salaries.

Position	Abbrev	FTE	Monthly
Support Coordinator / IS-Diag	SC-I-D	42,000	3,500
Support Coordinator / IS-Repair	SC-I-R	42,000	3,500
Support Coordinator / IS-Preventative Maintenance	SC-I-PM	42,000	3,500
Support Coordinator / Elec-Diag	SC-E-D	42,000	3,500
Support Coordinator / Elec-Repair	SC-E-R	42,000	3,500
Support Coordinator / Elec-Preventative Maintenance	SC-E-PM	42,000	3,500
Support Coordinator / Program Technician	SC-P	42,000	3,500
Info Services - Kiosk Specialist	IS-K	30,000	2,500
Info Services 5 - Radio Technician	IS-5R	51,180	4,265
Info Services 5 - Networks / Servers	IS-5N	51,180	4,265
Info Services 5 - Software	IS-5S	51,180	4,265
Info Services 6 - Radio Technician	IS-6R	54,780	4,565
Info Services 6 - Networks / Servers	IS-6N	54,780	4,565
Info Services 6 - Software	IS-6S	54,780	4,565
Info Services 7 - Networks / Servers	IS-7N	60,708	5,059
Info Services 7 - Software	IS-7S	60,708	5,059
Fiber Optic Technician	IS-F	60,000	5,000
Electrician	ELEC	46,392	3,866
Traffic Signal Technician 3	TS-3	45,024	3,752

Table 7-1: Assumed Monthly Salary Rates for ODOT Staff.
(Sources: 59, 60, 61, 62, 63)

- Fringe benefits. Based on discussions with ODOT staff, it was assumed that 70 percent of salary would represent an appropriate estimate of employee fringe benefits and support costs.

- Overtime compensation. ORS 279.340 provides for state employees to be paid at a premium for work in excess of 40 hours in a given week (50). For simplicity, it is assumed that no work would be performed which would require overtime compensation rates.

Table 7-2 provides estimates of annual maintenance costs for ODOT personnel by region. Costs for centralized maintenance support employees based in Salem, such as TSSU and centralized IS support, are included in the region their maintenance activities occur.

7.3 Vendor/Contractor Costs

For the purposes of estimating vendor and contractor costs, a distinction is made between maintenance provided by vendors and maintenance provided by contractors. Vendor maintenance refers to maintenance activities which, due to the specialized nature of a component, are performed exclusively by the vendor or supplier. Examples of this include repairs to automatic vehicle location (AVL) in-vehicle units, emergency call boxes, and similar "black-box" components. Estimating vendor maintenance costs is complicated by the following factors.

- The cost of repairs for a given black box component may vary considerably from one repair to another. In some cases, the cost of repair may be deemed to be more expensive than replacement, so the vendor may elect simply to replace the defective component.

- Vendors may change over time. Vendors may offer differing degrees of warranty coverage, affecting the vendor maintenance costs that need to be borne by ODOT. Some vendors may offer lifetime warranties for certain components, which would reduce ODOT's maintenance costs. In some cases, warranty coverage may also change when one vendor is bought out by another.

- According to anecdotal evidence, vendor maintenance is required infrequently for successful device operations, such as in the cases of the AVL in-vehicle units and emergency call boxes described above.

	Region					State
	1	2	3	4	5	Total
Existing	$ 140,355	$ 243,117	$ 23,282	$ 92,196	$ 47,694	$ 546,644
Existing + STIP	$ 171,439	$ 323,427	$ 37,120	$ 193,526	$ 175,709	$ 901,221
Existing + Strategic Plan	$ 203,650	$ 273,676	$ 112,878	$ 145,538	$ 170,312	$ 906,054

Table 7-2: Estimated Personnel Costs by Region.

Contractor Support	ODOT Salary	Labor Premium	Overhead	Monthly Cost
Support Coordinator	3,500	10%	1.50	5,775
Information Services - Kiosks	2,500	10%	1.50	4,125
Information Services Level 5	4,265	10%	1.50	7,037
Information Services Level 6	4,565	10%	1.50	7,532
Information Services Level 7	5,059	10%	1.50	8,347
Information Services - Fiber Optics	5,000	10%	1.50	8,250
Electrician	3,866	10%	1.50	6,379
Traffic Signal Technician 3	3,752	10%	1.50	6,191

Table 7-3: Assumed Monthly Salary Rates for Contractors.

For these reasons, explicit vendor maintenance costs are excluded from the maintenance budget.

Contract maintenance includes maintenance activities that do not have to be exclusively performed by the vendor, although the vendor may perform them if they are selected in a competitive bidding process. As was discussed last chapter, there is considerable variety in the types of contracts that may be used, each with different cost implications. For simplicity, the following assumptions have been imposed over all contractual maintenance included in ODOT's ITS maintenance program.

- Contract structure. It is assumed that contractors would bill on a time-and-materials basis. The cost of materials, such as replacement and spare parts, will be considered in sections 7.5 and 7.6. The overhead rate is assumed to be 150 percent of salary.

- Labor rates. It is assumed, for the purpose of estimating maintenance costs, that the maintenance contractor would have similar staffing classifications as ODOT. Hourly rates for contract maintenance are assumed to be 10 percent higher than comparable ODOT rates. Table 7-3 shows estimates of assumed labor rates for contract maintenance staff.

- Overtime. Similar to ODOT personnel costs, no overtime compensation is assumed for contractors, although contractors may be eligible for it[7].

