Working Paper

National Costs of the Metropolitan ITS Infrastructure: Update to the FHWA 1995 Report

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Preface

An addendum has been added to this report to update the estimates of the costs remaining to deploy Intelligent Transportation System (ITS) infrastructure elements in the 75 largest metropolitan areas in the United States. Specifically, this addendum provides estimates to the deployment costs expended through 1999 and then updates the remaining costs to deploy ITS infrastructures based on this 1999 deployment cost estimate. Sections of the report affected are 3D, 4, and 5. The addendum can be found at the end of the original report. The original report was dated September 1999 and published on the ITS JPO EDL as document # 11923.

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EXECUTIVE SUMMARY

This working paper has been prepared to provide new estimates of the costs to deploy Intelligent Transportation System (ITS) infrastructure elements in the largest metropolitan areas in the United States. It builds upon estimates that were distributed in June 1995 by the Federal Highway Administration (FHWA).[1] Since 1995, new sources of ITS cost estimates have appeared. Hence, it is now useful to determine whether the national deployment cost estimate has changed appreciably.

Methodology for Estimating National ITS Costs

When deployment costs are estimated at the national level, decisions must be made on the level of aggregation that will be used, as well as several other steps. The 1995 FHWA cost estimates used the following seven steps:

1. Decision on cost categories, and method for aggregating to national totals:
   a. Capital and annual O&M costs
   b. Largest metropolitan areas grouped into three size classes, and then aggregated to a national total.
2. Choice of cost elements
3. Estimation of average unit costs
4. Decision on the size ranges of the three metropolitan groups, and selection of an average, or generic, area, for each of the three groups.
5. Decision on the market penetration, or market size, in the base year for each cost element.
6. Decision on the number of each cost element (market size) in each of the three metropolitan size groups for *full ITS deployment*.
7. The last step is to carry out the necessary arithmetic.

Methodology for Modifying the Cost Estimates

This working paper used essentially the same seven steps as above, and made several modifications to the decisions based on the new data, as follows (steps above are indicated in parentheses):

- Changes to the cost elements that are used (step #2)
- Changes to average unit costs (step #3)
- Changes to the number of metropolitan areas that are in each of the three size groups (step #4)
- Changes to the market penetration in the base year (step #5)

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[1] Office of Traffic Management and Intelligent Transportation Systems (HTV-10), *Cost Estimate and Assumptions for the Core Infrastructure*, FHWA, June 1995. The ITS Infrastructure was called the Core Infrastructure in 1995.

- Changes to market size for full deployment have been addressed in a *parametric analysis (step #6)*.

Conclusions

The paper has developed a significant amount of new information that affects national ITS infrastructure costs. Readers will see that changes have been made both at the individual cost element level, as well as in the number of metropolitan areas that fall into different size classes. The details of these changes are discussed in Section 3.

Those who want to know what the *new values are for national ITS deployment costs*, and what were the *significant factors* in the changes, should examine Section 5.

There are fairly large increases in the costs for the three generic geographic areas in both Capital and Annual O&M Costs, however, these are offset by a reduction in the number of metropolitan areas in each size class. The net result is almost no change in total costs. Nationally, the estimate for the capital costs of fully deploying ITS in metropolitan areas has *changed from $74.4 billion to $73.0 billion, a decrease of 2 percent*. The estimate for O&M costs *increased from $7.3 billion to 7.6 billion, or 4 percent.* These changes account for all of the modifications to the cost estimates, which were listed above, except for the modifications to the market size for full deployment.

A different view of the summary data can be taken, where the interest is on the *cost of the 75 largest metropolitan areas.* The capital costs for the top 75 are estimated to *increase by 20 percent*, from $31.5 billion to $37.7 billion. Annual O&M costs for the top 75 areas *increase 33 percent*, from $3.3 billion to $4.3 billion per year.

The major difference between the small changes, nationally, and the larger ones for the top 75 metropolitan areas, is that the new estimates for the national-level costs involve a *major decrease in the number of metropolitan areas that are being considered*, while the estimates for the top 75 areas keep the number of areas constant, at 75.

To summarize, the new numerical results are as follows:

- National capital costs for 300 MSAs — $73.0 billion
- National annual O&M costs for 300 MSAs — $7.6 billion
- Capital costs for 75 largest MSAs — $37.7 billion
- Annual O&M costs for 75 largest MSAs — $4.3 billion

To investigate how the level of *full deployment* might affect the estimate of investment needs, a *parametric analysis* was performed for the generic large and medium areas. This analysis was performed for three different constant values – 50%, 67%, and 80% – for the percent that the deployment levels might be of the full deployment quantities used in the remainder of the paper.

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The 100% level was defined as the “could” case, while the lower percentages were defined as possible “should” cases.

For example, for “Should” deployment levels equal to 67% of the Could levels, the generic large area would only need $393 million, on average, instead of $589 million. Furthermore, if we take into account that, on average, 14.8% of the “should” case full deployment has already occurred, then only $334 million would be required. Hence, it can be seen that an estimate of the investment needed at the national level depends quite heavily on the values estimated for the Should Case and Base Case (1997) deployment levels.

SECTION 1. INTRODUCTION

This working paper has been prepared to provide new estimates of the costs to deploy metropolitan Intelligent Transportation System (ITS) infrastructures in the largest metropolitan areas in the United States. It builds upon estimates that were distributed in June 1995 by the Federal Highway Administration (FHWA).[1] Since 1995, new sources of ITS cost estimates have appeared. Hence, it is now useful to determine whether the national deployment cost estimate has changed appreciably.

The 1995 report used data from the Phase I National ITS Architecture Program[2], as well as other data sources in several states.[3] The current working paper has used two new data sources from TransCore[4] and CH2M Hill[5]. Both of these sources used the June 1995 report (Reference 1) as their starting point, and then added information from more recent local deployments. In addition, the Mitretek report utilized cost estimates from two other recent sources.[6]

Structure of This Working Paper The paper has four additional sections and two appendices. Section 2 presents and describes the original cost spread sheet that was developed in Reference 1. It also presents the methodology that was used there as a *seven step process*. FHWA's discussion of their methodology and deployment scenarios are reproduced in Appendix A. Their detailed cost spreadsheet is reproduced in Appendix B.

In Section 3, updates are described for several of the *seven steps* that were described in Section 2. The updates have all been made using new estimates that have become available after 1995. After each update is described, a new cost spreadsheet is introduced to show the effect of changing that step. These detailed spreadsheets are shown in Appendix C. Several summary tables are presented in Section 3 that show the incremental effect of each update. The longer tables from Section 2 and Section 3 were placed in Appendices B and C, so that the flow of text can be more easily followed.

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[1] Office of Traffic Management and Intelligent Transportation Systems (HTV-10), *Cost Estimate and Assumptions for the Core Infrastructure*, FHWA, June 1995. The ITS Infrastructure was called the Core Infrastructure in 1995.

