Working Paper:
The ITS Cost Data Repository at Mitretek Systems

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Executive Summary

Mitretek Systems has been tasked by the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) to collect available information on ITS costs and maintain the information in a cost database, which serves as the *ITS Cost Data Repository*. The repository is to be a central site for estimates of ITS costs that the ITS JPO can use for policy analyses, benefit/cost analyses, and to distribute to the ITS community.

At this time, cost estimates have been collected from several sources, and the bulk of these data have been reviewed. The data from the different sources reside in a single directory on one PC computer, in their original formats, or translated into Microsoft Excel 5.0 format. Each data source has generally provided ITS costs in a single file. The various sets of cost estimates that have been collected have not been integrated into a single database.

This Working Paper has been written to describe the status of the Cost Repository. It is expected that the JPO and Mitretek will decide on future activities with the data in the Repository. Discussions are needed with cost experts in DOT, transportation agencies, and others, on what categories of costs, and levels of detail, are most useful to others. We also need to discuss whether or not to rationalize the differences between the current unit cost estimates.

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1. Introduction and Purpose of the ITS Cost Repository

Mitretek has been tasked by the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) to collect available information on ITS costs and maintain the information in a cost database, which serves as the *ITS Cost Data Repository*. The repository is to be a central site for estimates of ITS costs that the ITS JPO can use for policy analyses, benefit/cost analyses, and to distribute to the ITS community.

At this time, cost estimates have been collected from several sources, and the bulk of these data have been reviewed. The data from the different sources reside in a single directory on one PC computer, in their original formats, or translated into Microsoft Excel 5.0 format. Each data source has generally provided ITS costs in a single file. An exception to this is when the Excel Workbook capability has been used to present separate files on the different pages of the workbook. The various sets of cost estimates that have been collected have not been integrated into a single database.

This Working Paper has been written to describe the status of the Cost Repository to the ITS JPO, and other interested parties. It is expected that the JPO and Mitretek will decide on future activities with the data in the Repository. These should include discussions with cost experts in DOT, transportation agencies, and others on what categories of costs and levels of detail are most useful to others. Another possibility is to carry out a study, comparing the available costs with the benefit data in the ITS Benefits Inventory that resides at Mitretek[1].

Costs vs. Cost Saving Benefits. This paper does not address the *cost savings* that could be obtained from implementing ITS services. These are savings that might accrue from not having to invest in as many new lanes of roadway, or from reduced fleet operating costs. These savings generally pertain to non-ITS costs, even though they may be expenditures by the same agencies that make ITS investments. Cost-savings is one of the benefit categories that is discussed in the recent report on the ITS Benefits Inventory at Mitretek[2].

Structure of the Paper. The structure of the remainder of this paper is as follows. Section 2 describes the sources and characteristics of the cost data. Section 3 shows the cost data elements used in the various sources, and the unit cost estimates. Section 4 discusses how market penetration estimates have been presented, and how they are combined with unit costs. Section 5 discusses the status of developing synthesized cost estimates and files. Finally, Section 6 provides a brief discussion of

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[1] Proper, Allen T, and Cheslow, Melvyn D., *ITS Benefits: Continuing Successes and Operational Test Results*, FHWA, October 1997

[2] Proper, Allen T, and Cheslow, Melvyn D., ibid.

possible next steps. It should be noted that all of the tables in the paper are placed at the end for ease of reading the text and comparing the tables.

2. Sources of ITS Cost Data and Their Characteristics

In this section, the ITS cost estimates that are currently in the Cost Repository are identified, data elements in each source are itemized, and examples of their unit cost estimates are presented.

Data Sources. The ITS cost estimates that are available electronically in the Cost Repository are listed here chronologically (Note that the references for the sources in this list are introduced as the text describes them below.):

- IVHS Architecture, Initial Cost Analysis by Rockwell International, 1994[3]
- Core Infrastructure, FHWA, 1995
- ITS Architecture Cost Analysis by the Joint Architecture Team, 1996
- ITS National Investment and Market Analysis by Apogee, 1997
- Costs by TransCore, 1997
- Seattle by CH2M Hill, 1998
- In-Vehicle and Infrastructure Costs by ORNL, 1998
- San Antonio MMDI from SAIC, 1998
- Mitretek Estimates (based on several of the above cost files), 1998

All of these cost estimates are available as Excel spreadsheets, except for those by ORNL. This information is only available in a Microsoft Access database. The National ITS Architecture costs are available in both Excel and in Access.

Characteristics of the Cost Data Sources. Each data source has provided cost estimates for a set of ITS elements. The two initial sets, or taxonomies, were: (1) the components of the National ITS Architecture[4], and (2) the components of the Core Infrastructure[5]. The National Architecture includes infrastructure and in-vehicle costs. The Core Infrastructure, which has also been called the Intelligent Transportation Infrastructure (ITI), and is now referred to as the Intelligent Transportation System Infrastructure, does not include in-vehicle equipment. The infrastructure taxonomy in the Core

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[3] Note that this reference has been replaced by the report in footnote #4, but it is identified here because it was a major source for some of the cost estimates to follow.

[4] Joint Architecture Team, *ITS Architecture Cost Analysis*, FHWA, June 1996

[5] Johnson, Christine M., "A Core ITS Infrastructure -- The Essential Building Blocks", in *ITS Quarterly*, Fall 1995; and Office of Traffic Management and ITS (HTV-10), *Cost Estimates and Assumptions for the Core Infrastructure*, FHWA, June 1995

Infrastructure is not exactly the same as that used in the National Architecture[6]. However, this has become less important as more recent cost studies have developed modified taxonomies.

All of the data sources provide estimates for two general categories of cost, defined as capital and operating, or as non-recurring and recurring. These costs can be combined within a life-cycle costing framework[7]. Although many of the cost sources have estimated life-cycle costs, this aspect of ITS costing has not yet been the focus of the cost repository effort.

<u>Unit Costs, Area-Wide Costs, and Market Sizes</u>. Most of the cost sources provide estimates of three types of variables:

- Unit capital and unit annual O&M costs for each cost element
- Capital costs and annual O&M costs aggregated for an area
- Market sizes, or market penetrations, for each cost element for this area

A *unit cost* can be defined (not surprisingly) as the cost of a unit of a particular element, where the unit has to be specifically defined. For example, a unit could be a *single* computer in a traffic management center (TMC), or all of the computers in a *single* TMC, or all of the unique computing power for a *single* function in a TMC. Another example of definitional variation is where a unit is a single variable message sign (VMS), or the sign including support structures, or the VMSs in one mile. Each of these definitions has been used in at least one of the cost data sources.

Although some data sources only provide estimates of unit costs, most provide estimates of the *costs of the ITS elements in an area*. This requires estimates of *how many* of each ITS element is required in an area. Hence, there must be estimates of *market size,* or *market penetration*. Depending on the source, an area has been one corridor, a metropolitan area, or the entirety of the metropolitan areas in the country. Estimating market sizes requires the consideration, at least conceptually, of the following:

- The market size for each cost element in the area during a *base year*. (The base year can be the current year, or a recent year when sufficient market size data are available.)
- The *maximum* market size that *should or could* be deployed or implemented[8]
- The year the area costs are estimated for
- The market sizes for that year
- Any variation over time of the unit costs

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[6] Mitretek Systems, *Building the ITI: Putting the National Architecture Into Action,* Federal Highway Administration, April 1996.
[7] FHWA, Life Cycle Cost Symposium, December, 1993
[8] Oak Ridge National Laboratory (ORNL), *Tracking the Deployment of the Integrated Metropolitan ITS Infrastructure: FY 1997 Results*, Federal Highway Administration, September 1998. This report discusses the implications of the *should vs. could* cases

The market size for the year that the costs are estimated should fall between the base year market size and the maximum market size. For all of the cost data sources so far examined in the repository, 0% was used as the penetration in the base year, and 100% as the maximum. Future use of the ITS deployment tracking data[9] will allow the base year estimates to be improved.

3. Cost Data Elements and Unit Costs.

The ITS components that were used for *reporting* costs by the two architecture reports[10] were identified as *equipment packages*. To make estimates of the unit costs for an equipment package, the architecture teams examined an additional level of detail, which they called equipment. The cost of an equipment package was obtained by aggregating the estimated costs of the equipment. Two examples of the final architecture cost database are shown in tables 3-1a and 3-1b. These costs were estimated for an abstract urban area named Urbansville, which has a size and highway network similar to the Detroit area.

The equipment within an equipment package are generally at a more detailed level than are the costing elements in most of the other sources. This can be helpful as background material for analysts who are developing their own cost elements. However, it is often too detailed a taxonomy for analysts at the planning stage to utilize for their own cost breakdowns.

The costs developed for the Core Infrastructure[11] by the FHWA represented the first attempt at reporting costs at a national level. This was done for metropolitan infrastructure elements, only. The FHWA estimated costs for three generic metropolitan areas, large, medium, and small, which differed only by size. They then classified the 200 or so largest urban areas into one of the three size classes, and aggregated the costs for all of these areas to produce a national cost.

For the large metropolitan area, the Core Infrastructure analysis used unit costs from the Phase 1 architecture (which was based on Urbansville) as a starting point, and then improved upon these with costs from ITS projects in several states[12]. These large area unit costs are shown in table 3-2. The unit costs that were estimated for large areas were assumed to apply also for the medium and small areas. Hence, there were no economies of scale, or geographic variations in the unit costs.

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[9] ORNL ibid.

[10] Rockwell International, *IVHS Architecture, Initial Cost Analysis,* FHWA, October 1994; and Joint Architecture Team, ibid.

[11] Office of Traffic Management and ITS (HTV-10), ibid.

[12] Office of Traffic Management and ITS (HTV-10), ibid.