- Travel time. It is assumed that ODOT would pay for a certain portion of travel time – up to one hour each way – in any maintenance contract. Any travel time in addition to

[7] According to ORS 279.334, contractors are eligible for overtime pay:
- for all overtime in excess of eight hours a day or 40 hours in any one week when the work week is five consecutive days, Monday through Friday; or
- for all overtime in excess of 10 hours a day or 40 hours in any one week when the work week is four consecutive days, Monday through Friday; and
- for all work performed on Saturday and on recognized legal holidays (50).

	Region					State
	1	2	3	4	5	Total
Existing	$ -	$ 6,484	$ 12,967	$ -	$ 20,754	$ 40,205
Existing + STIP	$ 40,528	$ 9,726	$ 17,512	$ 12,967	$ 20,754	$ 101,487
Existing + Strategic Plan	$ 585,181	$ 425,714	$ 437,911	$ 474,445	$ 454,975	$2,378,226

Table 7-4: Estimated Contractor Costs by Region.

this would be incorporated in the contractor's overhead rate. This would provide a contractor with the incentive to put staff in close proximity to field devices, which would improve response time.

- Work efficiency. It is assumed that contractors will not be able to perform work more efficiently than ODOT staff who have been adequately trained in similar maintenance activities.

Table 7-4 presents estimates of vendor costs by region for each of the forecast years.

7.4 Training

The previous chapter discussed training and skills deficiencies within ODOT, identifying areas where training gaps need to be closed. Because ODOT has one or more staff members who are experts in each deployed device, it was determined that a comprehensive and continual cross-training program could resolve most training deficiencies within ODOT. Two areas were identified where ODOT may yield benefit from relying on paid training provided outside of the organization. In both of these areas, ODOT has some maintenance experience – primarily through TSSU – but more training would be desirable.

- Commercial vehicle applications. Because maintenance on ODOT's weigh-in-motion systems is currently performed via a vendor contract, ODOT does not have significant day-to-day experience with the maintenance requirements of these systems. Remedial training may be advisable, even though it has been recommended that ODOT continue to use a contract relationship for this maintenance, in order for ODOT to protect itself against potential complications with the existing contractor.

- Fiber optic maintenance. ODOT currently has some fiber optic maintenance abilities within TSSU. Additional training – along with supporting test equipment – would allow ODOT to be more responsive to instances when critical communications links are damaged. Due to the cost of test equipment, however, maintenance of fiber optics communications networks has been recommended as an activity for contracting.

Cost estimates for these two types of training are shown in Figure 7-1. These are provided for illustrative purposes; it is recommended that ODOT does not enroll technicians in these classes if it plans to use contracting for maintenance of these devices. If ODOT pursues a continual program of cross-training its own staff, these training efforts should be a one-time

Commercial vehicle applications	
Number of days	2
Cost per hour	$125
Lodging (per night)	$75
Travel costs	$1,000
Total Training Cost	$3,150

Fiber optic training	
Number of students	3
Cost per class*	$1,195
ETA certification	$150
Lodging (per night)	$75
Total Training Cost	$4,935

Notes:

ETA - Electronics Technicians Association

* - Cost is estimate for one company which conducts courses in Portland. Other companies offer training in other states or video tape training.

Figure 7-1: Remedial Training Costs.

(Source: 64)

expense. All training costs would be allocated to Region 2, since these activities would occur on a statewide basis.

7.5 Device Replacement

Another component of the maintenance budget is the cost of device replacement. In general, the maintenance budget should reflect only emergency replacements, as normal technological upgrades and replacements would be included as either a part of the STIP or other funding programs. Emergency device replacement will result from exceptional circumstances such as lightning damage and cabinet knockdowns. In order to preserve the operational integrity of the ITS infrastructure by minimizing downtime, it is recommended that ODOT budget for the costs of such emergency device replacement.

In order to estimate the cost of emergency device replacement, estimates for the capital cost and life cycle of each piece of equipment were developed from a variety of sources, including Oregon's ITS Strategic Plan (3), other maintenance plans (7, 9), and vendors (65). For each piece of equipment, failure rates – i.e. the probability of component failure within a twelve-month period – were estimated in part from anecdotal evidence provided by some vendors (66). It was assumed that the likelihood of emergency replacement would increase with the degree of environmental exposure. Table 7-5 summarizes these assumptions for each ITS device.

The estimated replacement cost for each device component is derived according to the equation shown in Figure 7-2. This equation reflects normal device upgrades.

$$\underbrace{\left(\text{Inventory} - \frac{\text{Inventory}}{\text{Life Cycle}}\right)}_{\text{Inventory that is not upgraded in a given year}} \times \begin{pmatrix}\text{replacement}\\ \text{cost}\end{pmatrix} \times \begin{pmatrix}\text{failure}\\ \text{rate}\end{pmatrix} = \begin{pmatrix}\text{emergency device}\\ \text{replacement costs}\end{pmatrix}$$

Figure 7-2: Calculating Emergency Device Replacement Costs.