[2] Rockwell International, *IVHS Architecture, Initial Cost Analysis*, FHWA, October 1994

[3] According to reference 1, cost data were obtained from transportation agencies in Texas, Virginia, Massachusetts, Washington, Georgia, Minnesota, Maryland, Delaware, and California.

[4] TransCore, Appendix E to Draft Version of *ITS Planning Handbook*, January 1996, unpublished.

[5] CH2M Hill, *Seattle ITS Case Study*, Alternative Cost Estimate Spreadsheets, under contract to Mitretek Systems, January 1998

[6] Joint Architecture Team, *ITS Architecture Cost Analysis*, Federal Highway Administration, June 1996; Daniels, Ginger, et al., *Guidelines for Funding Operations and Maintenance of ITS/ATMS,* Texas Transportation Institute, August 1996

Section 4 provides a discussion of the current status of our ability to update estimates of the Full Market Penetration levels. Section 5 presents some conclusions and recommendations.

The detailed tables in Section 3 and Appendix C present a significant amount of new information that affects national ITS infrastructure costs. New cost elements are introduced, as are new values for the base-year deployment levels. Some analysts who need to understand how the costs on ITS elements are determined, will want to review the detailed tables carefully, to check on the accuracy of the assumptions and the results.

For those who may only need to understand *what new information* has been used, and *how it has changed the national cost estimates*, reading Section 2, and reviewing the summary tables in Sections 3 and 5, will be of value.

Finally, for those who may just want to know what the *new values are for national ITS deployment costs*, and what were the *significant factors* in the changes, the tables in Section 5 may be satisfactory.

SECTION 2. STEPS USED TO PRODUCE THE 1995 NATIONAL ITS COST ESTIMATE

When deployment costs are estimated at the national level, or even at a metropolitan level, a decision must be made on the level of aggregation that will be used. At one extreme, one could attempt to be very precise, and make estimates for every ITS project that would be implemented in the next several years. Each project is made up of many elements, -- e.g., equipment, facilities, communications, staff -- and therefore, the costs for each of these elements would be considered, and then aggregated for each project, then for each metropolitan area, and finally, nationally. At the other extreme, one could make a single national estimate of the implementation costs using a factor such as ITS implementation cost per mile of roadway, or cost per vehicle miles traveled (VMT). The data are not readily available to carry out either of these two extreme approaches.

However, an intermediate approach can be used, which has less stringent data requirements. The 1995 FHWA cost estimates did just that. That estimate used the following seven steps:

1. Decision on definitions and the level of aggregation:
    - A. The analysis estimates costs for each metropolitan area, and then aggregates to obtain a national total.
    - B. The average unit cost for each cost element is held constant throughout the analysis. This assumes that there is no change in unit costs over the implementation time period. It also assumes that there are no scale economies (or diseconomies), or geographic variations in the unit costs. This is a fundamental simplifying assumption.
    - C. Two categories of cost were estimated for each cost element: capital, and annual O&M costs
    - D. The geographic extent of ITS implementations in a metropolitan area varies according to area population. For the 1995 analysis, three size groupings were selected, large, medium and small, and every metropolitan area was assigned to one of the three groups.

2. Choice of cost elements, for both ITS and supporting functions. The cost elements were initially based on the Phase I ITS Architecture project. Some of the more technologically advanced aspects of the architecture, such as automated highways, and intersection collision avoidance, were eliminated. Other cost elements of the architecture were disaggregated, or augmented, based on data from recent ITS projects. (See footnote #3.) The cost elements are listed in Table 2-1.

Table 2-1
Cost Elements, Unit Costs, and Units of Measurement Used in FHWA 1995 Report

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 Sensors	4	0.2
HOV lane control & monitoring equip.	250	12.5
TRAVELER INFORMATION		
Fixed CMS & Controllers	200	10
Fixed HAR & Controllers	20	1
Hybrid CMS	20	1
Ramp Meter Systems (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
TMCs		
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

Table 2-1
Cost Elements, Unit Costs, and Units of Measurement Used in FHWA 1995 Report

COST ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)
TRANSIT VEHICLE INTERFACES		
Kiosks, cellular radio, etc per vehicle	6.3	0.315
EMERGENCY MANAGEMENT CENTERS		
Computers & Hardware	340	17
Software (various)	60	3
Facilities & Communications	4000	200
O & M Personnel	0	50
EMERGENCY VEHICLE SERVICES		
Cellular radio, Communications /vehicle	0.3	0.015
INCIDENT MANAGEMENT EQUIPMENT		
Vehicles	50	2.5
Portable HAR	50	2.5
Portable CMS	30	1.5
O & M Personnel	0	50
SYSTEM DESIGN & INTEGRATION		
TMC, TIC, EMC, TRANSIT MC	5400	0
ELECTRONIC TOLL COLLECTION SYSTEM		
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 Computer equipment	130	7
ELECTRONIC FARE PAYMENT SYSTEM		
Central Computer System	3000	150
Ticket Vending Machines	60	3
System Engr. Program 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

3. Estimation of the average unit costs for each of the cost elements. There is flexibility in the "unit" that is chosen. For example, the unit cost may be defined as the cost per metropolitan area, cost per transportation management center, or cost per mile. As indicated in the reference in footnote # 2, the unit costs came from several sources. Generally, the decision on what value to select when there was more than one source was made on the basis of engineering judgement about the ITS services. The unit costs and the units of measurement for each of the cost elements used in the 1995 report are shown in Table 2-1. For several of the cost elements, the units of measurement are not explicitly identified.

4. Decision on the three metropolitan size groups, and selection of an average, or generic, area, for each of the three groups. First, FHWA selected Detroit to be the generic area for the large-size group, since a modification of that area was used for analyzing costs and benefits of the National ITS Architecture[7]. FHWA then selected the population size classes: over 750,000 for large; 200,000 to 750,000, medium; and 50,000 to 200,000, small. Knoxville, Tennessee was the generic medium-sized area, and Cheyenne, Wyoming was the generic small area. FHWA then estimated that there were 75 large, 125, medium, and 200, small metropolitan areas in the country. These results are shown in Table 2-2.

Table 2-2
Parameters for the Three Size Classes and Generic Metro Areas
As Used by FHWA (1995) to Estimate National Metropolitan Infrastructure Costs

Size Class	Population Range	Generic Area	Number of Metro Areas in the Size Class
Large	Over 750,000	Detroit	75
Medium	200,000 to 750,000	Knoxville	125
Small	Under 200,000	Cheyenne	200

Source: Office of Traffic Management and Intelligent Transportation Systems (HTV-10), *Cost Estimate and Assumptions for the Core Infrastructure*, FHWA, June 1995. The ITS Infrastructure was called the Core Infrastructure in 1995.

5. Decision on the market penetration or market size in the base year for each cost element. This variable can also have different interpretations. It could be defined as the current average deployment for the metropolitan areas in each of the three size groups, or as zero penetration. *The FHWA report chose zero penetration for every cost element*, because no better data were available at that time. Because of this choice, they pointed out that their estimate of the full-deployment costs for ITS is a "*worst case scenario*". (This means that it is the highest cost scenario.)