Table 3-1a: Example of Cost Elements and Unit Prices in the National ITS Architecture Final Report

Roadway Basic Surveillance (RS5)

	Equipment Description	Years to Replacement (Life Cycle)	Unit Price (Low)	Unit Price (High)	Quantity (Low)	Quantity (High)	Comparative Technology	Retail Price *	Unit Price	Quantity
Non-Recurring (Initial Capital Investment)			**Introductory State ***						**Steady State ***	
	Loops - 1 Double Set w/ Controller, Power, etc. (per location)	5	5	8			Existing Site	6	5	
							Installations			
	Video Cameras (color)	10	30	50			Prices from	40	30	
	Towers (per camera location)	20	30	50			New England	30	30	
							and Virginia			
							Projects per			
							LBA			
Recurring (Operations & Maintenance)			**Introductory State ***						**Steady State ***	
	Loop Replacement Maintenance (10% of capital)		0.5	0.8					0.5	
	Ramp Meters (5% of capital)		1.5	2.5					1.5	
	Video Cameras (2% of capital)		0.6	1					0.6	
	Leased Line Costs borne by TMC									

** All prices are in thousands of 1995 dollars.*

Table 3-1b: Example of Cost Elements and Unit Prices in the National ITS Architecture Final Report

Roadway Traffic Information Dissemination (RS14)

	Equipment Description	Years to Replacement (Life Cycle)	Unit Price (Low)	Unit Price (High)	Quantity (Low)	Quantity (High)	Comparative Technology	Retail Price *	Unit Price	Quantity
Non-Recurring (Initial Capital Investment)			**Introductory State ***						**Steady State ***	
	CMS	20	80	120			Existing	100	80	
	HAR	20	16	20			Existing	16	16	
	Fixed Fiber Optic Advanced Warning Signs	10	10	15			Existing	12	10	
	Fixed Fiber Optic Advanced Warning Signs at Remote EMS Loc.	10	18	22			Existing	20	18	
	Tower Structures for CMS	20	100	150			Existing	100	100	
							per LBA			
Recurring (Operations & Maintenance)			**Introductory State ***						**Steady State ***	
	CMS (5% of capital)		4	6			Estimate		4	
	HAR (5% of capital)		0.8	1			Estimate		0.8	
	Fixed Fiber Optic Advanced Warning Signs (5% of capital)		0.5	0.8			Estimate		0.5	
	Fixed Fiber Optic Advanced Warning Signs at Remote EMS Loc. (10% of capital)		1.8	2.2			Estimate		1.8	
	Leased Line Costs borne by TMCS									

** All prices are in thousands of 1995 dollars.*

Table 3-2 Cost Elements and Unit Costs: FHWA Core Infrastructure

COST ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)
SURVEILLANCE		
Point Detection (loops)	0.8	0.04
CCTV Cameras	20	1
Video Image Processing/intersection	40	2
Environmental Snensors	4	0.2
HOV lane control & monitoring equipt	250	12.5
TRAVELER INFORMATION		
Fixed CMS & Controlers	200	10
Fixed HAR & Controllers	20	1
Hybrid CMS	20	1
Ramp Meter Systeems (per interchange)	40	2
Signal Upgrades	5	0.25
COMMUNICATION		
Callboxes	5	0.5
Fiber-Optic Cable/mile	240	12
Signal Communication per Intersection	10	0.5
TRAFFIC MGMT CENTERS		
Computers & Hardware/TMC	680	34
Software (various)/TMC	220	11
Facilities and Communications/TMC	4000	200
O & M Personnel/TMC	0	50
TRAVELER INFO CENTERS		
Computers and Hardware	102	5.1
Software (various)	300	15
Facilities & Communication	4000	200
Kiosks	30	10
O & M Personnel	0	50
TRANSIT MANAGEMENT CENTER		
Computers & Hardware	340	17
Software (various)	90	4.5
Facilities & Communication	4000	200
O & M Personnel	0	50
TRANSIT VEHICLE INTERFACES		
Kiosks, cellular radio, etc per vehicle	6.3	0.315
EMERGENCY MANAGEMMENT CENTERS		
Computers & Hardware	340	17
Software (various)	60	3
Facillities & Communications	4000	200
O & M Personnel	0	50
EMERGENCY VEHICLE SERVICES		
Cellular radio, Communications /vehicle	0.3	0.015

Table 3-2 Cost Elements and Unit Costs: FHWA Core Infrastructure

COST ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)
INCIDENT MANAGEMENT EQUIPMENT		
Vehicles	50	2.5
Portable HAR	50	2.5
Portable CMS	30	1.5
O & M Personnel	0	50
SYS DESIGN & INTEGRATION		
TMC, TIC, EMC, TRANSIT, MC	5400	0
ELECTRONIC TOLL COLLECTION SYS		
Manual AVI (per lane)	73	147
Automatic AVI (per lane)	70	48
Manual Automatic AVI (per lane)	125	116
AVI Dedicated (per lane)	16	5
Express AVI (per lane)	16	5
AVI Plaza Cpomputer equipment	130	7
ELECTRONIC FARE PAYMENT SYS		
Central Computer System	3000	150
Ticket Vending Machines	60	3
Sys Engr. Prog Mgt, Installation	16000	0
Training & Documentation	80	4
Bus Farebox	7	0.35
Station Controller	20	1
Turnstile	27.5	1.375
Ticket Office Machine & Validator	24.4	1.22
Smart Card	0.01	0.0005

The Core Infrastructure costs improved on the Phase I architecture costs by obtaining additional cost information. The final architecture costs also improved on the Phase I costs. But these two efforts were not coordinated, so that multiple estimates of unit costs resulted.

The unit costs of Apogee Associates[13] were primarily based on the final architecture costs. However, Apogee modified an important aspect of the communications costs in the architecture costing report. "Recognizing the potentially large magnitude of market transactions involving the purchase of communications equipment and services by the public sector, a 50% volume discount was applied to the communication [costs, given] the gradual spread of shared resource partnerships."[14] The Apogee effort includes in-vehicle costs, as well as infrastructure costs. However, trucking fleet costs were omitted. Because the level of detail was similar to that in the architecture cost analysis, these unit costs will not be shown in this paper.

TransCore prepared their cost estimates[15] to be part of a handbook for integrating ITS into urban transportation planning[16]. They used the Core Infrastructure costing tables for their format[17]. As with the FHWA estimates, TransCore considered metropolitan infrastructure elements only. The estimates added some new cost elements, disaggregated a few, and changed unit cost values for several. One change was in using a rule of thumb of 15% for O&M costs as a percent of capital costs, whereas FHWA used 5%.

The final version of the TransCore planning handbook[18] deleted the cost tables, and replaced them with a reference to the costs in the final ITS Architecture report. The costs prepared by TransCore have been included in the Cost Repository, because they represent a second source for the ITI unit costs. These unit costs are shown in table 3-3.

A recent ITS costing effort was performed by CH2M Hill[19] as part of a study by Mitretek to modify existing planning models to integrate ITS projects[20]. This study used cost estimates made by the Washington State DOT, as well as costs reported in the National Architecture report and O&M costs

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[13] Apogee Research, Inc., *ITS National Investment and Market Analysis*, ITS America, May 1997
[14]Apogee Research, Inc., ibid., Final Report, page 35.
[15] TransCore, Appendix E to Draft version of Planning Handbook, January 1996, unpublished
[16] Smith, Steve, *Integrating Intelligent Transportation Systems Within the Planning Process: An Interim Handbook*, January, 1998
[17] Office of Traffic Management and ITS (HTV-10), ibid.
[18] Smith, Steve, ibid.
[19] Hill, Chris, Case Study Alternatives Cost Estimate Spreadsheets, CH2M Hill, January 1998
[20] Hatcher, S. Gregory et al., *Incorporating ITS into Transportation Planning: Phase 1 Final Report*, FHWA, September, 1997

Table 3-3 Cost Elements and Unit Costs: TransCore

ELEMENTS	UNIT COST	O & M	UNIT
	CAPITAL ($K)	% of	O&M ($K)
		Capital Cost	
SURVEILLANCE			
Point Detection (loops) per lane-mile	2	10%	0.2
Processor (170 series), Cabinet and Foundation	6.25	5%	0.3125
Point Detection (Overhead)	4.5	5%	0.225
CCTV	25	10%	2.5
CCTV Pole and Foundation	18	5%	0.9
Video Image Processing (VIP) /intersection	40	10%	4
Environmental Sensors	4	5%	0.2
HOV lane control & monitoring equipment	250	10%	25
Automatic Vehicle Identification (AVI)	40	10%	4
Automatic Vehicle Location (AVL)	250	10%	25
Weigh-in-Motion		10%	0.1
TRAVELER INFORMATION			
Mid Range Fixed CMS & Controllers	60	5%	3
Full Matrix CMS & Controllers	80	5%	4
Portable CMS	50	5%	2.5
Cantilever Mounting Structure	75	5%	3.75
Overhead Structure (6 lanes each way)	120	5%	6
Overhead Structure (4 lanes each way)	100	5%	5
Fixed HAR & Controllers	20	10%	2
Portable HAR	40	10%	4
Kiosk	15	10%	1.5
Traveler Advisory Telephone	5	10%	0.5
COMMUNICATION			
Fiber-Optic Cable/mile	240		240
Coaxial Cable			0
Twisted Pair			
Spread Spectrum	15		
Interagency Communication (fax, Modem, Email, etc.)			
Leased Line			
Signal	.04/month	0%	
Video	.3/month	0%	
TRAFFIC CONTROL			
Signal System			
Central Computer System (closed loop)	10		
Central Computer System (distributed)	30		
Controller Upgrade	5		
Emergency Vehicle Pre-emption	2		
Transit Vehicle Pre-emption	2		
Railroad Pre-emption	0.5		
Ramp Metering	40	10%	
TRANSPORTATION MANAGEMENT CENTER			
Computers & Hardware			
Small Area (<250,000 population)	476	15%	
Medium Area (250,000 - 750,000 population)	544	15%	
Large Area (>750,000 population)	680	15%	
Software (various)	220		
Facilities and Communications			
Small Area (<250,000 population)	2800	15%	
Medium Area (250,000 - 750,000 population)	3200	15%	
Large Area (>750,000 population)	4000	15%	
ADDITIONAL TMCs	4900		
TRAVELER INFO CENTERS			
Computers and Hardware			
Small Area (<250,000 population)	71.4	15%	
Medium Area (250,000 - 750,000 population)	81.6	15%	

Table 3-3 Cost Elements and Unit Costs: TransCore

Large Area (>750,000 population)	102	15%	
Software (various)	300		
Facilities & Communication			
Small Area (<250,000 population)	2800	15%	
Medium Area (250,000 - 750,000 population)	3200	15%	
Large Area (>750,000 population)	4000	15%	
Kiosks	15	10%	
TRANSIT MANAGEMENT CENTER			
Computers & Hardware			
Small Area (<250,000 population)	238	15%	
Medium Area (250,000 - 750,000 population)	272	15%	
Large Area (>750,000 population)	340	15%	
Software (various)	90		
Facilities & Communication			
Small Area (<250,000 population)	2800	15%	
Medium Area (250,000 - 750,000 population)	3200	15%	
Large Area (>750,000 population)	4000	15%	
TRANSIT VEHICLE INTERFACES			
In-vehicle unit per vehicle	6.3	10%	0
EMERGENCY MANAGEMENT CENTERS			
Computers & Hardware			
Small Area (<250,000 population)	238	15%	
Medium Area (250,000 - 750,000 population)	272	15%	
Large Area (>750,000 population)	340	15%	
Software (various)	60		
Facilities & Communications			
Small Area (<250,000 population)	2800	15%	
Medium Area (250,000 - 750,000 population)	3200	15%	
Large Area (>750,000 population)	4000	15%	
EMERGENCY VEHICLE SERVICES			
Cellular radio, Communications /vehicle	0.3	10%	
SYS DESIGN & INTEGRATION			
TMC, TIC, EMC, TRANSIT, MC			
Small Area (<250,000 population)	3800	15%	
Medium Area (250,000 - 750,000 population)	4300	15%	
Large Area (>750,000 population)	5400	15%	
ELECTRONIC TOLL COLLECTION SYS			
Manual AVI (per lane)	73		
Automatic AVI (per lane)	70		
Manual Automatic AVI (per lane)	125		
AVI Dedicated (per lane)	16		
Express AVI (per lane)	16		
AVI Plaza Computer equipment	130		
ELECTRONIC FARE PAYMENT SYS			
Central Computer System	3000		
Ticket Vending Machines	60		
Sys Engr. Prog Mgmt, Installation	16000	0%	
Training & Documentation	80		
Bus Farebox	7		
Station Controller	20		
Turnstile	27.5		
Ticket Office Machine & Validator	24.4		
Smart Card	0.01	0%	

developed by the Texas Transportation Institute[21]. This costing effort considered infrastructure costs only, except for the inclusion of ITS equipment in transit vehicles. Unit cost estimates are shown in table 3-4. It should be noted that the Mitretek study developed costs both for ITS projects, as well as for conventional highway and transit projects. Hence, the study provides ITS cost-savings that can be reported in the Mitretek Benefits Reports[22], as well as costs that will go into the Cost Repository.