Device	Component	Replacement cost (est.)	Life Cycle (yrs)	Annual failure rate
Closed-Circuit Television (CCTV)	Field camera	35,000	10	10%
	Camera server	5,000	4	2%
	Video switching equipment	100,000	10	2%
Video Detection Systems	Field unit	25,000	10	10%
Road and Weather Information System (RWIS)	Field unit	20,000	10	10%
	Regional server	5,000	4	2%
	Statewide server	5,000	4	2%
Travel Time Estimation	Field unit	15,000	10	5%
	Server	5,000	4	2%
Automatic Vehicle Location (AVL)	In-vehicle equipment	1,000	10	5%
	Server	5,000	4	2%
Advanced Traffic Management System	Server	5,000	4	2%
	Workstation	2,500	4	2%
Mayday Callboxes	Field unit	15,000	10	5%
Urban Automatic Incident Detection System	Server	5,000	4	2%
Intersection-Based Incident Detection System	Server	5,000	4	2%
Computer-Aided Dispatch	Workstation	2,500	4	2%
Incident Response Vehicles	On-board sign	30,000	10	10%
Hazardous Materials Response	Server	5,000	4	2%
800-number information	Server	5,000	4	2%
Internet access	Server	5,000	4	2%
Kiosks	Field unit	15,000	7	10%
	Server	5,000	4	2%
Icy Bridge Warning System (Low-Tech)	Sign	5,000	10	10%
Tunnel lane closure advisory	Sign	5,000	10	10%
Snow Zone Advisory	Sign	5,000	10	10%
Snow Zone Changeable Message Sign	Sign	5,000	10	10%
Oversize Vehicle Closure CMS	Sign	5,000	10	10%
Permanent Variable Message Signs (VMS)	Sign	125,000	10	10%
Portable Variable Message Signs (VMS)	Sign	30,000	10	10%
Highway Advisory Radio (HAR)	Field unit	50,000	20	10%
Icy Bridge Detectors	Field unit	25,000	5	10%
Oversize load detectors	Field unit	25,000	5	10%
Variable speed limit signs	Field unit	25,000	5	10%
Queue Detection System	Field unit	5,000	10	5%
Weigh-in-Motion (WIM) Stations	Field unit	52,200	10	5%
Downhill Speed Advisory Systems	Field unit	82,200	10	5%
Fiber optic networks	Per mile	10,000	20	1%
Radio Communications	Console	15,000	10	5%
	Handheld unit	1,000	10	5%
Maintenance Coordination	Laptop	2,500	4	2%

Table 7-5: Device Life Cycle, Cost and Failure Assumptions.

Because the likelihood of emergency replacement in any region may be small in a given year, it is recommended that this money be allocated to a central fund, controlled by ODOT's ITS unit in Salem, from which regions may draw as emergency repair needs occur.

On this basis, Table 7-6 shows the estimated annual cost of emergency device replacement under each of the three forecast years. It should be noted that these costs are greater than either the personnel or contracting costs.

	State Total
Existing	$ 642,806
Existing + STIP	$1,023,358
Existing + Strategic Plan	$3,993,222

Table 7-6: Estimated Emergency Replacement Costs.

7.6 Spare Parts

Having an inventory of spare parts for its ITS devices will help ODOT in two principal ways. First, some preventative maintenance activities will involve systematic replacement or substitution of easily worn components, such as light bulbs, display boards and similar hardware. An active spare parts inventory would help to ensure that preventative maintenance activities may occur as scheduled. Second, repair maintenance activities may also be expedited by having spare parts on hand. Anecdotal evidence has suggested that the ability to get spare parts quickly is one of the most common reasons to rely on contract maintenance (67, 68, 36).

The cost, type and quantity of spare parts required is highly dependent upon the manufacturer and model of a particular component, its environmental exposure, and its maintenance history. To provide a budgetary estimate for spare parts, the Caltrans District 7 maintenance plan (6) was used to define the average money allocated for spare parts for several ITS devices, including CCTV, VMS and HAR. This average cost was divided into the cost of device replacement identified in Section 7.5 to develop an estimate of the cost of spare parts as a percentage of device cost. Table 7-7 shows these percentages for each of the ITS devices evaluated in this study. Based on these percentages, the estimated cost of spare parts for each of ODOT's regions is shown in Table 7-8.

7.7 Test/Specialized Equipment

The final component of the maintenance budget is the cost of specialized equipment that is required in the maintenance of field devices. The cost of such equipment for maintenance of fiber optics communications network was used as the primary justification for relying on contract maintenance. Based on conversations with ODOT's ITS Unit, the cost of any equipment that is used exclusively for ITS maintenance should be included in the maintenance budget.

Percentage*	Devices
1%	CCTV; video detectors; RWIS; kiosks; changeable message signs; HAR; oversize load detectors; variable speed limit signs; queue detection systems; fiber optic networks
0.5%	Travel time estimation; AVL; incident response vehicles; VMS; WIM; downhill speed advisory systems; radio communications

* - Annual cost of spare parts as a percentage of device cost.

Table 7-7: Spare Parts Cost as Percentage of Device Cost.

	Region					State
	1	2	3	4	5	Total
Existing	$ 25,345	$ 10,622	$ 3,594	$ 6,625	$ 5,841	$ 52,027
Existing + STIP	$ 40,200	$ 15,998	$ 4,605	$ 13,044	$ 18,716	$ 92,563
Existing + Strategic Plan	$ 136,825	$ 53,242	$ 48,257	$ 50,971	$ 55,457	$ 344,752

Table 7-8: Estimated Spare Parts Cost by Region.

Equipment needs are expected to vary by region, based on their current equipment inventory. As a starting point, it is suggested that the following pieces of equipment be acquired for each region for field maintenance.

- Laptop computer. This can be used to help assist in troubleshooting some devices in the field. This would be a second laptop for each region, in addition to the laptop provided for the support coordinator's use.
- Portable video monitor. This can enable a camera technician to test the image being transmitted by a CCTV camera.
- Portable digital multimeter. This may be used in a variety of electrical diagnostic activities. It is assumed that each region already has at least one multimeter. However, multimeters are relatively inexpensive, and having additional ones would ensure that field maintenance activities do not have to wait for the availability of a multimeter.

Additional equipment may be required depending upon regional needs. An examination of other maintenance plans (6, 7, 5, 69) suggests that most other equipment involved in ITS maintenance, with the exception of fiber optic test equipment, is commonly available in most highway maintenance shops.

Table 7-9 provides an estimate for equipment costs for each region. It is assumed that these equipment costs would be incurred during the STIP.