[7] Joint Architecture Team, ITS Architecture, Evaluatory Design, FHWA, 1996

6. Decision on the number of each cost element (market size) in each of the three metropolitan size groups for *full ITS deployment*. These numbers are selected to be consistent with the units of measurement chosen in step #3. This step requires that the term *"Full Deployment"* be defined. It may be taken to be the maximum implementation that is possible, such as implementing adaptive signals at every arterial intersection; or as the implementation that meets certain traffic control standards; or as the level that is possible under budgetary constraints for a jurisdiction. The FHWA report generally used the first definition, namely the maximum possible. (This is consistent with the worst case scenario.) The number of each cost element for full deployment in the three size classes is shown in Appendix Table B-1.

7. The last step is to carry out the necessary arithmetic:

   - The unit costs are *multiplied* by the number of units necessary for full deployment for *each element* in each of the three generic areas.
   - For each of the three generic areas, the results for each element are *added* together to get the costs for *all elements* used in full deployment.
   - These costs are *multiplied* by the number of metro areas in each of the three size classes to get the deployment costs for *all metro areas in each size class*.
   - The costs for the three classes are *added* together to obtain the estimate of *national deployment* ITS costs in metropolitan areas.

The results of these arithmetic steps in the FHWA report are shown in Table B-2. At the bottom of that table, several summary cost values are shown. These are estimates of the capital costs and the annual O&M costs for the three generic metropolitan areas, for all metro areas in each of the three size classes, and for the national total for all metropolitan areas. For convenience, the summary cost values alone are also listed in Table 2-3. Note that life-cycle costs were not estimated, only the initial capital and annual O&M costs.

In Section 3, these summary costs will be compared with the results of the changes that will be described in that section.

Table 2-3
Summary Costs from FHWA (1995) National Metropolitan Infrastructure Costs

Geographic Descriptor	Capital Costs	Annual O&M Costs
Generic Large Area	$420M	$44M
Generic Medium Area	$278M	$26
Generic Small Area	$41M	$4M
Total, Large Areas (75)	$31.5B	$3.3B
Total, Medium Areas (125)	$34.8B	$3.2B
Total, Small Areas (200)	$8.2B	$0.8B
National Total	$74.4B	$7.3B

Source: Office of Traffic Management and Intelligent Transportation Systems (HTV-10), *Cost Estimate and Assumptions for the Core Infrastructure*, FHWA, June 1995. The ITS Infrastructure was called the Core Infrastructure in 1995.

SECTION 3. UPDATES TO THE 1995 ESTIMATE OF NATIONAL ITS COSTS

This section discusses several modifications that to the original 1995 estimate of the national costs for full deployment of the metropolitan ITS infrastructure.[8] These changes are presented in the following order, with the number following each change item identifying the step that it corresponds to in Section 2:

- Changes to unit costs (step #3)
- Changes to the cost elements that are used (step #2)
- Changes to the number of metropolitan areas that are in each of the three size groups (#4)
- Changes to the market penetration in the base year (step #5)

These changes are based on additional data that have become available since 1995.

Changes to full deployment levels have been addressed in a *parametric analysis* in Section 4. A parametric, or sensitivity, analysis has been used because of the lack of a common definition of *full deployment*, and because of a lack of data. New data are expected to be collected in the next two years that will allow for a more precise investigation.

3A. Changes to Unit Costs

There have been several new estimates of the unit costs of ITS elements.[9] Some of the estimates are based on the cost elements that were developed for the final version of the National ITS Architecture[10]. These cost elements are generally more detailed than the ones that were shown in Table 2-1. The cost elements in the Architecture appear to Mitretek to be too detailed for a national-level analysis. In addition, there are some differences between the way that the cost elements are grouped in the National Architecture as compared to the Core ITS Infrastructure.[11] Therefore, the updating of the FHWA unit costs has *focused instead on two other recent reports, one by TransCore[12], and the other by CH2M Hill.[13]*

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[8] Office of Traffic Management and Intelligent Transportation Systems (HTV-10), *Cost Estimate and Assumptions for the Core Infrastructure*, FHWA, June 1995.

[9]See Cheslow, Melvyn, *Working Paper: The ITS Cost Data Repository at Mitretek Systems*, Mitretek Systems, November 1998

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

[11]Mitretek Systems, *Building the ITI: Putting the National Architecture into Action*, FHWA, April 1996

[12]TransCore, Appendix E to Draft Version of *ITS Planning Handbook*, January 1996, unpublished

[13]CH2M Hill, *Seattle ITS Case Study*, Alternative Cost Estimate Spreadsheets, under contract to Mitretek Systems, January 1998

Table C-1 (in appendix C) shows the unit cost estimates that were made by the three sources (which are identified in footnotes 1, 12, and 13). For many of the cost elements, the two recent sources continued to use the original FHWA unit costs. Often this occurred for a cost element's capital costs, with a change in the rule of thumb used for the O&M costs (e.g., 15% of capital costs, instead of 5%).

Upon observing all of the cost elements that now populated Table C-1, Mitretek decided to restructure the groupings of the elements. A major reason for this had to do with the way that freeway and arterial-related elements were placed in the original tables. *Surveillance* elements for both freeways and arterials were grouped together in Tables 2-1 and C-1, as were the *communications* elements for both. Arterial and freeway *control* elements were grouped together under traveler information.[14] With the new categorization, the freeway and arterial related elements were separated from each other, and arterial and freeway control groups were added.

The new categorization makes clearer what cost elements should be introduced for a new corridor, or area-wide project. It will facilitate the addition of new cost data sources, as will be seen in subsequent tables. The new categorization also will assist evaluators who compare the costs and benefits connected with a single ITS improvement, or group of improvements. For example, benefits of freeway services are usually analyzed separately from benefits of arterial ITS services.

Table 3-1 shows the synthesis that was performed for the unit cost estimates from the three sources described in Table C-1. These costs were changed from the original FHWA estimates whenever either of the other two more recent estimates differed from the original. Often, simple averages were used. The actual rules used are indicated in the table.

Table 3-1 not only contains revised unit costs for many of the cost elements in Table 2-1, it also contains *unit costs for the additional cost elements that were introduced in references 12 or 13.* These additional cost elements are designated as [NEW] in Table 3-1, and *will be discussed in Section 3B.*

The updated unit costs from Table 3-1 are input into the original FHWA table, Table B-1, producing new national estimates, as shown in Table C-2. Note that Table C-2 includes the complete list of updated cost elements, similar to Table 3-1.

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[14] In fact, new signal control and freeway control categories had been utilized in Table C-1, as compared to Table 2-1. However, it appeared that there would still be accounting difficulties when the cost elements from the two new sources were introduced. Hence more extensive changes to the taxonomy were made.