The ORNL cost database[23], which was prepared as part of a FHWA-sponsored study of future

in-vehicle ITS equipment, has both infrastructure and in-vehicle costs, and has been built as multiple files within a Microsoft Access database. These data reside in the Cost Repository, but have not yet been analyzed.

SAIC is currently collecting cost data for several of the Metropolitan Model Deployment Initiatives (MMDI) sites. So far, they have provided an early draft estimate of the costs for the San Antonio MMDI[24] to the cost repository. The MMDI projects include public and private cost sharing, and involve ITS infrastructure and in-vehicle investments. It may prove difficult to obtain the costs of in-vehicle equipment that are provided by private sector partners. Hence, at present, the San Antonio data in the Cost Repository are for infrastructure only. These data are still in draft form, and will not be shown here. Nevertheless, this cost collection exercise has indicated that the different taxonomies for the cost elements that have been used so far may not represent the way that some public agencies actually develop separate contracting instruments.

In addition to all of the cost estimates discussed above, the Cost Repository contains some summarizing cost tables (spreadsheets) prepared by Mitretek that shows the unit cost estimates from three sources side by side. This table is shown in table 3-5. This table has been used to prepare a single set of estimates by merging the three sources. This effort is described in section 5.

4. Market Penetration and Area Cost Estimates by the Data Sources

As mentioned above, none of the cost sources listed in section 2 provided unit costs estimates alone. All made cost estimates for some particular geographic area, as well.

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[21] Daniels, Ginger, and Starr, Tim, *Guidelines for Funding Operations and Maintenance of ITS/ATMS*, Texas Transportation Institute, 1996
[22] Proper, Allen T, and Cheslow, Melvyn D., ibid.
[23] Das, Sujit, et al., *Costs of In-Vehicle Information Systems and Associated Infrastructure*, Oak Ridge National Laboratory, October 1998
[24] Carter, Mark, Cost Data for San Antonio, working draft, September 1998

Table 3-4 Cost Elements and Unit Costs:Ch2M Hill for Seattle Corridor

ITEM	DESCRIPTION	UNIT CAPITAL	UNIT O&M	ECONOMIC LIFE	DATA SOURCE
ITS/TRAFFIC SYSTEMS					
SURVEILLANCE					
Detection Loops	In-pavement loops and cables to nearest controller.	per mile	per mile	10	Capital-Build up based upon cost components of typical projects; O&M-TTI
Closed Circuit TV Camera	Monitor traffic operations along State's Routes	per each	per each	10	Capital-WSDOT; O&M-TTI
Automatic Vehicle Identification/Roadside Equipment	Roadside equipment to identify bus, check schedule and provide transit priority at traffic signal	per signal	per signal	10	Capital-King County/Metro; O&M-TTI
Automatic Vehicle Location/Field Equipment	Field differential GPS stationary site to provide fixed location information to compensate for topography and buildings	per site	percent of capital cost	10	Capital-Denver Regional Transit District; O&M-estimated
Data Station	Support detection system	per each	percent of capital cost	10	Capital-WSDOT; O&M-TTI
TRAVELER INFORMATION					
Variable Message Signs	VMS on overhead structures	per each	per each	10	Capital-WSDOT; O&M-TTI
Fixed HAR & Controllers	Highway Advisory Radio site located at strategic locations as a part of traffic management system	per each	per each	10	Capital-WSDOT; O&M-TTI
Kiosk	Located at transit centers	per each	per each	10	Capital-King County/Metro; O&M-TTI
COMMUNICATION					
Fiber-Optic Cable	For extended freeway surveillance systems	per mile	per mile	10	Capital-WSDOT; O&M-TTI
Fiber-Optic Hubs	Interchange fiber-optic lines	per each	per each	10	Capital-WSDOT; O&M-TTI
Twisted Pair	For extended adaptive traffic control systems	per mile	per mile	10	Capital-WSDOT; O&M-TTI
TRAFFIC CONTROL					
Coordinated/Adaptive Signal System - Local Controller	Replace existing controllers and cabinets at major intersections	per controller	per controller	10	Capital-Buildup based upon cost components of typical projects; O&M-TTI
Coordinated/Adaptive Signal System - Master Controller	Tie local controllers to the system	per controller	per controller	10	Capital-Buildup based upon cost components of typical projects; O&M-TTI
Ramp Metering	Freeway entrance ramp metering station	per each	per each	10	Capital-WSDOT; O&M-TTI
TRAFFIC MANAGEMENT					
Computers & Hardware	For adaptive signal system and additional freeway system management where applicable	per each	per each	5	Capital and O&M-National Architecture Studies
Software (various)	For adaptive signal system	per each	per each	5	Capital and O&M-National Architecture Studies
Communications Extension	For linkage to adaptive traffic control	per mile	per mile	10	Capital-WSDOT; O&M-TTI
TRANSIT MANAGEMENT					
Computers & Hardware for AVL System	Computer system to receive and process AVL polling data from buses and provide location, schedule adherence, and incidence information to dispatchers	per each	percent of capital cost	10	Capital-Denver Regional Transit District: O&M-National Architecture Studies
Software	Software for AVL Controller and Dispatch Stations	per each	percent of capital cost	10	Capital-Denver Regional Transit District: O&M-National Architecture Studies
Facilities and Communications	Radio communications to receive AVL data, and dispatch stations including CRTs and microcomputers	per each	percent of capital cost	10	Capital-Denver Regional Transit District: O&M-National Architecture Studies
TRANSIT VEHICLE INTERFACES					
In-vehicle Transponder for AVI	Transponder device located on buses used to identify bus at roadside readers at for signal priority treatment	per bus	percent of capital cost	10	Capital-King County/Metro; O&M-National Architecture Studies
In-vehicle AVL Equipment	AVL on-board equipment for establishing vehicle location, assessing schedule status, and interfacing with driver	per bus	per bus	10	Capital-Denver Regional Transit District: O&M-TTI

Table 3-4 Cost Elements and Unit Costs:Ch2M Hill for Seattle Corridor

INCIDENT MANAGEMENT					
Central Tracking/Dispatch	Central tracking system/software and Mayday software/GIS integration; dispatch	per each	percent of capital cost	10	Capital-WSDOT:O&M-National Architecture Studies
In-vehicle Dynamic Route Guidance	For tracking system and route guidance to provide faster response to incidents	per each	percent of capital cost	10	Capital-Rockwell Path Master system plus add-on items; O&M-National Architecture Studies
USER DISBENEFITS					
Pre-Trip Planning Services	Interactive fixed-end trip planning service; 10% of travelers; no capital cost beyond baseline	Not Applicable	per subscription		Capital-NA; O&M-Mitretek assumption
Personal Dynamic Route Guidance	In-vehicle equipment costs include GPS, map database, communications transceiver, processor, GUI, and display	per device	per subscription	7	Capital-National Architecture Studies; O&M-Mitretek assumption
HIGHWAY/TRANSIT FACILITIES					
SOV FACILITIES					
Expressway Conversion	Conversion of unlimited access arterial to partial access control; add 2 lanes	per mile	per mile	20	Capital-Build up based upon cost components of typical project; O&M-Houston Division of TxDOT
Limited Access Widening	Widening of full access controlled freeway; add 2 lanes	per mile	per mile	20	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-Houston Division of TxDOT
Interchange (full or half)	Grade separated crossing with access ramps connecting the crossing roadways; diamond configuration; for Expressway	per each	percent of capital cost	30	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB analysis
Grade Separated Crossing	Grade separated crossing of two roads without ramp connections; for Expressway	per each	percent of capital cost	30	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB analysis
HOV/TRANSIT FACILITIES					
New HOV Lanes on Freeway	Add barrier separated HOV lanes to existing freeway	per mile	per mile	20	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB analysis
Upgrade HOV Lanes on Freeway	Upgrade existing HOV lanes to barrier separated lanes on a freeway	per mile		20	Capital-Build up based upon cost components of typical project; O&M-Incremental costs assumed negligible
New HOV Lanes on Deck-Truss Bridge	Add HOV lanes to deck-truss bridge/no barrier or buffer separation	per foot	percent of capital cost	30	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB analysis
New HOV Lanes on Expressway	Add HOV lanes to expressway/no barrier or buffer separation	per mile	per mile	20	Capital-Build up based upon cost components of typical project; O&M-Houston Division of TxDOT
New HOV Contra-Flow Reversible Lane on Freeway Express Lanes	Add HOV moveable barrier-separated lane	per mile	per mile	20	Capital-Adapted from prior P.S. HOV study estimates; O&M - Houston Division of TxDOT/San Diego Coronado Bridge
Arterial Transit Lanes/Two Directions	Add HOV/transit lanes to an existing arterial	per mile	per mile	20	Capital-Build up based upon cost components of typical project; O&M - Houston Division of TxDOT
Arterial Transit Lanes/Reversible	One center reversible lane	per mile	per mile	20	Capital-Adapted from prior P.S. HOV study estimates; O&M - Houston Division of TxDOT/TTI
HOV Direct Access/Local Half Reversible Drop	Direct ramps between express lanes and local street	per each	per each	30	Capital-Adapted from prior P.S. HOV study estimates; O&M-Houston Division of TxDOT/TTI
HOV Direct Access/Local Half Drop	Direct ramps between median freeway HOV lanes and local street	per each	percent of capital cost	30	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT modified per PB estimates
HOV Direct Access/Local Full Texas T	Direct ramps between median freeway HOV lanes and local street	per each	percent of capital cost	30	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT modified per PB estimates
HOV Direct Access/Local Half Drop to Outside	Direct ramps between outside general purpose freeway lanes and local street	per each	per at-grade ramp mile	30	Capital-Adapted from prior P.S. HOV study estimates; O&M-Based on Houston Division of TxDOT figures
HOV Direct Access/Local Full In-Line	Direct ramps between median HOV lanes and in-line station w/ pedestrian link	per each	per at-grade ramp mile	30	Capital-Adapted from prior P.S. HOV study estimates; O&M-Based on Houston Division of TxDOT figures
HOV Direct Access/Fwy-to-Fwy	Direct ramps between freeways to/from one direction and another (e.g. between east and north)	per each	percent of capital cost	30	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT modified per PB estimates
HOV Direct Access/Fwy-to-Fwy Reversible	Direct reversible ramp between median HOV lanes and express lanes	per each	per each	30	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT/Houston Division of TxDOT/TTI

Table 3-4 Cost Elements and Unit Costs:Ch2M Hill for Seattle Corridor

Park and Ride Lot	Parking facility including bus transit shelter and pedestrian enhancements	per parking stall	per 100 stalls	20	Capital-Averaged from WSDOT examples; O&M-Based on Houston Division of TxDOT figures
Transit Bus - 40 foot Diesel or 60 foot Diesel Articulated	Standard intracity transit bus	per vehicle	per thousand revenue vehicle hours	12	Capital-King County/Metro; O&M-King County/Metro
Transit Bus - 60 foot Dual Power Articulated	Special bus for use in downtown Seattle transit tunnel	per vehicle	per thousand revenue vehicle hours	12	Capital-King County/Metro; O&M-based upon annual vehicle hours times cost per vehicle hour
RIGHT-OF-WAY					
R/W Adjacent to Arterial	Right-of-Way acquisition costs along expressways and arterials in north Seattle	per acre	Not Applicable	100	Capital-Input from WSDOT; O&M-NA
R/W Adjacent to Freeway	Right-of-Way acquisition costs along freeways in north Seattle	per acre	Not Applicable	100	Capital-Input from WSDOT; O&M-NA
R/W Takes/Damages	Typical extra cost to cover relocations and/or damages	per parcel	Not Applicable	100	Capital-Input from WSDOT; O&M-NA