Type of Equipment	Purpose	Estimated Unit Cost	Quantity	Cost Per Region
Laptop Computer	Used for maintenance coordination Used for testing of field devices	$ 3,800	2	$ 7,600
Portable Video Monitor	Use to view images received from a video signal source	$ 1,060	1	$ 1,060
Digital Multimeter	Measures a multitude of signal parameters	$ 400	1	$ 400

Table 7-9: Cost of Test/Specialized Equipment.

(Source: 6)

Device	Staffing	Fringe	Spares	Replace	Vendor	Total
	Cost Component					
Closed-Circuit Television (CCTV)	45,161	31,613	20,700	178,350	-	275,824
Video Detectors	1,595	1,117	1,000	9,000	-	12,712
Road and Weather Information System (RWIS)	47,905	33,534	4,300	36,450	-	122,189
Automatic Vehicle Location (AVL)	2,738	1,917	60	390	-	5,105
Advanced Traffic Management System	32,213	22,549	-	825	-	55,587
Callboxes	759	531	-	2,700	-	3,990
Computer-Aided Dispatch	5,729	4,010	-	338	-	10,077
Incident Response Vehicles	4,916	3,441	1,050	18,900	-	28,307
Alphanumeric Paging	68	48	-	-	-	116
800-number Information	11,278	7,895	-	75	-	19,248
Internet Access	35,669	24,968	-	75	-	60,712
Icy Bridge Warning CMS	548	384	50	450	-	1,432
Tunnel Lane Closure CMS	386	270	50	450	-	1,156
Radio-Controlled Snow Zone CMS	3,376	2,363	200	1,800	-	7,739
Telephone-Activated Snow Zone CMS	5,430	3,801	400	3,600	-	13,231
Oversize Vehicle Restriction CMS	870	609	50	450	-	1,979
Permanent Variable Message Signs	52,168	36,517	15,625	281,250	-	385,560
Portable Variable Message Signs	60,629	42,440	3,450	62,100	-	168,619
Highway Advisory Radio (HAR)	741	519	500	4,750	-	6,510
Icy Bridge Detectors	588	412	250	2,000	-	3,250
Queue Detection System	653	457	50	225	-	1,385
Weigh-in-Motion (WIM) Stations	396	277	2,871	25,839	35,660	65,043
Downhill Speed Advisory Systems	2,781	1,947	411	3,699	4,545	13,383
Radio Communications	4,958	3,470	1,010	9,090	-	18,528
Total	**321,555**	**225,089**	**52,027**	**642,806**	**40,205**	**1,281,682**

Table 7-10: Maintenance Budget by Device – Existing.

	Cost Component						
Device	**Staffing**	**Fringe**	**Spares**	**Replace**	**Test Eq**	**Vendor**	**Total**
Closed-Circuit Television (CCTV)	75,951	53,166	31,550	276,000	5,300	-	441,967
Video Detectors	2,560	1,792	1,500	13,500	-	-	19,352
Road and Weather Information System (RWIS)	123,603	86,523	11,700	103,050	-	-	324,876
Automatic Vehicle Location (AVL)	20,402	14,282	330	2,520	-	-	37,534
Advanced Traffic Management System	32,759	22,931	-	863	-	-	56,553
Callboxes	759	531	-	2,700	-	-	3,990
Regional Incident Detection System	1,965	1,376	-	75	-	-	3,416
Intersection-Based Incident Detection System	2,692	1,885	-	150	-	-	4,727
Computer-Aided Dispatch	5,729	4,010	-	338	-	-	10,077
Incident Response Vehicles	7,725	5,407	1,650	29,700	-	-	44,482
Alphanumeric Paging	68	48	-	-	-	-	116
Highway Travel Conditions Reporting System	21,334	14,934	-	-	-	-	36,268
800-number Information	11,278	7,895	-	75	-	-	19,248
Internet Access	35,669	24,968	-	75	-	-	60,712
Icy Bridge Warning CMS	548	384	50	450	-	-	1,432
Tunnel Lane Closure CMS	386	270	50	450	-	-	1,156
Radio-Controlled Snow Zone CMS	3,376	2,363	200	1,800	-	-	7,739
Telephone-Activated Snow Zone CMS	5,430	3,801	400	3,600	-	-	13,231
Oversize Vehicle Restriction CMS	870	609	50	450	-	-	1,979
Permanent Variable Message Signs	81,206	56,844	23,750	427,500	-	-	589,300
Portable Variable Message Signs	68,106	47,674	3,750	67,500	-	-	187,030
Highway Advisory Radio (HAR)	741	519	500	4,750	-	-	6,510
Icy Bridge Detectors	902	631	250	2,000	-	-	3,783
Oversize Load Detectors	9,156	6,409	1,250	10,000	-	-	26,815
Queue Detection System	653	457	50	225	-	-	1,385
Weigh-in-Motion (WIM) Stations	756	530	5,481	49,329	-	68,078	124,174
Downhill Speed Advisory Systems	4,989	3,493	822	7,398	-	9,090	25,792
Fiber Optic Networks	198	139	8,000	7,600	-	24,319	40,256
Radio Communications	7,317	5,122	1,230	11,070	-	-	24,739
Maintenance Coordination	3,000	2,100	-	190	40,000	-	45,290
Total	**530,128**	**371,093**	**92,563**	**1,023,358**	**45,300**	**101,487**	**2,163,929**

Table 7-11: Maintenance Budget by Device – STIP.