Table 3-1
Synthesis of Cost Elements and Unit Costs Based On
Core Infrastructure, TransCore, and CH2M Hill

ELEMENTS	UNIT COST CAPITOL ($K)	SOURCE OF REVISED CAPITAL COSTS C = Core; T = TransCore; S = Seattle; M = Mitretek; AV. = Average; AV3 = AV. of C, T, S	UNIT COST O & M ($K)	SOURCE OF REVISED O&M COSTS 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	T,C, 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	AV. 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

Table 3-1
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
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
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 [DELETE]	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	

The cost elements whose unit cost changes produced the *largest changes in the generic large area capital costs* between Tables B-1 and C-1 are listed here, along with their impacts[15]:

- Loop detectors: From $32 M to $44M
- Twisted pair wire to signals: From $25M to $37.5M
- Fiber optic cable on freeways: From $96M to $106M
- System Design for Electronic Fare Payment: From $16M to $5.4M

To assist the reader in comparing the new estimates with the original FHWA ones, Table 3-2 provides a *comparison of two different summary cost statistics* -- one set from Table B-1, which was estimated by FHWA in 1995, and the other that occurs when the *revised* unit costs of Table 3-1 are used. (Note that only the *revised* unit costs are considered here, not the ones designated as [NEW]).

Table 3-2
Comparison of Summary Costs: FHWA Core Infrastructure Costs vs. Updated Unit Costs

Geographic Descriptor	Original Capital Costs	Updated Capital Costs	*% Change Capital Costs*	Original Annual O&M Costs	Updated Annual O&M Costs	*% Change Annual O&M Costs*
Generic Large Area	$420M	$425M	*1%*	$44M	$48M	*9%*
Generic Medium Area	$278M	$284M	*2%*	$26	$28M	*11%*
Generic Small Area	$41M	$42M	*4%*	$4M	$4M	*11%*
Large Areas	$31.5B	$31.8B	*1%*	$3.3B	$3.6B	*10%*
Medium Areas	$34.8B	$35.4B	*2%*	$3.2B	$3.4B	*11%*
Small Areas	$8.2B	$8.5B	*4%*	$0.8B	$0.9B	*16%*
National Total	$74.4B	$75.7B	*2%*	$7.3B	$7.9B	*11%*

Note: Numbers are rounded

This table shows that with the revised estimates of unit costs (and all other factors left unchanged), the national-level capital costs increase by about 2%, and annual O&M costs by about 11%. These differences are relatively small, compared to the ones which will be presented in the remainder of Section 3.

[15]It may be somewhat difficult to trace these changes since the categorizations change.

3B. Changes to the Cost Elements

There were several changes made to the *cost elements* by the two newer cost reports. These changes fell into three classes. First were cost elements that were *added* to the FHWA list. Second were *disaggregation*s of FHWA cost elements. For example, a variable message sign element was disaggregated into the sign, itself, and the supporting structure. Many disaggregations were used here, because they made the physical and operational makeup of the cost elements clearer. The last change was *deleting* cost elements.

Table 3-1, which was first introduced in Section 3A., listed *all of the cost elements* that have been identified in *any of the three relevant reports*. The elements fall into one of these classes:

- Those elements with unchanged unit costs
- Those elements with updated unit costs
- Those elements that were added to the original FHWA list, identified as [NEW]
- Those that have been deleted from the FHWA list, identified as [DELETED]

Table 3-1 also identified the *unit costs*, and the *source(s*) of the new costs. A list of all of the cost elements, along with the quantities that have been selected, is provided in Table 3-3.

During the updating, Mitretek worked to ensure that unnecessary redundancy, or double-counting, was not introduced in the quantities of any of the cost elements, due to of differences in the element descriptions in the three source documents. This was particularly applied to the surveillance processing and communications elements.

As an example of this effort, consider leased communications services, which were a major category of cost elements that were identified as [NEW] in Table 3-1. Estimates of unit costs for the leased lines are provided in that table. However, to prevent double-counting of owned and leased communications lines when estimating metropolitan costs, the quantity of leased lines was set to zero in the following analyses, and only owned lines are counted, as shown in Table 3-3. Obviously, many actual areas will choose leased lines instead of, or in addition to, owned lines. But, for simplicity, only one type is assumed throughout this report.

Table 3-3

Updated List of ITS Cost Elements and Quantities for Large, Medium and Small SMAs

ELEMENTS	QUANTITY LARGE SMAs	QUANTITY MEDIUM SMAs	QUANTITY SMALL SMAs
SURVEILLANCE - ARTERIALS			
Loop Detectors per signal per approach lane	30,000	15,000	500
Other arterial loop detectors	3,600	6,400	600
Overhead Point Detectors [NEW]	0	0	0
Processor (170 series), 1 per direction per half mile (Arterials) [NEW]	10,000	4,000	200
CCTV Cameras per signalized intersection	250	150	60
CCTV pole and foundation [NEW]	250	150	60
Video Image Processing/intersection	250	150	0
AVI equip. to identify priority veh./intersection [NEW]	2500	1500	50
AVL equip (to supplement GPS)/site [NEW]	3	0	0
SURVEILLANCE - FREEWAYS			
Loop Detectors per fwy lane per half mile	6,400	3,600	400
Overhead Point Detectors [NEW]	0	0	0
Data Station (Fwy), 1 per half mile [NEW]	800	600	100
CCTV Cameras per freeway mile	400	300	50
CCTV pole and foundation [NEW]	400	300	50
Emissions & Environmental Sensors	100	70	20
COMMUNICATION - ARTERIALS			
Twisted-pair to Signals (per intersection)	2500	1500	50
Wireless radio [NEW]	0	0	0
Leased line to signals [NEW]	0	0	0
Leased line to video [NEW]	0	0	0
COMMUNICATION - FREEWAYS			
Fiber-Optic Cable/ freeway mile	400	300	50
Fiber-optic hub - 1 per 5 mi. of fiber [NEW]	0	0	0
Leased line to video [NEW]	0	0	0
TRAFFIC SIGNAL CONTROL			
Central Computer System (Closed Loop) NEW	0	0	0
Central Computer System (Distributed) NEW	0	0	0
Master controllers for distributed system (1 per 25 intersections) [NEW]	100	60	2
Signal controller replacement per intersection [NEW]	0	0	0
Signal controller upgrade (per intersection)	2500	1500	50
Signal Preemption: Transit, Emergency Vehicle, RR [NEW]	125	0	0
FREEWAY MANAGEMENT @ ROADSIDE			
HOV lane control & monitoring equip.	10	8	0
Ramp Meter Systems (per interchange)	400	300	0
TRAVELER INFORMATION @ ROADSIDE/SITE			
Full Matrix VMS & Controllers (without structure)	100	75	25
Overhead Structure[Separated out]	100	75	25
Hybrid VMS with structure (Arterials)	100	80	0
Fixed HAR & Controllers	10	7	2
Callboxes: each direction per half-mile	1600	1200	0
Kiosks	200	150	50
INCIDENT MANAGEMENT EQUIPMENT			
Portable VMS	15	10	10
Portable HAR	10	5	3
Special Pickup Trucks (w. Dynamic Route Guidance)	40	25	0
O & M Personnel	40	30	5