REFERENCES:

TransCore-Interim Handbook on ITS Within the Transportation Planning Process, TransCore (formerly JHK & Associates), December 1996, Appendix E.
WSDOT-TSMC SC & DI Operations/Implementation Plan, WSDOT, October 1994.
TTI-Guidelines for Funding Operations and Maintenance of ITS/ATMS, Texas Transportation Institute, November 1996.
National Architecture Studies-ITS Architecture Cost Analysis, Federal Highway Administration/Joint Architecture Team, June 1996.
King County/Metro-King County transit operator, Dan Overguard/David Cantay/Mike Voris, May 1997.
Denver RTD-Denver Regional Transit District, Lou Ha, June 1997.
Houston Division of TxDOT - Estimates provided for the Katy Highway MIS

Table 3-5 Three ITS Unit Cost Estimates: Core Infrastructure Costs, TransCore ITS Planning Handbook, and CH2M Hill for Seattle Case Study

COST ELEMENTS	Unit Capital Cost $1,000	Source of Estimate	TransCore O & M Cost as % of Capitol	TransCore O & M Cost $1,000	Core Infrastr. O&M Cost $1,000	CH2M Hill Infrastr. O&M Cost $1,000	
SURVEILLANCE							
Point Detection: Loops (1 per approach lane to a signal)	$0.80	Core			0.04		
Point Detection: Loops (1 per lane per half mile)	$0.80	Core			0.04		
Point Detection: Loops (1 per lane per half mile)	$1.46	CH2M Hill				0.075	
Point Detection: Loops (1 per lane per half mile)	$1.0	TransCore	10%	0.10			
Point Detection (Overhead)(1 per lane per half mile)	$2.25	TransCore	5%	0.11			
Processor (170 series), 1 per direction per half mile for point detectors (Cabinet and Foundation)	$6.25	TransCore	5%	0.31			
Data Station, 1 per half mile	$25	CH2M Hill				0.5	
CCTV Cameras/Site	$20	Core			1		
CCTV	$25	TransC, CH2M	10%	2.5		1.3	
CCTV Pole and Foundation	$18	TransCore	5%	0.9			
Video Image Processing (VIP) /intersection	$40	Core	10%	4	2		
Environmental Sensors	$4	Core	5%	0.2	0.2		
AVI equip. to identify priority veh./intersection	$40	TransCore	10%	4			
AVI equip. to identify priority veh./intersection	$25	CH2M Hill				1.5	
AVL equip to supplement GPS/site	$250	TransCore	10%	25			
AVL equip to supplement GPS/site	$300	CH2M Hill				6	
COMMUNICATION							
Fiber-Optic Cable/mile	$240	Core			12		
Fiber-Optic Cable/mile	$290	CH2M Hill				0.8	
Fiber-Optic Hub (Interchange) (1 per 5 miles of fiber)	$110	CH2M Hill				8	
Wireless Radio	$15	TransCore					
Twisted-pair to Signals (per intersection)	$10	Core			0.50		
Twisted-pair to Signals (per intersection)	$19.4	CH2M Hill					
Leased lines to signals	.04/montl	TransCore	0%	0			
Leased lines to roadside video	.30/montl	TransCore	0%	0			
TRAFFIC SIGNAL CONTROL							
Central Computer System (distributed)	$30	TransCore					
Central Computer System (closed loop)	$10	TransCore					
Coordinated/Adaptive System (Local Controller))	$17.5	CH2M Hill				0.5	
Coordinated/Adaptive Master (1 per 20-25 Locals)	$10	CH2M Hill				0.5	
Signal Controller Upgrade	$5	Core			0.25		
Emergency Vehicle Pre-emption	$2.0	TransCore					
Transit Vehicle Pre-emption	$2.0	TransCore					
Railroad Pre-emption	$0.5	TransCore					
FREEWAY MANAGEMENT							
Ramp Meter System (per interchange)	$40	Core	10%	4	2		
Ramp Meter System (per interchange)	$30	CH2M Hill				3	
HOV lane control & monitoring equipment	$250	Core	10%	25	12.5		
TRANSPORTATION MANAGEMENT CENTER							
Computers & Hardware							
Large Area (>750,000 population)	$680	Core	15%	102	34		
Medium Area (250,000 - 750,000 population)	$544	Core	15%	81.6	27.2		
Small Area (<250,000 population)	$476	Core	15%	71.4	23.8		
Computers & Hardware (per work station)	$185	CH2M Hill				170	
Software (various)	$220	Core			11		
Software (various)	$225	CH2M Hill				34	
Central Dispatch/Tracking Software (Incident Mgmt.)	$600	CH2M Hill				30	
Facilities and Communications							
Large Area (>750,000 population)	$4,000	Core	15%	600	200		
Medium Area (250,000 - 750,000 population)	$3,200	Core	15%	480	160		
Small Area (<250,000 population)	$2,800	Core	15%	420	140		
O & M Personnel		Core			50		

Table 3-5 Three ITS Unit Cost Estimates: Core Infrastructure Costs, TransCore ITS Planning Handbook, and CH2M Hill for Seattle Case Study

			TransCore		Core	CH2M Hill	
	Unit		O & M		Infrastr.	Infrastr.	
	Capital	Source	Cost	O & M	O&M	O&M	
	Cost	of	as % of	Cost	Cost	Cost	
COST ELEMENTS	$1,000	Estimate	Capitol	$1,000	$1,000	$1,000	
TRAVELER INFORMATION CENTERS							
Computers and Hardware							
Large Area (>750,000 population)	$102	Core	15%	15.3	5.1		
Medium Area (250,000 - 750,000 population)	$81.6	Core	15%	12.24	4.1		
Small Area (<250,000 population)	$71.4	Core	15%	10.71	3.1		
Software (various)	$300	Core			15		
Facilities & Communication							
Large Area (>750,000 population)	$4,000	Core	15%	600	200		
Medium Area (250,000 - 750,000 population)	$3,200	Core	15%	480			
Small Area (<250,000 population)	$2,800	Core	15%	420			
O & M Personnel		Core			50		
ROADSIDE/SITE TRAVELER INFORMATION							
Fixed VMS & Controllers with structure	$200	Core			10		
Full Matrix VMS with Controllers & overhead structure	$125	CH2M Hill				4	
Full Matrix VMS & Controllers (without structure)	$80	TransCore	5%	4			
Mid Range Fixed VMS & Controllers (without structure)	$60	TransCore	5%	3			
Cantelever Mounting Structure	$75	TransCore	5%	3.75			
Overhead Structure (6 lanes each way)	$120	TransCore	5%	6			
Overhead Structure (4 lanes each way)	$100	TransCore	5%	5			
Hybrid VMS with structure (Arterials)	$20	Core			1		
Fixed HAR & Controllers	$20	Core, CH2M Hi	10%	2	1	1	
Kiosks	$30	Core			10		
Kiosks	$15	TransCore	10%	1.5			
Kiosks	$18	CH2M Hill				5	
Callboxes (Traveler Advisory Telephone)	$5	Core			0.50		
INCIDENT MANAGEMENT EQUIPMENT							
Portable VMS	$30	Core			1.5		
Portable VMS	$50	TransCore	5%	2.5			
Portable HAR	$50	Core			2.5		
Portable HAR	$40	TransCore	10%	4			
Special Pickup Trucks	$50	Core			2.5		
In-Vehicle Dynamic Route Guidance per vehicle	$4	CH2M Hill				$0.4	
O & M Personnel		Core			50		
EMERGENCY MANAGEMENT CENTERS							
Computers & Hardware							
Large Area (>750,000 population)	$340	Core	15%	$51	17		
Medium Area (250,000 - 750,000 population)	$272	Core	15%	$41	13.6		
Small Area (<250,000 population)	$238	Core	15%	$36	11.9		
Software (various)	$60	Core			3		
Facilities & Communications							
Large Area (>750,000 population)	$4,000	Core	15%	$600	200		
Medium Area (250,000 - 750,000 population)	$3,200	Core	15%	$480	160		
Small Area (<250,000 population)	$2,800	Core	15%	$420	140		
O & M Personnel		Core			50		
EMERGENCY VEHICLE SERVICES							
Cellular radio, Communications /vehicle	$0.30	Core	10%		0.02		
TRANSIT MANAGEMENT CENTER							
Computers & Hardware							
Large Area (>750,000 population)	$340	Core	15%	51	17		
Medium Area (250,000 - 750,000 population)	$272	Core	15%	40.8	13.6		
Small Area (<250,000 population)	$238	Core	15%	35.7	11.9		
Computers & Hardware for AVL System	$300	CH2M Hill				45	
Software (various)	$90	Core			4.5		
Software (various)	$150	CH2M Hill				3	
Facilities & Communication							

Table 3-5 Three ITS Unit Cost Estimates: Core Infrastructure Costs, TransCore ITS Planning Handbook, and CH2M Hill for Seattle Case Study

			TransCore		Core	CH2M Hill	
	Unit		O & M		Infrastr.	Infrastr.	
	Capital	Source	Cost	O & M	O&M	O&M	
	Cost	of	as % of	Cost	Cost	Cost	
COST ELEMENTS	$1,000	Estimate	Capitol	$1,000	$1,000	$1,000	
Large Area (>750,000 population)	$4,000	Core	15%	600	200		
Medium Area (250,000 - 750,000 population)	$3,200	Core	15%	480	160		
Small Area (<250,000 population)	$2,800	Core	15%	420	140		
Facilities & Communication	$500	CH2M Hill				75	
O & M Personnel		Core			50		
TRANSIT VEHICLE INTERFACES							
In-vehicle Cellular Radio unit per vehicle	$6.3	Core	10%	0.63	0.32		
Transponder for AVI per vehicle	$0.6	CH2M Hill				0.01	
In-Vehicle AVL Equipment per vehicle	$9.0	CH2M Hill				1.5	
ELECTRONIC FARE PAYMENT							
Central Computer System	$3,000	Core			150		
Ticket Vending Machines	$60	Core			3		
Training & Documentation	$80	Core			4		
Bus Farebox	$7	Core			0.35		
Station Controller	$20	Core			1		
Turnstile	$27.5	Core			1.38		
Ticket Office Machine & Validator	$24.4	Core			1.22		
Smart Cards	$0.01	Core			0		
ELECTRONIC TOLL COLLECTION							
Manual AVI (per lane)	$73	Core			147		
Automatic AVI (per lane)	$70	Core			48		
Manual Automatic AVI (per lane)	$125	Core			116		
AVI Dedicated (per lane)	$16	Core			5		
Express AVI (per lane)	$16	Core			5		
AVI Plaza Computer equipment	$130	Core			7		
SYSTEM DESIGN & INTEGRATION							
Metro Total: TMC, TIC, EMC, Transit MC							
Large Area (>750,000 population)	$5,400	Core					
Medium Area (250,000 - 750,000 population)	$4,300	Core					
Small Area (<250,000 population)	$3,800	Core					
Electronic Fare Payment System	$16,000	Core			0		
Sys Engr. Prog Mgt, Installation							
TRAVELER SERVICES							
Smart Card (Electronic Fare Payment)	$0.01	Core	0%	0	0		
Pre-Trip Planning Service per subscription	$0	CH2M Hill				0.12	
Personal Dynamic Route Guidance per subscription	$0.80	CH2M Hill				0.12	

The architecture reports made cost estimates for the Urbansville scenario. For the final architecture report, the architecture team also made cost estimates for generic rural (Mountainsville) and inter-city (Thruville) scenarios. The system costs for each of the scenarios were obtained by multiplying numbers in three different files. Scenario descriptive parameters were in one file, the market penetration percentages for the analysis year in a second, and the unit costs in a third. However, the identical unit costs were used in all three geographic scenarios. The market penetration estimates were made at the equipment package level.