	Cost Component					
Device	**Staffing**	**Fringe**	**Spares**	**Replace**	**Vendor**	**Total**
Closed-Circuit Television (CCTV)	101,661	71,163	97,700	871,350	155,166	1,297,040
Video Detectors	21,663	15,164	26,500	238,500	-	301,827
Road and Weather Information System (RWIS)	24,627	17,240	25,900	230,850	292,725	591,342
Travel Time Estimation	1,462	1,023	6,025	54,075	127,528	190,113
Automatic Vehicle Location (AVL)	54,285	37,999	2,680	23,370	101,985	220,319
Advanced Traffic Management System	65,362	45,753	-	2,063	-	113,178
Callboxes	759	531	-	2,700	-	3,990
Regional Incident Detection System	1,924	1,347	-	75	-	3,346
Intersection-Based Incident Detection System	2,669	1,869	-	150	-	4,688
Computer-Aided Dispatch	5,480	3,837	-	338	-	9,655
Incident Response Vehicles	6,031	4,222	1,650	29,700	-	41,603
Pre-planned Detour Routes	432	304	-	-	-	736
Hazardous Material Response	1,787	1,251	-	75	-	3,113
Alphanumeric Paging	68	48	-	-	-	116
Highway Travel Conditions Reporting System	21,297	14,908	-	-	-	36,205
800-number Information	11,197	7,838	-	75	-	19,110
Internet Access	35,628	24,940	-	75	-	60,643
Kiosks	3,516	2,462	35,600	304,788	236,036	582,402
Icy Bridge Warning CMS	538	377	50	450	-	1,415
Tunnel Lane Closure CMS	381	267	50	450	-	1,148
Radio-Controlled Snow Zone CMS	3,172	2,220	200	1,800	-	7,392
Telephone-Activated Snow Zone CMS	5,275	3,693	400	3,600	-	12,968
Oversize Vehicle Restriction CMS	837	586	50	450	-	1,923
Permanent Variable Message Signs	68,964	48,275	38,750	697,500	53,870	907,359
Portable Variable Message Signs	12,510	8,757	69,300	1,247,400	1,094,789	2,432,756
Highway Advisory Radio (HAR)	710	497	500	4,750	-	6,457
Icy Bridge Detectors	431	300	5,250	42,000	38,130	86,111
Oversize Load Detectors	100	70	1,250	10,000	8,791	20,211
Variable Speed Limit Signs	503	352	5,000	40,000	44,164	90,019
Queue Detection System	645	452	50	225	-	1,372
Weigh-in-Motion (WIM) Stations	751	525	5,481	49,329	67,146	123,232
Downhill Speed Advisory Systems	47,625	33,338	10,686	96,174	133,577	321,400
Fiber Optic Networks	198	139	8,000	7,600	24,319	40,256
Radio Communications	27,605	19,324	3,680	33,120	-	83,729
Maintenance Coordination	2,875	2,015	-	190	-	5,080
Total	**532,968**	**373,086**	**344,752**	**3,993,222**	**2,378,226**	**7,622,254**

Table 7-12: Maintenance Budget by Device – Strategic Plan.

7.8 Maintenance Budget

Appendix N presents a series of tables detailing cost estimates for ODOT's comprehensive ITS maintenance budget. This section will summarize the findings on a device and regional level.

7.8.1 By Device

Tables 7-10, 7-11 and 7-12 summarize the ITS maintenance budget by device under the existing, STIP and Strategic Plan forecast years, respectively. The budget is divided into the components discussed earlier: personnel, training, vendor/contractor costs, device replacement, spare parts, and test/specialized equipment. The maintenance budget under existing deployment levels is estimated at $1,281,682. By the conclusion of the STIP, the annual maintenance budget is estimated to be $2,163,929, which represents a 69 percent increase over the existing deployment level budget. If the Strategic Plan is implemented as presented in this plan, the maintenance budget will increase to an estimated $7,622,254, which represents a 595 percent increase over the existing budget level.

Figure 7-3 shows how the share of the maintenance budget spent on personnel, contractor and other cost components changes over the three budget forecast years. As can be seen, the largest portion of the maintenance budget for each of the three years is devoted to emergency device replacement. In terms of staffing costs, the mix of costs shifts toward using contractor maintenance as the Strategic Plan becomes reality.

Table 7-13 presents the budget data by device in a different format, by identifying the devices that comprise the largest portion of the statewide maintenance budget. Permanent VMS, CCTV, RWIS and portable VMS are the four devices which account for the largest portions of

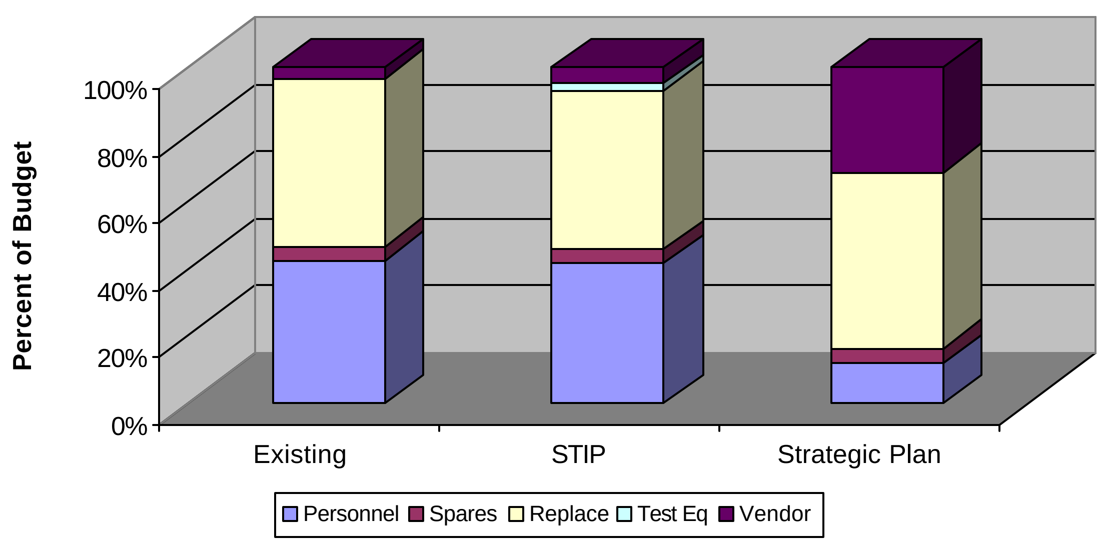

Figure 7-3: Maintenance Spending by Cost Component.