Table 3-3

Updated List of ITS Cost Elements and Quantities for Large, Medium and Small SMAs

ELEMENTS	QUANTITY LARGE SMAs	QUANTITY MEDIUM SMAs	QUANTITY SMALL SMAs
TRANSPORTATION MGMT CTRS (Number per metro area)	6	4	1
Central Dispatch/Routing Equip (I per area) [NEW]	1	1	0
Computers & Hardware/TMC	100%	80%	70%
Software (various)/TMC	1	1	1
Facilities & Communications/TMC	100%	80%	70%
O & M Personnel/TMC	36	24	15
TRAVELER INFORMATION CENTER			
Computers and Hardware	100%	80%	70%
Software (various)	1	1	1
Facilities & Communication (stand-alone)	100%	80%	70%
O & M Personnel	30	25	10
EMERGENCY RESPONSE CENTER			
Computers & Hardware	100%	80%	70%
Software (various)	1	1	1
Facilities & Communications (stand-alone)	1	0.8	0.7
O & M Personnel	3	2	1
EMERGENCY SERVICES EQUIPMENT			
Cellular radio, comm. services per vehicle	3300	2500	500
TRANSIT MANAGEMENT CENTER			
Computers & Hardware	100%	80%	70%
Software (various)	1	1	1
Facilities & Communication (stand-alone)	100%	80%	70%
O & M Personnel	3	2	1
TRANSIT VEHICLE INTERFACES			
Cellular radio, display, etc per vehicle	2000	1200	100
AVI Transponder (on Signal Priority routes) [NEW]	0	0	0
In-vehicle AVL equip. per vehicle [NEW]	0	0	0
ELECTRONIC FARE PAYMENT SYSTEM			
In Transit Mgmt Center			
Central Computer System	1	1	0
Training & Documentation	1	1	0
At ticketing site			
Station Controller [DELETE]	65	35	0
Ticket Office Machine & Validator	100	80	0
Ticket Vending Machines	500	300	0
Turnstile [DELETE]	600	400	0
On Transit Vehicles			
Bus Farebox	2000	1200	0
Smart Card	2,000,000	1,000,000	0
Sys Engineering. Etc. [MOVED]			
ELECTRONIC TOLL COLLECTION SYSTEM			
AVI Plaza Computer equipment	20	10	0
Manual AVI (per lane)	30	10	0
Automatic AVI (per lane)	15	5	0
Manual Automatic AVI (per lane)	15	5	0
AVI Dedicated (per lane)	30	10	0
Express AVI (per lane)	30	10	0
SYS DESIGN & INTEGRATION			
TMC, TIC, EMC, Transit MC	100%	80%	70%
Electronic Fare Payment System	100%	60%	0%

The results of adding and deleting the new *cost elements* to Table C-2 are shown in Table C-3. The added or deleted cost elements that produced the *largest changes in the generic large area capital costs* between Tables C-2 and C-3 are listed here, with their impacts:

- AVI equipment to identify priority vehicles at intersections — $82M[16]
- Processor (170 series) on arterials — $62M
- Data stations on freeways — $20M
- Turnstiles for automatic fare payment — -$16M

The summary information from Table C-2 is shown in Table 3-4, which compares the effect of updating the unit cost and the cost elements with updating the unit costs, alone.

Table 3-4
Comparison of Summary Costs:
Updated Unit Costs and Cost Elements vs. Updated Unit Costs, Alone

Geographic Descriptor	Capital Costs: Updated Unit Costs	Capital Costs: Updated Unit Costs & Cost Elements	*% Difference*	Annual O&M Costs: Updated Unit Costs	Annual O&M Costs: Updated Unit Costs & Cost Elements	*% Difference*
Generic Large Area	$425M	$589M	*39%*	$48M	$58M	*21%*
Generic Medium Area	$284M	$372M	*31%*	$28M	$33M	*20%*
Generic Small Area	$42M	$50M	*18%*	$4M	$5M	*8%*
Large Areas	$31.8B	$44.2B	*39%*	$3.6B	$4.3B	*21%*
Medium Areas	$35.4B	$46.5B	*31%*	$3.4B	$4.1B	*20%*
Small Areas	$8.5B	$9.9B	*17%*	$0.9B	$1.0B	*8%*
National Total	$75.7M	$100.6B	*33%*	$7.9M	$9.4B	*19%*

Note: Numbers are rounded

This table shows that *updating the list of ITS cost elements* increases the national-level capital costs by about 33%, and annual O&M costs by about 19%. Hence, updating the list of costed elements has a much larger effect than changing the unit costs.

[16] The $82M for AVI equipment at intersections, and $62M for 170 series processors on arterials are based on assumption of extensive deployment for each ITS element.

3C. Changes to the Number of Metropolitan Areas in Each of the Three Size Groups

Of the reports that have been referenced so far, only the 1995 FHWA analysis[17] has made an estimate of national ITS infrastructure costs. However, there is a study by Apogee Associates that did carry out a national-level calculation.[18] For the metropolitan infrastructure investment part of their analysis, they took their unit costs from the National ITS Architecture, and then used the approach in the FHWA's Core Infrastructure Report to factor up to national totals. In essence, Apogee carried out the same seven steps that were described in Section 2, even though they used different cost elements and unit costs. For them, steps #2 and #3 were based on the National Architecture; these cost estimates were not utilized in this current paper because of their detail, as mentioned in Section 3A.

Apogee's treatment of step #4, where they determined the number of Metropolitan Statistical Areas (MSAs)in each of the three size classes, produced some significantly different results from the FHWA paper. Using the same size class definitions, Apogee listed the MSAs that fell into each of the three size classes[19]. They found fewer areas in each of the three classes than did the FHWA, as shown in Table 3-5. Mitretek's check of a list of the MSAs from the Bureau of Census indicated that the Apogee list should be used.

Table 3-5
Number of Metropolitan Statistical Areas (MSAs) by Size Category

Source	Large MSAs	Medium MSAs	Small MSAs
FHWA	75	125	200
Apogee	60	105	132

Using the Apogee figures for the numbers of MSAs, the ITS costs change, as shown in Table C-3, and the summary costs change as shown in Table 3-6.

The incremental effect of reducing the number of metropolitan areas to the levels used by Apogee is fairly large, with estimates for both capital and O&M costs at the national level *dropping 20 percent*. Note that there is no incremental change to the estimate for each generic area when the only variables being modified are the *number of areas*. Note, also, that except for rounding errors, O&M costs are reduced by the same percentage as are capital costs.

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[17] FHWA, 1995, ibid.