The Core Infrastructure cost estimates were presented in a single spreadsheet. Only metropolitan ITS infrastructures were included for three urban area size groups. The cost elements were identical for each of the three infrastructures. This approach used a single set of unit costs (including both capital and O&M costs), columns of market sizes for each of the three size groups, and numbers of metropolitan areas in each size group. An example of this database is shown in table 4-1.

Apogee followed the FHWA's Core Infrastructure costing document in the general structure of their reporting. They utilized the Core infrastructure elements, and the three geographic scenarios from that source. However, Apogee also used unit costs from the National Architecture to examine in-vehicle ITS equipment, as well as more advanced technologies that were included in the Architecture, and excluded from the Core Infrastructure.

TransCore's area-wide costing applied their ITS unit costs to a single medium-sized metropolitan area called Anytown. In general, this area did not have as large a market size as the medium-sized area that FHWA examined. These estimates are shown in table 4-2.

The costing by CH2M Hill is useful, because it addresses a specific known area. However, its disadvantage is that it examined only a single corridor. Nevertheless, their assumptions are very well documented. An example of their corridor costs is shown in table 4-3.

The market size estimates in the ORNL database were performed for Urbansville and Thrusville, from the National Architecture study.

The San Antonio MMDI costing has been drawn from actual investments in ITS systems. Most of the systems have not been operational long enough for good O&M data to be obtained. The market sizes, as with the Seattle estimates, are based on real data.

Most of these ITS cost databases have used some data from actual ITS implementations, as well as judgmental estimates based on analogous data and engineering experience.

5. Synthesis of the Various Cost Estimates

Table 4-1
Market Sizes and Total Cost Estimates for the Core Infrastructure (Metropolitan ITS Infrastructure)

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANITY LARGE	QUANITY MEDIUM	QUANITY SMALL	O & M COST LARGE ($K)	CAPITOL LARGE ($K)	O & M COST MEDIUM ($K)	CAPITOL MEDIUM ($K)	O & M COST SMALL ($K)	CAPITOL SMALL ($K)
SURVEILLANCE											
Point Detection (loops)	0.8	0.04	40,000	25000	1500	1600	32000	1000	20000	60	1200
CCTV Cameras	20	1	650	450	110	650	13000	450	9000	110	2200
Video Image Processing/intersection	40	2	250	150	0	500	10000	300	6000	0	0
Environmental Snensors	4	0.2	100	70	40	20	400	14	280	8	160
HOV lane control & monitoring equipt	250	12.5	10	8	0	125	2500	100	2000	0	0
SUBTOTAL ($K)						2895	57900	1864	37280	178	3560
TRAVELER INFORMATION											
Fixed CMS & Controlers	200	10	100	75	25	1000	20000	750	15000	250	5000
Fixed HAR & Controllers	20	1	10	7	2	10	200	7	140	2	40
Hybrid CMS	20	1	100	80	0	100	2000	80	1600	0	0
Ramp Meter Systeems (per interchange)	40	2	400	300	0	800	16000	600	12000	0	0
Signal Upgrades	5	0.25	2500	1500	50	625	12500	375	7500	12.5	250
SUBTOTAL ($K)						2535	50700	1812	36240	264.5	5290
COMMUNICATION											
Callboxes	5	0.5	1600	1200	0	800	8000	600	6000	0	0
Fiber-Optic Cable/mile	240	12	400	300	50	4800	96000	3600	72000	600	12000
Signal Communication per intersection	10	0.5	2500	1500	50	1250	25000	750	15000	25	500
SUBTOTAL ($K)						6850	129000	4950	93000	625	12500
TMC's			6	4	1						
Computers & Hardware/TMC	680	34	1	0.8	0.7	34	680	27.2	544	23.8	476
Software (various)/TMC	220	11	1	1	1	11	220	11	220	11	220
Facilities and Communications/TMC	4000	200	1	0.8	0.7	200	4000	160	3200	140	2800
O & M Personnel/TMC	0	50	36	24	15	1800	0	1200	0	750	0
SUBTOTAL ($K)						12270	29400	5592.8	15856	924.8	3496
TRAVELER INFO CENTERS											
Computers and Hardware	102	5.1	1	0.8	0.7	5.1	102	4.08	81.6	3.57	71.4
Software (various)	300	15	1	1	1	15	300	15	300	15	300
Facilities & Communication	4000	200	1	0.8	0.7	200	4000	160	3200	140	2800
Kiosks	30	10	200	150	50	2000	6000	1500	4500	500	1500
O & M Personnel	0	50	30	25	10	1500	0	1250	0	500	0
SUBTOTAL ($K)						3720.1	10402	2929.08	8081.6	1158.6	4671.4
TRANSIT MANAGEMENT CENTER											
Computers & Hardware	340	17	1	0.8	0.7	17	340	13.6	272	11.9	238

Table 4-1

Market Sizes and Total Cost Estimates for the Core Infrastructure (Metropolitan ITS Infrastructure)

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANITY LARGE	QUANITY MEDIUM	QUANITY SMALL	O & M COST LARGE ($K)	CAPITOL LARGE ($K)	O & M COST MEDIUM ($K)	CAPITOL MEDIUM ($K)	O & M COST SMALL ($K)	CAPITOL SMALL ($K)
Software (various)	90	4.5	1	1	1	4.5	90	4.5	90	4.5	90
Facilities & Communication	4000	200	1	0.8	0.7	200	4000	160	3200	140	2800
O & M Personnel	0	50	3	2	1	150	0	100	0	50	0
SUBTOTAL ($K)						371.5	4430	278.1	3562	206.4	3128
TRANSIT VEHICLE INTERFACES											
Kiosks, cellular radio, etc per vehicle	6.3	0.315	2000	1200	100	630	12600	378	7560	31.5	630
SUBTOTAL ($K)						630	12600	378	7560	31.5	630
EMERGENCY MANAGEMMENT CENTERS											
Computers & Hardware	340	17	1	0.8	0.7	17	340	13.6	272	11.9	238
Software (various)	60	3	1	1	1	3	60	3	60	3	60
Facillities & Communications	4000	200	1	0.8	0.7	200	4000	160	3200	140	2800
O & M Personnel	0	50	3	2	1	150	0	100	0	50	0
SUBTOTAL ($K)						370	4400	276.6	3532	204.9	3098
EMERGENCY VEHICLE SERVICES											
Cellular radio, Communications /vehicle	0.3	0.015	3300	2500	500	49.5	990	37.5	750	7.5	150
SUBTOTAL ($K)						49.5	990	37.5	750	7.5	150
INCIDENT MANAGEMENT EQUIPMENT											
Vehicles	50	2.5	40	25	0	100	2000	62.5	1250	0	0
Portable HAR	50	2.5	10	5	3	25	500	12.5	250	7.5	150
Portable CMS	30	1.5	15	10	10	22.5	450	15	300	15	300
O & M Personnel	0	50	40	30	5	2000	0	1500	0	250	0
SUBTOTAL ($K)						2147.5	2950	1590	1800	272.5	450
SYS DESIGN & INTEGRATION											
TMC, TIC, EMC, TRANSIT, MC	5400	0	1	0.8	0.7	0	5400	0	4320	0	3780
SUBTOTAL ($K)						0	5400	0	4320	0	3780
ELECTRONIC TOLL COLLECTION SYS											
Manual AVI (per lane)	73	147	30	10	0	4410	2190	1470	730	0	0
Automatic AVI (per lane)	70	48	15	5	0	720	1050	240	350	0	0
Manual Automatic AVI (per lane)	125	116	15	5	0	1740	1875	580	625	0	0
AVI Dedicated (per lane)	16	5	30	10	0	150	480	50	160	0	0
Express AVI (per lane)	16	5	30	10	0	150	480	50	160	0	0
AVI Plaza Cpomputer equipment	130	7	20	10	0	140	2600	70	1300	0	0
SUBTOTAL ($K)						7310	8675	2460	3325	0	0

Table 4-1
Market Sizes and Total Cost Estimates for the Core Infrastructure (Metropolitan ITS Infrastructure)

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANITY LARGE	QUANITY MEDIUM	QUANITY SMALL	O & M COST LARGE ($K)	CAPITOL LARGE ($K)	O & M COST MEDIUM ($K)	CAPITOL MEDIUM ($K)	O & M COST SMALL ($K)	CAPITOL SMALL ($K)
ELECTRONIC FARE PAYMENT SYS											
Central Computer System	3000	150	1	1	0	150	3000	150	3000	0	0
Ticket Vending Machines	60	3	500	300	0	1500	30000	900	18000	0	0
Sys Engr. Prog Mgt, Installation	16000	0	1	0.6	0	0	16000	0	9600	0	0
Training & Documentation	80	4	1	1	0	4	80	4	80	0	0
Bus Farebox	7	0.35	2000	1200	0	700	14000	420	8400	0	0
Station Controller	20	1	65	35	0	65	1300	35	700	0	0
Turnstile	27.5	1.375	600	400	0	825	16500	550	11000	0	0
Ticket Office Machine & Validator	24.4	1.22	100	80	0	122	2440	97.6	1952	0	0
Smart Card	0.01	0.0005	2000000	1000000	0	1000	20000	500	10000	0	0
SUBTOTAL ($K)						4366	103320	2656.6	62732	0	0
TOTAL PER METRO AREA						$43,515	$420,167	$24,825	$278,039	$3,874	$40,753
NUMBER OF LARGE METRO AREAS			75								
NUMBER OFMEDIUM METRO AREAS				125							
NUMBER OF SMALL METRO AREAS					200						
<u>NATIONAL TOTALS FOR EACH SIZE CLASS</u>											
CAPITAL COSTS ($B)							$31.5		$34.8		$8.2
ANNUAL O&M COSTS ($B)						$3.26		$3.10		$0.77	