	Existing			STIP			Strategic Plan		
Rank	**Device**	**Budget**	**Pct.**	**Device**	**Budget**	**Pct.**	**Device**	**Budget**	**Pct.**
1	Permanent VMS	385,560	30.1%	Permanent VMS	589,300	27.2%	Portable VMS	2,432,756	31.9%
2	CCTV	275,824	21.5%	CCTV	441,967	20.4%	CCTV	1,297,040	17.0%
3	Portable VMS	168,619	13.2%	RWIS	324,876	15.0%	Permanent VMS	907,359	11.9%
4	RWIS	122,189	9.5%	Portable VMS	187,030	8.6%	RWIS	591,342	7.8%
5	WIM	65,043	5.1%	WIM	124,174	5.7%	Kiosks	582,402	7.6%
6	Web Site	60,712	4.7%	Web Site	60,712	2.8%	Downhill Speed System	321,400	4.2%
7	ATMS	55,587	4.3%	ATMS	56,553	2.6%	Video Detectors	301,827	4.0%
8	Incident Resp. Vehicles	28,307	2.2%	Coordination	45,290	2.1%	AVL	220,319	2.9%
9	800-number	19,248	1.5%	Incident Resp. Vehicles	44,482	2.1%	Travel Time Estimation	190,113	2.5%
10	Radio Systems	18,528	1.4%	Fiber Optics	40,256	1.9%	WIM	123,232	1.6%
	All other devices	82,065	6.4%	All other devices	249,289	11.5%	All other devices	654,464	8.6%

Table 7-13: Top Ten Devices by Statewide Maintenance Costs.

the maintenance budget under both the existing and STIP deployment levels. Under the Strategic Plan, kiosks become the fifth most expensive maintenance item, supplanting weigh-in-motion stations.

7.8.2 By Region

Tables 7-14, 7-15 and 7-16 provide a regional breakdown of the maintenance budget for each of the three forecast years. Under the existing and STIP deployments, Regions 1 and 2 have similar amounts of money allocated for ITS maintenance. Since part of the budget in Region 2 reflects centralized server support activities, the maintenance budget levels clearly indicate the concentration of deployment in urban Region 1. By the time the Strategic Plan is completed, the maintenance budget across the regions is expected to be more evenly distributed.

	Cost Component					
Region	**Personnel**	**Replace**	**Spare Parts**	**Test Equipment**	**Vendors**	**Total**
1	140,355	298,880	25,345	-	-	**464,580**
2	243,117	148,736	10,622	-	6,484	**408,959**
3	23,282	46,246	3,594	-	12,967	**86,089**
4	92,196	68,625	6,625	-	-	**167,446**
5	47,694	80,319	5,841	-	20,754	**154,608**
Total	546,644	642,806	52,027	-	40,205	**1,281,682**

Table 7-14: Maintenance Budget by Region – Existing.

	Cost Component					
Region	**Personnel**	**Replace**	**Spare Parts**	**Test Equipment**	**Vendors**	**Total**
1	171,439	390,826	40,200	9,060	40,528	**652,053**
2	323,427	224,983	15,998	9,060	9,726	**583,194**
3	37,120	55,383	4,605	9,060	17,512	**123,680**
4	193,526	127,809	13,044	9,060	12,967	**356,406**
5	175,709	224,357	18,716	9,060	20,754	**448,596**
Total	901,221	1,023,358	92,563	45,300	101,487	**2,163,929**

Table 7-15: Maintenance Budget by Region – STIP.

	Cost Component					
Region	**Personnel**	**Replace**	**Spare Parts**	**Test Equipment**	**Vendors**	**Total**
1	203,650	1,422,280	136,825	-	585,181	**2,347,936**
2	273,676	664,500	53,242	-	425,714	**1,417,132**
3	112,878	579,222	48,257	-	437,911	**1,178,268**
4	145,538	596,223	50,971	-	474,445	**1,267,177**
5	170,312	730,997	55,457	-	454,975	**1,411,741**
Total	906,054	3,993,222	344,752	-	2,378,226	**7,622,254**

Table 7-16: Maintenance Budget by Region – Strategic Plan.