[18] Apogee Associates, *Final Report: ITS National Investment and Market Analysis*, ITS America, May 1997

[19] For counts, see Apogee Associates, ibid. Table 3.1 on page 37. For the lists of MSAs, see Apogee Associates, *Task C – Identification of Investment Requirements, ITS National Investment and Market Analysis*, ITS America, May 1997

Table 3-6
Comparison of Summary Costs: Addition of Updated Number of Metropolitan Statistical Areas (MSAs) to Updated Unit Costs and Cost Elements

Geographic Descriptor	Capital Costs: Changed Unit Costs And Cost Elements	Capital Costs: Plus Addition of Updated Number of MSAs	*% Difference*	Annual O&M Costs: Updated Unit Costs & Cost Elements	Annual O&M Costs: Plus Addition of Updated No. of MSAs	*% Difference*
Generic Large Area	$589M	$589M	*0%*	$58M	$58M	*0%*
Generic Medium Area	$372M	$372M	*0%*	$33M	$33M	*0%*
Generic Small Area	$50M	$50M	*0%*	$4.8M	$4.8M	*0%*
Large Areas	$44.2B	$35.3B	*-20%*	$4.3B	$3.5B	*-20%*
Medium Areas	$46.5B	$39.1B	*-16%*	$4.1B	$3.5B	*-16%*
Small Areas	$9.9B	$6.6B	*-34%*	$0.96B	$0.63B	*-34%*
National Total	$100.6B	$80.9B	*-20%*	$9.4M	$7.6B	*-20%*

Note: Numbers are rounded

3D. Changes to Market Penetration in Base Year

It is very important to recognize and *account for previous ITS investments* in making estimates of the *additional expenditures that still must be made*. To account for these prior expenditures, we must have the *market penetration for the various cost elements for the current time period*. Until recently, there were no data that could be used to estimate current market penetration for ITS infrastructure elements. Therefore, the national estimates by both FHWA and Apogee, and the other reports that have been referenced, have all used 0% for this parameter.

However, the FHWA has supported a data collection and analysis effort, which has now produced national-level estimates for the deployment percentages of the infrastructure elements in 1997. The estimates are based on data collected from *78 of the nation's largest* metropolitan areas, by the Oak Ridge National Laboratory (ORNL)[20]. Deployment tracking boundaries were defined to be coincident with planning area boundaries established by the Metropolitan Planning

[20] Gordon, Steve, and Trombly, Jeffrey, *Tracking the Deployment of the Integrated Metropolitan ITS Infrastructure in the USA: FY 1997 Results*, Report FHWA-JPO-99-001, September 1998

Organizations (MPOs). The 1997 *deployment percentages* can be factored into the cost tables to produce estimates of the *percentages of the needed capital investment that has already been spent*, and thus can be subtracted from the total needed capital to provide estimates of the investments that must still be made.

Since the ORNL survey only addressed the metropolitan areas in the FHWA's *large size class*[21], a "quick and dirty" method was used by Mitretek to get deployment estimates for the medium and small classes. The ORNL report divided the 78 largest areas into three size classes. By examining the *trend*s in the estimated deployment percentages for ORNL's three groups, and then *extrapolating*, estimates of market penetration percentages were produced for the FHWA's medium size-class. Then the metropolitan-wide ratios between the FHWA's medium and large percentages that were obtained were applied to the ratio of FHWA's small to medium size classes.

The effects on the detailed cost estimates of using the ORNL survey data are shown in Table C-5. The columns in this table are defined as follows:

- Two columns of numbers – CAPITAL COST LARGE, and CAPITAL COST MEDIUM -- are reproduced from Table C-4.
- Two columns – % DEPLOYMENT BY 1997 LARGE and % DEPLOYMENT BY 1997 MEDIUM -- have been estimated from the figures in reference 20.
- Two columns – CAP COST EXPENDED BY '97 LARGE and CAP COST EXPENDED BY '97 MEDIUM are the products of the two columns for large, and the two columns for medium, respectively. These columns give the estimated dollar expenditure on ITS metropolitan deployment through 1997.
- The final two columns -- UPDATED CAP COST LARGE and UPDATED CAP COST MEDIUM -- provide estimates of the remaining investment needed for large and medium areas, respectively.

Estimates for small metro areas have not been made for the individual cost elements, because of the informal estimating process that was used.

Moving some of the capital expenditures to a period earlier than the present makes those costs sunk costs, and hence they are excluded from the estimates of future capital costs. However, this change does not affect the estimates for annual O&M costs for future years. The O&M costs for

[21]FHWA had 75 MSAs in their "large" category, while Apogee had 60 MSAs, and ORNL had 78 metropolitan areas. FHWA and Apogee used the *Census Bureau's* MSA boundaries and populations, while ORNL used *MPO* boundaries and populations. Developing 1997 deployment estimates for the MSA boundaries would probably not make major changes on the results in the current paper, due to basing the costs on *generic metropolitan areas.*

all of ITS capital costs must still be included in the future year estimates.[22] Hence, the estimates for *annual O&M costs remain unchanged*, when the market penetration for the current time period is factored in. The results are shown in Table C-5.

The comparison of the new summary cost measures with those in Table 3-6 are shown in Table 3-7. The table indicates that about 15 percent of the needed capital cost for ITS for large metropolitan areas was expended by 1997, and that approximately 10 percent for the 300 largest was expended by 1997.

By comparing the detailed estimates in Table C-5 with those in Table C-4, it can be determined which cost elements have the largest reduction in future costs due to taking into account the investments that have already occurred. However, since some of the estimates in Table C-5 are only for the cost element groups, or categories, the group-level will be used for this reporting. The ITS infrastructure groups with the largest reductions in estimates of future Generic Large Area Capital Costs are as follows:

- Arterial Roadside Communications — Reduction of $17M
- Electronic Fare Payment — Reduction of $15M
- Freeway Roadside Communications — Reduction of $10M

Detailed cost elements in each of these three infrastructure groups have been identified in the sections earlier as having major impacts from some of the updated estimates.

[22] The annual O&M cost estimates are for a period *after all of the ITS capital costs have been made*. In the near future, the annual O&M costs will grow, year by year, as the ITS deployments are completed, and become operational.