<u>NATIONAL TOTALS</u>

CAPITAL COSTS ($B)	$74.4
ANNUAL O&M COSTS ($B)	$7.14

Table 4-2 TransCore Market Sizes and Total Costs for Anytown

ELEMENTS	CAPITAL UNIT COST	O & M COST	O & M	Working Example for Anytown USA		
	($K)	% of Capitol	($K)	Total Quantity	Total Capital Cost	Total O&M Cost
SURVEILLANCE						
Point Detection (loops) per lane-mile	2	10%	0.2	480	960	48
Processor (170 series), Cabinet and Foundation	6.25	5%	0.313	220	1375	11
Point Detection (Overhead)	4.5	5%	0.225	120	540	6
CCTV	25	10%	2.5	40	1000	4
CCTV Pole and Foundation	18	5%	0.9	40	720	2
Video Image Processing (VIP) /intersection	40	10%	4	40	1600	4
Environmental Sensors	4	5%	0.2	0	0	0
HOV lane control &						
monitoring equipment	250	10%	25	0	0	0
AVI	40	10%	4	0	0	0
AVL	250	10%	25	0	0	0
Weigh-in-Motion		10%	0.1	0	0	0
SUBTOTAL ($K)					6195	75
TRAVELER INFORMATION						
Mid Range Fixed CMS & Controllers	60	5%	3	4	240	0.2
Full Matrix CMS & Controllers	80	5%	4	4	320	0.2
Portable CMS	50	5%	2.5	8	400	0.4
Cantelever Mounting Structure	75	5%	3.75	0	0	0
Overhead Structure (6 lanes each way)	120	5%	6	0	0	0
Overhead Structure (4 lanes each way)	100	5%	5	8	800	0.4
Fixed HAR & Controllers	20	10%	2	4	80	0.4
Portable HAR	40	10%	4	4	160	0.4
Kiosk	15	10%	1.5	50	750	5
Traveler Advisory Telephone	5	10%	0.5	0	0	0
SUBTOTAL ($K)					2750	7
COMMUNICATION						
Fiber-Optic Cable/mile	240		240		240	0
Coaxial Cable			0		0	0
Twisted Pair					0	0
Spread Spectrum	15			0	0	0
Interagency Communication					0	0
(fax, Modem, Email, etc.)					0	0
Leased Line					0	0
Signal	.04/month	0%			0	0
Video	.3/month	0%			0	0
SUBTOTAL ($K)					240	0
TRAFFIC CONTROL						
Signal System						
Central Computer System (closed loop)	10			0	0	0
Central Computer System (distributed)	30			1	30	1
Controller Upgrade	5			150	750	150
Emergency Vehicle Pre-emption	2			0	0	0
Transit Vehicle Pre-emption	2			0	0	0
Railroad Pre-emption	0.5			0	0	0
Ramp Metering	40	10%		40	1600	4
SUBTOTAL ($K)					2380	155
TRANSPORTATION MANAGEMENT CENTER						

Table 4-2 TransCore Market Sizes and Total Costs for Anytown

Computers & Hardware						
Small Area (<250,000 population)	476	15%		0	0	0
Medium Area (250,000 - 750,000 population)	544	15%		1	544	0.15
Large Area (>750,000 population)	680	15%		0	0	0
Software (various)	220			1	220	1
Facilities and Communications						0
Small Area (<250,000 population)	2800	15%		0	0	0
Medium Area (250,000 - 750,000 population)	3200	15%		1	3200	0.15
Large Area (>750,000 population)	4000	15%		0	0	0
ADDITIONAL TMCs	4900			0	0	0
SUBTOTAL ($K)					3964	1.3
TRAVELER INFO CENTERS						
Computers and Hardware						
Small Area (<250,000 population)	71.4	15%		0	0	0
Medium Area (250,000 - 750,000 population)	81.6	15%		1	81.6	0.15
Large Area (>750,000 population)	102	15%		0	0	0
Software (various)	300			0	0	0
Facilities & Communication						0
Small Area (<250,000 population)	2800	15%		0	0	0
Medium Area (250,000 - 750,000 population)	3200	15%		1	3200	0.15
Large Area (>750,000 population)	4000	15%		0	0	0
Kiosks	15	10%		30	450	3
SUBTOTAL ($K)					3281.6	3.3
TRANSIT MANAGEMENT CENTER						
Computers & Hardware						
Small Area (<250,000 population)	238	15%		0	0	0
Medium Area (250,000 - 750,000 population)	272	15%		0	0	0
Large Area (>750,000 population)	340	15%		0	0	0
Software (various)	90			0	0	0
Facilities & Communication				0	0	0
Small Area (<250,000 population)	2800	15%		0	0	0
Medium Area (250,000 - 750,000 population)	3200	15%		0	0	0
Large Area (>750,000 population)	4000	15%		0	0	0
SUBTOTAL ($K)					0	0
TRANSIT VEHICLE INTERFACES						
In-vehicle unit per vehicle	6.3	10%	0	0	0	0
SUBTOTAL ($K)					0	0
EMERGENCY MANAGEMENT CENTERS						
Computers & Hardware						
Small Area (<250,000 population)	238	15%		0	0	0
Medium Area (250,000 - 750,000 population)	272	15%		1	272	0.15
Large Area (>750,000 population)	340	15%		0	0	0
Software (various)	60			1	60	1
Facilities & Communications						
Small Area (<250,000 population)	2800	15%		0	0	0
Medium Area (250,000 - 750,000 population)	3200	15%		1	3200	0.15
Large Area (>750,000 population)	4000	15%		0	0	0
SUBTOTAL ($K)					3532	1.3
EMERGENCY VEHICLE SERVICES						
Cellular radio, Communications /vehicle	0.3	10%		0	0	0

Table 4-2 TransCore Market Sizes and Total Costs for Anytown

SUBTOTAL ($K)					0	0
SYS DESIGN & INTEGRATION						
TMC, TIC, EMC, TRANSIT, MC						
Small Area (<250,000 population)	3800	15%		0	0	0
Medium Area (250,000 - 750,000 population)	4300	15%		1	4300	0.15
Large Area (>750,000 population)	5400	15%		0	0	0
SUBTOTAL ($K)					4300	0.15
ELECTRONIC TOLL COLLECTION SYS						
Manual AVI (per lane)	73			0	0	0
Automatic AVI (per lane)	70			0	0	0
Manual Automatic AVI (per lane)	125			0	0	0
AVI Dedicated (per lane)	16			0	0	0
Express AVI (per lane)	16			0	0	0
AVI Plaza Computer equipment	130			0	0	0
SUBTOTAL ($K)					0	0
ELECTRONIC FARE PAYMENT SYS						
Central Computer System	3000			0	0	0
Ticket Vending Machines	60			0	0	0
Sys Engr. Prog Mgt, Installation	16000	0%		0	0	0
Training & Documentation	80			0	0	0
Bus Farebox	7			0	0	0
Station Controller	20			0	0	0
Turnstile	27.5			0	0	0
Ticket Office Machine & Validator	24.4			0	0	0
Smart Card	0.01	0%		0	0	0
SUBTOTAL ($K)					0	0
TOTAL					26643	243

Table 4-3
CH2M Hill Market Size and Corridor Costs for the ITS Rich Alternative

ITEM	CAPITAL COST						O & M COST: COMPUTED USING UNIT COSTS & QUANTITIES				O & M COST: COMPUTED AS % OF CAPITAL COST		DESCRIPTION	ASSUMPTIONS	SOURCE FOR COST DATA
	UNIT	UNIT COST ($K)	QUANTITY	TOTAL COST ($K)	ECONOMIC LIFE (YEARS)	ANNUALIZED COST ($K) *(Interest Rate = 7.0%)*	UNIT	UNIT COST ($K)	QUANTITY	ANNUAL COST ($K)	% OF CAPITAL COST	ANNUAL COST ($K)			
ITS/TRAFFIC SYSTEMS															
SURVEILLANCE															
Detection Loops	per mile	23.4	16	374	10	53	per mile	1.20	16	19			In-pavement loops and cables to nearest controller.	Four-lane per direction, install loop every half mile.	Capital-Build up based upon cost components of typical projects; O&M-TTI
Closed Circuit TV Camera	per each	25.0	26	650	10	93	per each	1.30	26	34			Monitor traffic operations along State's Routes	Install one every 1.2 mile per direction	Capital-WSDOT; O&M-TTI
Automatic Vehicle Identification/Roadside Equipment	per signal	25.0	235	5,875	10	836	per signal	1.50	235	353			Roadside equipment to identify bus, check schedule and provide transit priority at traffic signal	Includes reader, antenna, controller interface module, and local system communications. Transit vehicle equipment is listed separately.	Capital-King County/Metro; O&M-TTI
Automatic Vehicle Location/Field Equipment	per site	300	3	900	10	128					2%	18	Field differential GPS stationary site to provide fixed location information to compensate for topography and buildings	Assume 3 sites are needed. Transit vehicle and transit management equipment is listed separately.	Capital-Denver Regional Transit District; O&M-estimated
Data Station	per each	25.0	32	800	10	114					2%	16	To support detection	Install one station every half mile;O&M costs combined w/detection loops	Capital-WSDOT; O&M-TTI
Subtotal				8,599		1,224				406		34			
TRAVELER INFORMATION															
Variable Message Signs	per each	125	15	1,875	10	267	per each	4.00	15	60			VMS on overhead structures	Full matrix sign; includes controller and sign bridge structure	Capital-WSDOT; O&M-TTI
Fixed HAR & Controllers	per each	20.0	1	20	10	3	per each	1.00	1	1			Highway Advisory Radio site located at strategic locations run by WSDOT as a part of traffic management system	Add 1 new site at I-5/SR 99/SR 526	Capital-WSDOT; O&M-TTI
Kiosk	per each	18.0	10	180	10	26	per each	5.00	10	50			Located at transit centers	Install one kiosk per station	Capital-King County/Metro; O&M-TTI
Subtotal				2,075		296				111		296			
COMMUNICATION															
Fiber-Optic Cable	per mile	290	16	4,640	10	661	per mile	0.80	16	13			For extended freeway surveillance systems	Install along the I-5, SR526, SR526 and tie to existing WSDOT owned optic lines	Capital-WSDOT; O&M-TTI
Fiber-Optic Hubs	per each	110	3	330	10	47	per each	8.00	3	24			To interchange fiber-optic lines	Install one HUB per 3-5 miles	Capital-WSDOT; O&M-TTI
Twisted Pair	per mile	27.0	230	6,210	10	884	per mile	0.15	230	35			For extented adaptive traffic control systems	Includes trench, conduit, wire, junction boxes	Capital-WSDOT; O&M-TTI
Subtotal				11,180		1,592				71					
TRAFFIC CONTROL															
Coordinated/Adaptive Signal System - Local Controller	per controller	17.5	320	5,600	10	797	per controller	0.50	320	160			Replace existing controllers and cabinets at major intersections within study area	Basic O&M cost would remain the same as existing, except for cost related to maintain timing/data plans	Capital-Buildup based upon cost components of typical projects; O&M-TTI
Coordinated/Adaptive Signal System - Master Controller	per controller	10.0	14	140	10	20	per controller	0.50	14	7			To tie local controllers to the system	One master for every 20-25 local controller; O&M cost only related to maintain timing/data plans	Capital-Buildup based upon cost components of typical projects; O&M-TTI
Ramp Metering	per each	30.0	1	30	10	4	per each	3.00	1	3			Freeway entrance ramp metering station	O&M cost included equipment /hardware & timing plans	Capital-WSDOT; O&M-TTI
Subtotal				5,770		821				170					
TRAFFIC MANAGEMENT															
Computers & Hardware	per each	185	4	740	5	180	per each	170.00	4	680			For adaptive signal system and additional freeway system management where applicable	Assume one workstation, intergration and upgrades to existing signal control room; and one new employee each for Seattle, Lynnwood, WSDOT, and Everett	Capital and O&M-National Architecture Studies
Software (various)	per each	22.5	4	90	5	22	per each	34.00	4	136			For adaptive signal system	Included software installation, programing, and system analyst	Capital and O&M-National Architecture Studies
Communications Extension	per mile	27.0	4	108	10	15	per mile	0.15	4	1			For linkage to adaptive traffic control systems	Includes trench, conduit, wire, junction boxes	Capital-WSDOT; O&M-TTI
Subtotal				938		217				817					
TRANSIT MANAGEMENT															
Computers & Hardware for AVL System	per each	300	1	300	10	43					15%	45	Computer system to receive and process AVL polling data from buses and provide location, schedule adherance, and incidence information to dispatchers	Assume I-5 North Corridor allocation of 30 percent of the total cost.	Capital-Denver Regional Transit District: O&M-National Architecture Studies
Software	per each	150.0	1	150	10	21					2%	3	Software for AVL Controller and Dispatch Stations	Assume I-5 North Corridor allocation of 30 percent of the total cost.	Capital-Denver Regional Transit District: O&M-National Architecture Studies
Facilities and Communications	per each	500	1	500	10	71					15%	75	Radio communcations to receive AVL data, and dispatch stations including CRTs and microcomputers	Assume I-5 North Corridor allocation of 30 percent of the total cost. No additional dispatch staff needed.	Capital-Denver Regional Transit District: O&M-National Architecture Studies
Subtotal				950		135						123			
TRANSIT VEHICLE INTERFACES															
In-vehicle Transponder for AVI	per bus	0.6	408	245	10	35					2%	5	Transponder device located on buses used to identify bus at roadside readers at for signal priority treatment	All buses plus spares which are on routes which pass through transit priority intersections.	Capital-King County/Metro; O&M-National Architecture Studies
In-vehicle AVL Equipment	per bus	9.0	827	7,443	10	1,060	per bus	1.5	827	1,241			AVL on-board equipment for establishing vehicle location, assessing schedule status, and interfacing with driver	Consists of radio, vehicle logic unit, driver interface, radio antenna, and GPS antenna. All buses providing service in and through the I-5 North Corridor.	Capital-Denver Regional Transit District: O&M-TTI
Subtotal				7,688		1,095				1,241		5			
INCIDENT MANAGEMENT															
Central Tracking/Dispatch	per each	600	1	600	10	85					5%	30	Central tracking system/software and Mayday software/GIS integration; dispatch system.	System sized for I-5 North Corridor.	Capital-WSDOT:O&M-National Architecture Studies