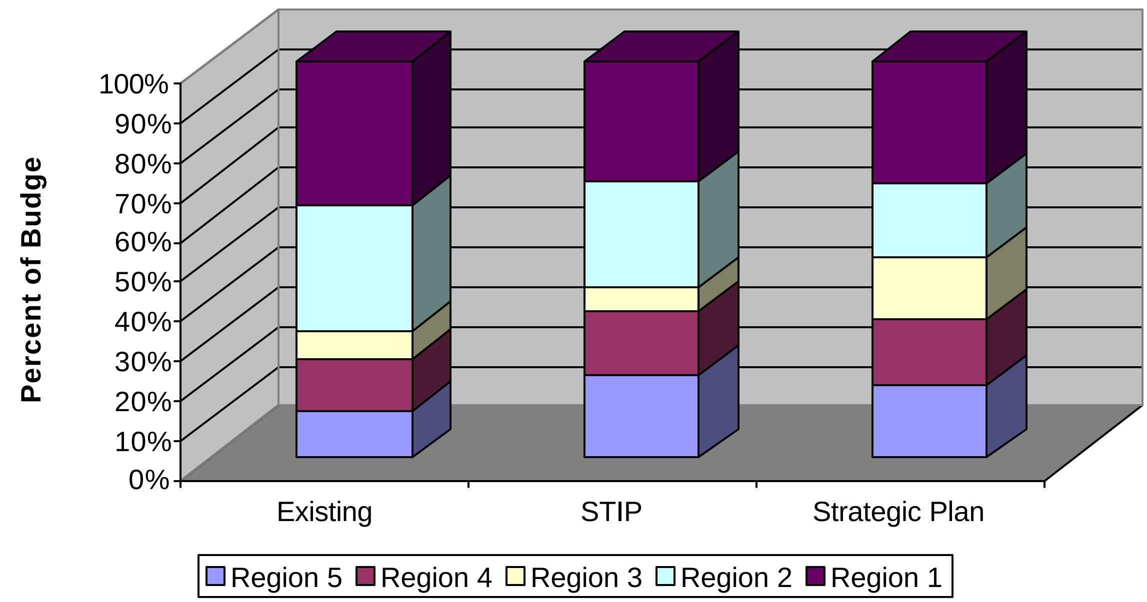

Figure 7-4: Maintenance Budget by Region.

The increased slant of the maintenance budget toward more rural regions is shown in Figure 7-4. This graph demonstrates clearly how the maintenance budget is going to be increasingly directed toward the more rural parts of Oregon.

7.9 Recommendations

This chapter has presented a comprehensive budget for planning purposes. In order to improve the reliability and accuracy of future planning budgets for ITS maintenance activities, it is recommended that the following actions be taken.

- Improve logging and tracking of maintenance activities. Historical cost data, at a device level, is the best predictor of future maintenance costs. This is the method used by the Arizona Department of Transportation in developing future estimates of operations and maintenance costs (9). A new system should allow ODOT to be able to track the amount of time spent on individual devices, as well as the amount of time spent on ITS maintenance by individual staff members.

- Develop an inventory of spare parts. In consultation with vendors and suppliers, ODOT should develop a list of parts which are essential to have on-hand in order to provide for timely repair of ITS devices.

- Identify equipment needed to maintain ITS devices. ODOT should review, at a regional level, the types of testing equipment that may need to be purchased in order to ensure that equipment availability does not impede ITS maintenance.

- Pursue cost competition with contractors on similar maintenance activities. ODOT may wish to contract only a portion of maintenance on a given device and perform the remainder in-house, in order to provide a comparison of the cost and efficiency of contract maintenance. This would help to identify whether using contracting at the levels indicated in this budget is fiscally sound.

- Consider maintenance costs in future deployment planning decisions. For example, the extensive deployment of portable VMS under the Strategic Plan will raise their maintenance costs to represent more than 30 percent of ODOT's statewide total.

8 SUMMARY

The purpose of this document has been to provide an ITS maintenance plan for ODOT. Because the plan has a long-range planning horizon and ITS is still a very dynamic field, this plan should be considered as setting a blueprint for ITS maintenance in the future. This chapter will review some of the major findings of this planning effort, and identify directions for further work.

8.1 Key Conclusions

Some intermediate conclusions were presented at the end of many of the chapters in this maintenance plan. As means of summary, this section will review the main conclusions of this document in two categories: first, the highlights of this plan, and second, findings encountered in the development of this plan.

8.1.1 Plan Highlights

Several key findings of this plan are summarized as follows.

<u>Development of a maintenance model</u>. The need for this plan was driven by the perspective that ITS maintenance has not been adequately considered or addressed to date, and that increasing deployment levels in the future mean that any such problems should be addressed. In developing this plan, these views were confirmed. The primary factors that currently hinder the performance of ITS maintenance include, but are not limited to:

- inadequate staffing levels and/or conflicting priorities,
- ambiguous responsibilities,
- inadequate training,
- poor logging and tracking systems, and
- non-standardized devices.

Based on discussions with stakeholders, it was agreed that a two-tier maintenance model, with separate maintenance processes depending upon whether or not a device is mainstreamed, was the best method for resolving many of these issues. While stakeholders agreed to the broad concept, many details relating to implementing the model remain.

<u>Prioritization guidelines</u>. Based on consultation with many stakeholders, guidelines were developed to prioritize ITS repair activities. These guidelines have been designed to reflect local needs in the context of ODOT's organizational mission, with the greatest emphasis placed on repairing those devices most critical to safety. To enforce these guidelines, it is important that the regions work in concert with the ITS Unit in Salem to identify those devices and locations which are most critical to the fulfillment of agency goals.

<u>Preventative maintenance</u>. In order to provide guidance for future maintenance activities, this plan included guidelines for frequency and type of preventative maintenance activities. If these activities are performed as recommended, it should improve the overall effectiveness of ODOT's ITS infrastructure.

Resource analysis. Through extensive contacts with ODOT staff members, vendors, other agencies and other resources, this plan developed per-device estimates of maintenance needs for all devices that ODOT either has in the ground or is planning on deploying. A comparison of resource needs against resource availability showed that ODOT apparently has enough staffing resources to perform proper maintenance now, although there are isolated training gaps which hurt the efficiency at which technicians can perform repairs. Resource gaps are projected to widen considerably in the future, implying that there will be a need for significant investment in additional staff, a reliance on significant contracting efforts, or some sort of combination. This document then presented guidance on which components of which devices should have contract maintenance.