Table 3-7
Comparison of Full Deployment Summary Costs:
With and Without Addition of ORNL 1997 Deployment Levels

Geographic Descriptor	Capital Costs: Without ORNL 1997 Deployment Levels	Capital Costs: With ORNL 1997 Deployment Levels	*% Difference*	Annual O&M Costs: Unchanged by 1997 Deployment Levels
Generic Large Area	$589M	$502M	*-15%*	$58M
Generic Medium Area	$372M	$347M	*-7%*	$33M
Generic Small Area	$49.8M	$48.3M	*-3%*	$4.8M
Large Areas	$35.3B	$30.1B	*-15%*	$3.5B
Medium Areas	$39.1B	$36.5B	*-7%*	$3.5B
Small Areas	$6.6B	$6.4B	*-3%*	$0.63B
National Total	$80.9B	$73.0B	*-10%*	$7.6M

Note: Numbers are rounded

SECTION 4. ALTERNATIVE VALUES OF FULL MARKET PENETRATION

Earlier, in Section 3D, the recent availability of *current* market penetration estimates for ITS infrastructure was discussed, and these data were used to reduce the estimates of still-needed investments. There is a similar requirement to correctly determine the *maximum* amount of needed infrastructure investment. This is defined in Section 2 as step 6 in the cost estimation process. Several concepts for this maximum level have been proposed:

- The absolute maximum amount that *could be deployed*, limited only by the ability to differentiate the level of detail in the information provided
- The amount that a transportation engineer would determine *should be deployed* based upon good engineering practices, such as meeting certain traffic operation criteria
- The amount that an economic analyst would determine *should be deployed*, based on costs and benefits to travelers and others
- The amount that can be deployed based on budgetary limitations and competition of funds with non-ITS transportation solutions

There have been no data or analyses thus far to determine the level of deployment that any of these definitions would imply. However, it is believed that the full deployment levels used in the currently referenced reports generally correspond to the first bullet above, namely, the maximum amount that *could* be deployed. The other bullets correspond to lower levels of deployment.

To show how the level of full deployment might affect the estimate of investment needs, a simple *parametric analysis* of the values for full market penetration has been performed for this working paper. The analysis is carried out *only for the generic large and medium areas*. No areal aggregations are included.

This analysis has used different constant values for *all* cost elements for the percent that the “should” deployment levels might be of the”could”level. The three values are 50%, 67%, and 80%. The 100% level is also included, and is defined, using the terminology in the first bullet, as the “could” case, while the lower percentages are defined as possible “should” cases, as in the other bullets.

The approach for calculating the results for these various cases is to start with information in Table C-5, and then add the appropriate constant value for the “Should” Full-Deployment Percentage.

A simplified version of this calculation has been carried out using only the first-level cost elements (with the second level cost elements deleted). The resultant table -- with the should level being set equal to 80% of the could level -- is shown as Table 4-1. Table 4-1 uses the first-level values of the percent deployed by 1997 from Table 3-5. These vary for the generic large area from 0% up to 46%. By carrying out the calculations and obtaining the sums for the two columns that show the Capital Cost for 80% of (Could Case-1997), it can be seen that $384 million is obtained for the large area, and $273 million for the medium area.

Table 4-1
Effect of Setting Full Deployment at 80% of "Could" Case for Generic Large and Medium Areas

Major ITS Cost Elements	GENERIC LARGE METRO AREA					GENERIC MEDIUM METRO AREA				
	Capital Cost for Could Case ($K)	% Deployed by 1997	Cap Cost Through 1997 ($K)	Should Case Full Deployment = 80% of Could Case	Should Case Full Deployment - 1997 Deployment	Capital Cost for Could Case ($K)	% Deployed by 1997	Cap Cost Through 1997 ($K)	Should Case Full Deployment = 80% of Could Case	Full Deployment - 1997 Deployment
SURVEILLANCE - ARTERIALS	$203,535	3%	$5,181	$162,828	$157,647	$110,490	1%	$971	$88,392	$87,421
SURVEILLANCE - FREEWAYS	$44,640	14%	$6,145	$35,712	$29,567	$32,140	2%	$569	$25,712	$25,143
COMMUNICATION - ARTERIALS	$37,500	46%	$17,256	$30,000	$12,744	$22,500	40%	$9,005	$18,000	$8,995
COMMUNICATION - FREEWAYS	$106,000	9%	$9,540	$84,800	$75,260	$79,500	3%	$2,385	$63,600	$61,215
TRAFFIC SIGNAL CONTROL	$13,750	46%	$6,325	$11,000	$4,675	$8,100	40%	$3,240	$6,480	$3,240
Freeway Management @ Roadside	$16,500	13%	$2,145	$13,200	$11,055	$12,500	1%	$125	$10,000	$9,875
Traveler Information @ Roadside	$31,900	22%	$7,018	$25,520	$18,502	$24,015	9%	$2,161	$19,212	$17,051
INCIDENT MANAGEMENT EQUIPMENT	$3,050	31%	$946	$2,440	$1,495	$1,875	5%	$94	$1,500	$1,406
TRANSPORTATION MGMT CENTERS	$30,000	17%	$5,100	$24,000	$18,900	$16,456	5%	$823	$13,165	$12,342
TRAVELER INFORMATION CENTER	$4,402	0%	$0	$3,522	$3,522	$3,582	0%	$0	$2,865	$2,865
EMERGENCY RESPONSE CENTER	$4,470	43%	$1,922	$3,576	$1,654	$3,590	40%	$1,436	$2,872	$1,436
EMERGENCY SERVICES EQUIPMENT	$990	43%	$426	$792	$366	$750	40%	$300	$600	$300
TRANSIT MANAGEMENT CENTER	$4,460	23%	$1,026	$3,568	$2,542	$3,592	2%	$72	$2,874	$2,802
TRANSIT VEHICLE INTERFACES	$12,600	16%	$2,016	$10,080	$8,064	$7,560	5%	$378	$6,048	$5,670
ELECTRONIC FARE PAYMENT SYS	$55,520	27%	$14,916	$44,416	$29,500	$34,432	4%	$1,377	$27,546	$26,168
ELECTRONIC TOLL COLLECTION SYS	$8,675	36%	$3,123	$6,940	$3,817	$3,325	36%	$1,197	$2,660	$1,463
SYS DESIGN & INTEGRATION	$10,800	40%	$4,320	$8,640	$4,320	$7,560	7%	$518	$6,048	$5,530
TOTAL PER METRO AREA	**$588,792**		**$87,404**	**$471,034**	**$383,630**	**$371,967**		**$24,651**	**$297,573**	**$272,922**
Derived Percentage of Could Case Capital Cost Expended Through 1997		**14.8%**					**6.6%**			
Aggregate Level Calculations Using Derived Percentage	$588,792	**14.8%**	$87,404	$471,034	$383,630	$371,967	**6.6%**	$24,651	$297,573	$272,922

Until the calculations for this table were actually completed, the 1997 percent deployed *for the entire deployment was not known*, because it depends upon the relative costs (weights) of the different cost elements. However, these values could be calculated after the table was completed, and the values of *14.8% for the large area* and *6.6% for the medium area* were obtained[23].

It can be shown algebraically that as long as the percent for the "Should" Case is larger than the largest value for the 1997 percent deployment shown in Table C-5 (this largest value is 46%), then the calculation shown in Table 4-1 can be carried out at an aggregate level, as indicated in the last row of Table 4-1. These calculations use the 14.8% and 6.6% values that were obtained as discussed in the above paragraph.

Hence, the calculations for the other values for the should case (100%, 67%, and 50%) can be carried out at the aggregate level, and they produce the results shown in Table 4-2 and Figure 4-1.