Table 4-3
CH2M Hill Market Size and Corridor Costs for the ITS Rich Alternative

ITEM	CAPITAL COST						O & M COST: COMPUTED USING UNIT COSTS & QUANTITIES				O & M COST: COMPUTED AS % OF CAPITAL COST		DESCRIPTION	ASSUMPTIONS	SOURCE FOR COST DATA
	UNIT	UNIT COST ($K)	QUANTITY	TOTAL COST ($K)	ECONOMIC LIFE (YEARS)	ANNUALIZED COST ($K) *(Interest Rate = 7.0%)*	UNIT	UNIT COST ($K)	QUANTITY	ANNUAL COST ($K)	% OF CAPITAL COST	ANNUAL COST ($K)			
In-vehicle Dynamic Route Guidance	per each	4.0	4	16	10	2					10%	2	For tracking system and route guidance to provide faster response to incidents	In-vehicle radio, GPS antenna, GPS route guidance system.	Capital-Rockwell Path Master system plus add-on items; O&M-National Architecture Studies
Subtotal				616		87						32			
HIGHWAY/TRANSIT FACILITIES															
SOV FACILITIES															
Expressway Conversion	per mile	6,142			20		per mile	11.2					Conversion of unlimited access arterial to partial access control; add 2 lanes	Two new lanes/6 lanes total; includes outside shoulders, sidewalks and pedestrian overcrossing structures; cost excludes interchanges & grade separations; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; O&M - Houston Division of TxDOT
Limited Access Widening	per mile	1,831			20		per mile	11.2					Widening of full access controlled freeway; add 2 lanes	Construct divided highway; substantial earthwork and drainage system construction required; R/W related costs included in R/W cost items	Capital-Build up based upon cost components; validated using recent WSDOT estimate; O&M - Houston Division of TxDOT
Interchange (full)	per each	10,631			30						0.5%		Grade separated crossing with access ramps connecting the crossing roadways; diamond configuration; for Expressway	Compressed diamond with retaining walls; crossing road crosses over expressway; includes signals at ramp terminals; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB estimates
Interchange (half)	per each	7,442			30						0.5%		Grade separated crossing with access ramps connecting the crossing roadways; diamond configuration; for Expressway	Compressed diamond with retaining walls; crossing road crosses over expressway; includes signals at ramp terminals; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB estimates
Grade Separated Crossing	per each	4,896			30						0.5%		Grade separated crossing of two roads without ramp connections; for Expressway	Crossing road crosses over expressway; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB estimates
Subtotal															
HOV/TRANSIT FACILITIES															
New HOV Lanes on Freeway	per mile	8,780			20			11.2					Add barrier separated HOV lanes to existing freeway	Limited/no existing median to enable widening; includes bridge widenings for crossing structures and reconstruction of ramps at interchanges; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M - Houston Division of TxDOT
Upgrade HOV Lanes on Freeway	per mile	7,616			20								Upgrade existing HOV lanes to barrier separated lanes on a freeway	Limited/no existing median to enable widening; includes bridge widenings for crossing structures and reconstruction of ramps at interchanges; R/W related costs included in R/W cost items; Incremental O&M costs assumed negligible	Capital-Build up based upon cost components of typical project;
New HOV Lanes on Deck-Truss Bridge	per foot	16.1			30						0.25%		Add HOV lanes to deck-truss bridge/no barrier or buffer separation	Add truss arch section to support widening; sidewalks replaced; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; validated using recent WSDOT estimate; O&M-WSDOT modified per PB estimates
New HOV Lanes on Expressway	per mile	7,626			20			11.2					Add HOV lanes to expressway/no barrier or buffer separation	Reconstruction of sidewalks, drainage system and utilities; landscaping enhancements; roadway and pedestrian crossing structures modified; excludes costs for bridge over ship canal; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; O&M - Houston Division of TxDOT
New HOV Contra-Flow Reversable Lane on Freeway Express Lanes	per mile	14,600			20		per mile	90					Add HOV moveable barrier-separated lane	Based upon cost estimate for I-5 Express Lanes/Ravenna-to-Howell HOV project; includes moveable barrier, and barrier-transfer machines and storage shed; additional O&M cost is included for reversible lane operation	Capital-Adapted from prior P.S. HOV study estimates; O&M - Houston Division of TxDOT/San Diego Coronado Bridge
Arterial Transit Lanes/Two Directions	per mile	7,323			20			11.2					Add HOV/transit lanes to an existing arterial	Reconstruction of sidewalks, drainage system and utilities; landscaping enhancements; R/W related costs included in R/W cost items	Capital-Build up based upon cost components of typical project; O&M - Houston Division of TxDOT
Arterial Transit Lanes/Reversable	per mile	6,240			20		per mile	17					One center reversable lane	Includes reconstruction of c&g and sidewalk; includes overhead lane control signal bridges; assumes removal of on-street parking; additional O&M cost is included for reversible lane operation; R/W related costs included in R/W cost items	Capital-Adapted from prior P.S. HOV study estimates; O&M - Houston Division of TxDOT/TTI
HOV Direct Access/Local Half Reversable Drop	per each	6,400			30		per each	46					Direct access ramps between express lanes and local street	Based upon cost estimate for I-5/NE 50th Street direct access project; assumes ½ mile of ramp maintenance with reversible ramp operations calculated on a per unit basis.	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT/TTI
HOV Direct Access/Local Half Drop	per each	9,360			30						0.5%		Direct access ramps between median freeway HOV lanes and local street	Based upon cost estimate for I-5/NE 145th Street direct access project	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT modified per PB estimates
HOV Direct Access/Local Full Texas T	per each	31,140			30						0.5%		Direct access ramps between median freeway HOV lanes and local street	Based upon cost estimate for I-5/Lynnwood Park-and-Ride direct access project	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT modified per PB estimates

Table 4-3
CH2M Hill Market Size and Corridor Costs for the ITS Rich Alternative

ITEM	CAPITAL COST						O & M COST: COMPUTED USING UNIT COSTS & QUANTITIES				O & M COST: COMPUTED AS % OF CAPITAL COST		DESCRIPTION	ASSUMPTIONS	SOURCE FOR COST DATA
	UNIT	UNIT COST ($K)	QUANTITY	TOTAL COST ($K)	ECONOMIC LIFE (YEARS)	ANNUALIZED COST ($K) *(Interest Rate = 7.0%)*	UNIT	UNIT COST ($K)	QUANTITY	ANNUAL COST ($K)	% OF CAPITAL COST	ANNUAL COST ($K)			
HOV Direct Access/Local Half Drop to Outside	per each	2,500			30		per at-grade ramp miles	11.2	0.5	6			Direct access ramps between outside general pupose freeway lanes and local street	Based upon cost estimate for SR525/164th Street SW direct access project; no widening or modifications to 164th Street crossing structure required	Capital-Adapted from prior P.S. HOV study estimates; O&M-Based on Houston Division of TxDOT figures
HOV Direct Access/Local Full In-Line	per each	2,970			30		per at-grade ramp miles	11.2	0.5	6			Direct access ramps between median HOV lanes and in-line station w/ pedestrian link	Based upon cost estimate for I-5/Mountlake Terrace direct access project	Capital-Adapted from prior P.S. HOV study estimates; O&M-Based on Houston Division of TxDOT figures
HOV Direct Access/Fwy-to-Fwy	per each	71,000			30						0.5%		Direct access ramps between freeways to/from one direction and another (e.g. between east and north)	Based upon cost estimate for I-5/I-405/SR525 NE Quadrant direct access project	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT modified per PB estimates
HOV Direct Access/Fwy-to-Fwy Reversible	per each	11,870			30		per each	46					Direct access reversible ramp between median HOV lanes and express lanes	Based upon cost estimate for SR520/I-5 Express Lanes direct access project; includes access control gates; assumes ½ mile of ramp maintenance with reversible ramp operations calculated on a per unit basis.	Capital-Adapted from prior P.S. HOV study estimates; O&M-WSDOT/Houston Division of TxDOT/TTI
Park and Ride Lot	per parking stall	6.1			20		per 100 stalls	2	25	50			Parking facility including bus transit shelter and pedestrian enhancements	Capital cost includes bus zone amenities, access improvements, stormwater detention, and landscaping.	Capital-Averaged from WSDOT examples;O&M-Based on Houston Division of TxDOT figures
Transit Bus - 40 foot Deisel	per vehicle	230	(8)	(1,840)	12	(232)	per thousand revenue vehicle hours	89	(25.4)	(2,261)			Standard intracity transit bus	For use on local service routes.	Capital-King County/Metro;O&M-King County/Metro
Transit Bus - 60 foot Deisel Articulated	per vehicle	375	(3)	(1,125)	12	(142)	per thousand revenue vehicle hours	89	(3.0)	(267)			Standard intracity transit bus	For use on express service routes.	Capital-King County/Metro;O&M-King County/Metro
Transit Bus - 60 foot Dual Power Articulated	per vehicle	900	(2)	(1,800)	12	(227)	per thousand revenue vehicle hours	89	(1.5)	(134)			Special bus for use in downtown transit tunnel	For use on express service routes which operate through the Seattle downtown transit tunnel.	Capital-King County/Metro;O&M-based upon annual vehicle hours times cost per vehicle hour
Subtotal				(4,765)		(601)				(2,600)					
RIGHT-OF-WAY															
R/W Adjacent to Arterial	per acre	900			100								Right-of-Way acquisition costs along expressways and arterials in north Seattle	Based upon typical costs for land along SR 99	Capital-Input from WSDOT; O&M-NA
R/W Adjacent to Freeway	per acre	500			100								Right-of-Way acquisition costs along freeways in north Seattle	Based upon typical costs for land along I-5	Capital-Input from WSDOT; O&M-NA
R/W Takes/Damages	per parcel	50.0			100								Typical extra cost to cover relocations and/or damages	Assumes posible costs to cure impacts from loss of access, or costs to relocate and re-establish business at a different location, or relocate resident.	Capital-Input from WSDOT; O&M-NA
Subtotal															
GRAND TOTAL				33,051		4,866				215		489			