Maintenance budget. Finally, this document presented a comprehensive, statewide maintenance budget classified on a device and regional level. Given the absence of historical data, many simplifying assumptions were developed in order to estimate future budgetary requirements. The plan shows that the maintenance budget is expected to increase significantly between now and the completion of the STIP, and to the end of the Strategic Plan as well.

8.1.2 Plan Development

ODOT's ITS maintenance plan appears to be the first document of its kind – a statewide plan that examines the end-to-end maintenance of ITS devices, not only with respect to technical issues, but examining organizational and institutional issues as well. In working on the development of this maintenance plan, many helpful insights were learned along the way that may assist in the development of a future maintenance plan, either by ODOT or by other transportation agencies.

- Stakeholder input is critical to the development of a successful maintenance plan. Outreach efforts by ODOT's ITS Unit succeeded in identifying diverse stakeholder groups whose combined perspectives proved to be invaluable in understanding the true issues with ITS maintenance. Moreover, soliciting stakeholder input has proved valuable in setting up an environment where recommendations may be implemented. Many methods – including face-to-face contact, telephone conversations, surveys and e-mail – proved to be useful in gathering information from stakeholders.

- A maintenance plan needs an agency champion. Getting these stakeholder groups to communicate requires a champion within the agency who is willing to coordinate and listen to various groups. For this plan, ODOT's ITS Unit, in conjunction with the ITS Executive Steering Committee, helped to champion the cause of ITS maintenance throughout the organization, achieving buy-in from many different constituencies.

- Organizational issues are as critical as technical issues. The temptation in developing a maintenance plan is to attempt to directly develop a maintenance budget, without examining organizational and institutional issues that may affect maintenance. For this plan, organizational issues determined what would be an optimal maintenance model, which in turn drove what resources would be needed for ITS maintenance.

- Geography is a critical plan consideration. The differences between urban and rural regions in ODOT affected many key elements in this plan, including repair prioritization, the nature of device deployment, travel time to service devices, and other factors. Similar planning efforts should strive to recognize the unique characteristics of each region within the planning area.

- Accurate device inventories drive accurate estimates of resource needs. ODOT is in the process of enhancing its ITS inventory database to include heretofore undocumented legacy systems. This should help future planning efforts. Other agencies wishing to engage in similar planning efforts should endeavor to have specific inventories for future deployment, through short-term funding programs as well as strategic planning efforts.

- Maintenance should not be an afterthought in ITS planning. This study has demonstrated the importance of proper maintenance of ITS devices to the success of ITS initiatives. It is anticipated that this planning effort will result in increased emphasis within ODOT of the ongoing maintenance needs of field devices, and how these needs may be recognized during procurement.

8.2 Recommendations for Further Action

This plan has presented many recommendations for ODOT designed to help either in ITS maintenance or in ITS maintenance planning activities. This section will emphasize some of these action items, not to minimize other items but to provide a strategic direction for ODOT to build off of this plan. These items are broken up into short-term, medium-term and long-term items.

8.2.1 Short-Term

These recommendations should be pursued within the next twelve months.

1. Continue to develop an organizational consensus as to the importance of ITS in fulfilling ODOT's mission.

2. Continue to pursue implementation of the two-tier maintenance model, including identifying individuals who will fill the support coordinator role for each region.

3. Research and implement a statewide logging and tracking system for ITS maintenance activities.

4. Develop regional guidelines for prioritization of ITS repair maintenance activities.

5. Develop checklists for preventative maintenance tasks on each device.

6. List and quantity an appropriate spare parts inventory for each device.

7. Identify and procure equipment that may be needed in performing diagnostics on ITS field devices.

8. Schedule cross-training activities to improve the overall skill level of ODOT technicians.

9. Investigate contracting alternatives on non-mission-critical devices.

10. Disseminate this plan document to other agencies, to assist them in analyzing ITS maintenance alternatives.

8.2.2 Medium-Term

These recommendations should be pursued in conjunction with the completion of the current STIP.

1. Develop process for on-going cross-training on new devices.

2. Improve the statewide logging and tracking system to minimize time on data entry.

3. Develop statewide, scalable standards for ITS devices, as well as a process for these standards to be developed and implemented in the future.

4. Investigate alternatives for competition between ODOT and contractors on ITS maintenance, in order to evaluate the benefits and consequences of contracting.

5. Research contracting alternatives that may be used in procurement of new devices to reduce maintenance costs.

8.2.3 Long-Term

These recommendations should be pursued as long-term concerns, over a ten- to twenty-year time frame.

1. Replace non-standardized devices with devices that are compatible with ODOT's standards.

2. Regularly evaluate ITS maintenance activities on a series of performance measures, including repair response time and the length of time a device is inoperable.

3. Pursue strategic planning efforts that incorporate maintenance planning as a key consideration.

8.3 Future Research Activities

There are other activities not related directly to ITS maintenance which are recommended as potential research activities to build on promising areas identified in this research project.

- <u>Maintenance model evaluation</u>. A before-and-after comparison of the effect of the two-tier maintenance model would help to evaluate how effective the model has been in improving ITS maintenance.

- Maintenance budget planning. Upon implementation of a statewide logging and tracking system, a database of historical cost data will then be available to estimate future maintenance costs, such as was done for ADOT through its maintenance tracking system (9). This would serve as a good follow-up to check and refine the assumptions developed in Appendix K.

- Statewide maintenance contracting. As ITS becomes mainstreamed, the decision to contract ITS maintenance activities should be viewed in the larger context of highway maintenance activities for ODOT. Future research efforts could identify other ODOT activities for which contracting would be appropriate, and how the decision to contract these activities may improve ITS maintenance.