Pre-Trip Planning Services	NA						per subscription	0.12	90,000	10,800			Interactive fixed-end trip planning service; 10% of travelers; no capital cost beyond baseline	5.5 mil trips withn/thru study area x 6.87 = 800 k hh; 2.33 trips/hh=1.86 mil persons; 75% eligible=900 k;10% penetration rate=90 k subscribers	Capital-NA; O&M-Mitretek assumption
Personal Dynamic Route Guidance	per device	0.8	113,000	90,400	7	16,774	per subscription	0.12	113,000	13,560			In-vehicle equipment costs include GPS, map database, communications transceiver, processor, GUI, and display	5.5 mil trips withn/thru study area x 6.87 = 800 k hh; 1.41 autos per hh=1.13 mil veh; 10% penetration rate=113 k veh	Capital-National Architecture Studies; O&M-Mitretek assumption

REFERENCES:

TransCore-Interim Handbook on ITS Within the Transportation Planning Process, TransCore (formerly JHK & Associates), December 1996, Appendix E.
WSDOT-TSMC SC & DI Operations/Implementation Plan, WSDOT, October 1994.
TTI-Guidelines for Funding Operations and Maintenance of ITS/ATMS, Texas Transportation Institute, November 1996.
National Architecture Studies-ITS Architecture Cost Analysis, Federal Highway Administration/Joint Architecture Team, June 1996.
King County/Metro-King County transit operator, Dan Overguard/David Cantay/Mike Voris, May 1997.
Denver RTD-Denver Regional Transit District, Lou Ha, June 1997.

Mitretek has begun to synthesize the information in the various cost databases in the repository. As part of this effort, the three unit cost estimates from FHWA, TransCore, and CH2M Hill, which are shown together in table 3-5, (and only these three) have been integrated so that there is only one cost estimate for each cost element. The result is shown in table 5-1, along with annotations about how each estimate was derived.

The table indicates that the newer estimates added additional cost elements to the ones used by the FHWA Core Infrastructure analysis, and changed the percentages that O&M costs are of capital costs. In a few cases, Mitretek made new estimates. For some of the ITS cost elements that were added by either TransCore or CH2M Hill, Mitretek estimated that O&M costs would be 5% of the capital costs, similar to the rule of thumb in the FHWA analysis. Mitretek also lowered the capital costs of a smart card, based on more recent information than was available in 1995.

6. Next Steps

This Working Paper has been written to describe the status of the Cost Repository. It is expected that the JPO and Mitretek will decide on future activities with the data in the Repository. One necessary activity is to have discussions with cost experts in DOT, transportation agencies, and others on what categories of costs and levels of detail are most useful to others. Another subject for discussion is whether or not to rationalize the differences between the current unit cost estimates, We recommend scheduling an initial meeting at DOT's earliest convenience.

After these steps are performed, a study could compare the available costs with the benefit data in the ITS Benefits Inventory that resides at Mitretek[25]. Another possibility for this later time period is to examine the life cycle costing of the various sources.

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[25]Proper, Allen T, and Cheslow, Melvyn D., ITS Benefits: Continuing Successes and Operational Test Results, FHWA, October 1997

Table 5-1 Synthesis of Cost Elements and Unit Costs Based On Core Infrastructure, TransCore, and CH2M Hill

ELEMENTS	UNIT COST CAPITOL	SOURCE OF REVISED CAPITAL COSTS	UNIT COST O & M	SOURCE OF REVISED O&M COSTS
	($K)	C = Core; T = TransCore; S = Seattle; M = Mitretek; AV = Average; AV3 = AV of C, T, S	($K)	C = Core; T = TransCore; S = Seattle; M = Mitretek; AV = Average; AV3 = AV of C, T, S
SURVEILLANCE - ARTERIALS				
Loop Detectors per signal per approach lane	1.10	AV3	0.07	AV3
Other arterial loop detectors	1.10	AV3	0.07	AV3
Overhead Point Detectors [NEW]	2.25	T	0.11	T
Processor (170 series), 1 per direction per half mile (Arterials) [NEW]	6.25	T	0.31	T
CCTV Cameras per signalized intersection	25	T, S	1.7	AV3
CCTV pole and foundation [NEW]	18	T	0.9	T
Video Image Processing/intersection	40	C	3	AV T, S
AVI equip. to identify priority veh./intersection [NEW]	33	AV T, S	2.6	AV T, S
AVL equip (to supplement GPS)/site [NEW]	275	AV T, S	16.5	AV T, S
SURVEILLANCE - FREEWAYS				
Loop Detectors per fwy lane per half mile	1.10	AV3	0.07	AV3
Data Station (Fwy), 1 per half mile [NEW]	25	S	0.50	S
CCTV Cameras per freeway mile	25	T; S	1.7	TC, S
CCTV pole and foundation [NEW]	18	T	0.9	T
Emissions & Environmental Sensors	4	C	0.2	C
Overhead Point Detectors [NEW]	2.25	T	0.11	T
COMMUNICATION - ARTERIALS				
Twisted-pair to Signals (per intersection)	15	AV C, S	0.75	C
Wireless radio [NEW]	15	T	?	?
Leased line to signals [NEW]	0		0.48	T
Leased line to video [NEW]	0		3.6	T
COMMUNICATION - FREEWAYS				
Fiber-Optic Cable/ freeway mile	265	AV C, S	13	C
Fiber-optic hub - 1 per 5 mi. of fiber [NEW]	110	S	8	S
Leased line to video [NEW]	0		3.6	T
TRAFFIC SIGNAL CONTROL				
Central Computer System (Closed Loop) NEW	10	T	0.5	M
Central Computer System (Distributed) NEW	30	T	1.5	M
Master controllers for distributed system (1 per 25 intersections) [NEW]	10	S	0.5	S
Controller replacement per intersection [NEW]	17.5	S	0.9	M
Signal controller upgrade (per intersection)	5	C	0.25	C
Signal Preemption: Transit, Emergency Vehicle, RR [NEW]	2	T	0.1	M
FREEWAY MANAGEMENT @ ROADSIDE				
HOV lane control & monitoring equip.	250	C	19	AV C, T
Ramp Meter Systems (per interchange)	35	AV C, T	3.5	T, S
TRAVELER INFORMATION @ ROADSIDE/SITE				
Full Matrix VMS & Controllers (without structure)	70	AV3 without structure	3.5	AV C, T
Overhead Structure[Separated out]	105	T	5	AV C, T
Hybrid VMS with structure (Arterials)	20	C	1	C
Fixed HAR & Controllers	20	C	1	C, S
Callboxes: each direction per half-mile	5	C	0.5	C
Kiosks	21	AV3	5.5	AV C, T
INCIDENT MANAGEMENT EQUIPMENT				
Portable VMS	40	AV C, T	2	C
Portable HAR	45	AV C, T	3.3	AV C, T
Special Pickup Trucks (w. Dyn. Route Guidance)	**50**	C; DRG from S	5	M
O & M Personnel	0		50	C
TRANSP. MGMT CTRS (Number per metro area)				
Central Dispatch/Routing Equip. (1 per area) [NEW]	600	S	30	S
Computers & Hardware/TMC	680	C	68	AV C, T
Central Dispatch/Routing Equip.	400	S	20	
Software (various)/TMC	220	C	11	C
Facilities & Communications/TMC	4000	C	400	AV C, T
O & M Personnel/TMC	0		50	C
TRAVELER INFORMATION CENTER				
Computers and Hardware	100	C	10	AV C, T
Software (various)	300	C	15	C
Facilities & Communication (stand-alone)	4000	C	400	AV C, T
O & M Personnel	0		50	C

Table 5-1 Synthesis of Cost Elements and Unit Costs Based On Core Infrastructure, TransCore, and CH2M Hill

ELEMENTS	UNIT COST CAPITOL	SOURCE OF REVISED CAPITAL COSTS	UNIT COST O & M	SOURCE OF REVISED O&M COSTS
	($K)	C = Core; T = TransCore; S = Seattle; M = Mitretek; AV = Average; AV3 = AV of C, T, S	($K)	C = Core; T = TransCore; S = Seattle; M = Mitretek; AV = Average; AV3 = AV of C, T, S
EMERGENCY RESPONSE CENTER				
Computers & Hardware	340	C	17	C
Software (various)	60	C	3	C
Facilities & Communications (stand-alone)	4000	C	400	AV C, T
O & M Personnel	0		50	C
EMERGENCY SERVICES EQUIPMENT				
Cellular radio, comm. services per vehicle	0.3	C	0.02	C
TRANSIT MANAGEMENT CENTER				
Computers & Hardware	340	C	51	AV T, S
Software (various)	120	AV C, S	6	C
Facilities & Communication (stand-alone)	4000	C	400	AV T, S
O & M Personnel	0		50	C
SUBTOTAL ($K)				
TRANSIT VEHICLE INTERFACES				
Cellular radio, display, etc per vehicle	6.3	C	0.47	AV C, T
AVI Transponder (on Signal Priority routes) [NEW]	0.6	S	0.01	S
In-vehicle AVL equip. per vehicle [NEW]	9	S	1.5	S
ELECTRONIC FARE PAYMENT SYS				
In Transit Mgmt Center				
Central Computer System	3000	C	150	C
Training & Documentation	80	C	4	C
At ticketing site				
Station Controller [DETETE]	20	C	1	C
Ticket Office Machine & Validator	24	C	1.2	C
Ticket Vending Machines	60	C	3	C
Turnstile [DELETE]	27.5	C	1.4	C
On Transit Vehicles				
Bus Farebox	7	C	0.35	C
Smart Card	0.003	M	0	
Sys Engineering. Etc. [MOVED]				
ELECTRONIC TOLL COLLECTION SYS				
AVI Plaza Computer equipment	130	C	7	C
Manual AVI (per lane)	73	C	147	C
Automatic AVI (per lane)	70	C	48	C
Manual Automatic AVI (per lane)	125	C	116	C
AVI Dedicated (per lane)	16	C	5	C
Express AVI (per lane)	16	C	5	C
SYS DESIGN & INTEGRATION				
TMC, TIC, EMC, Transit MC	5400	C	0	
Electronic Fare Payment Sys	5400	M (set equal to above line)	0	