Table 4-2 and Figure 4-1 show, for example, that if the "Should" deployment levels are found to be 67% of the Could levels, then the generic large area would only need $393 million, instead of $589 million. Furthermore, if we take into account that, $87.4 million of the "should" case full deployment has already occurred, then only $305 million would be required..

Hence, it can be seen that making an estimate of the investment needed at the national level depends quite heavily on the values estimated for the Should Case and Base Case (1997) deployment levels. Of course, it is likely, that these values will vary, not only by cost element, but also according to the geography and transportation networks of each specific area.

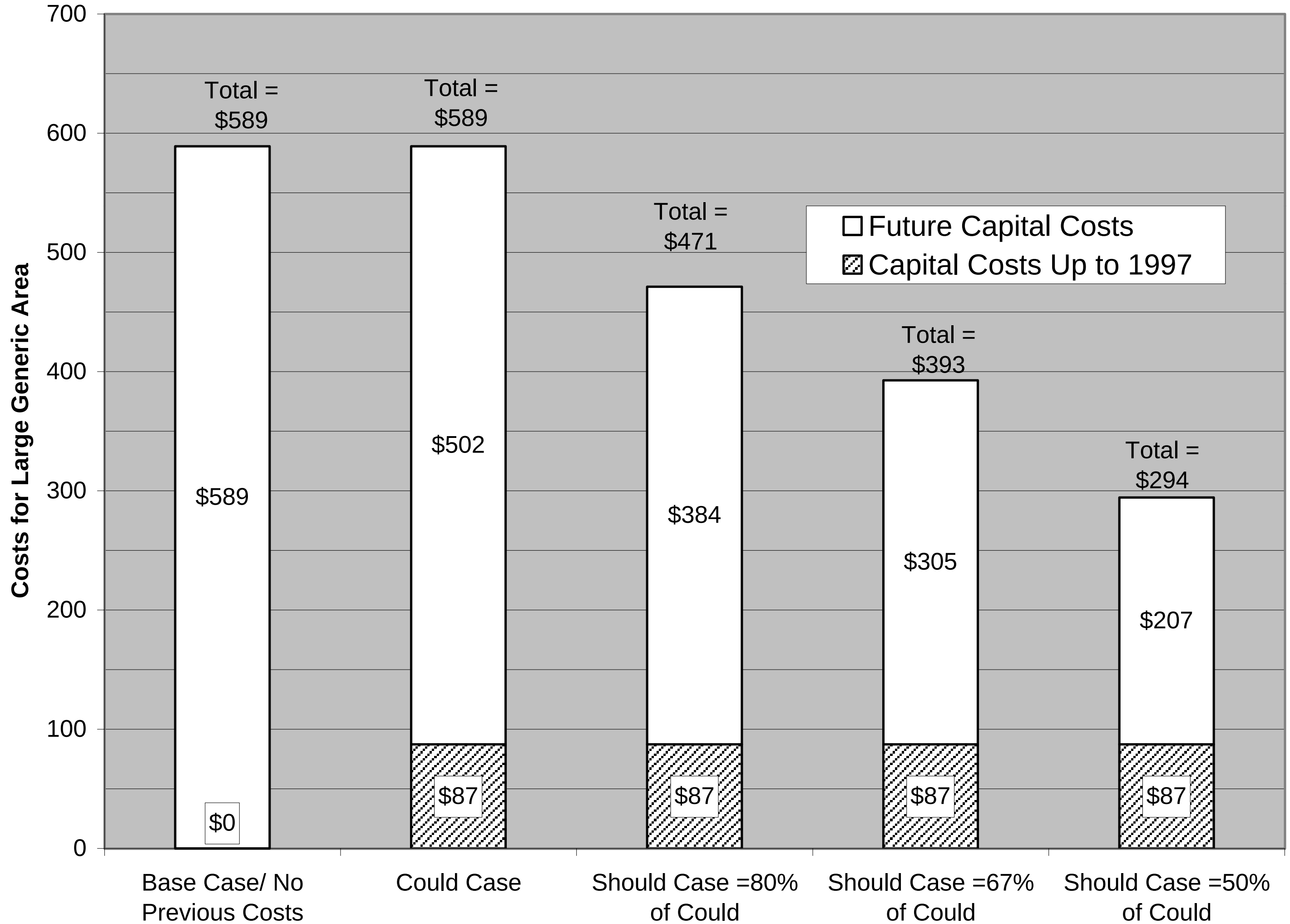
[23] The 14.8% value differs from the 14.7% at the end of Table C-5, because the calculation in this section was carried out with the simplified version of the list of cost elements.

Table 4-2
Parametric Analysis of Changing From the "Could" Case Full Deployment Level to Various "Should" Cases
For the Generic Large and Medium Areas

GENERIC LARGE METRO AREA							GENERIC MEDIUM METRO AREA					
Capital Cost for "Could" Case Full Deploy-ment ($M)	% Deployed Through 1997	Cap Cost Through 1997 ($M)	Parametrically Selected "Should" Case Cap Costs as % of "Could" Case	Capital Cost for "Should" Case Deploy-ment ($M)	**Should Case Cap Cost - 1997 Cap Cost ($M)**	("Should" Case - '97) Cap Cost as % of "Could" Case Cap Cost	Capital Cost for "Could" Case Full Deploy-ment ($M)	% Deployed Through 1997	Cap Cost Through 1997 ($M)	Parametrically Selected "Should" Case Cap Costs as % of "Could" Case	Capital Cost for "Should" Case Deploy-ment ($M)	**Should Case Cap Cost - 1997 Cap Cost ($M)**
$589	14.8%	$87	*100%*	$589	**$502**	85%	$372	6.6%	$25	*100%*	$372	$347
$589	14.8%	$87	*80%*	$471	**$384**	65%	$372	6.6%	$25	*80%*	$298	$273
$589	14.8%	$87	*67%*	$393	**$305**	52%	$372	6.6%	$25	*67%*	$248	$223
$589	14.8%	$87	*50%*	$294	**$207**	35%	$372	6.6%	$25	*50%*	$186	$161

Note: The overall 1997 Deployment Percentages for the Generic Large (14.8%) and Medium Areas (6.6%) are derived in Table 4-1

**Figure 4-1: Future Costs of Full ITS Deployment for the Large Generic Area
A Paramentric Analysis Varying the Definition of Full Deployment and Accounting For Previous (Sunk) Costs ($Millions)**



SECTION 5. CONCLUSIONS AND NEXT STEPS

5A. Conclusions.

The *detailed tables* in Section 3 and Appendix C have presented a significant amount of new information that affects the estimates of national ITS infrastructure costs. Major changes include the introduction of new cost elements, and new values for base-year deployment levels. We have also made changes to unit costs, and to the number of metropolitan areas that fall in different size classes.

These tables also indicate that the number of size classes, the choice of the generic area for each size class, and the geographic boundaries of the metropolitan areas, can all affect the estimate of the national total for metropolitan ITS deployment costs.

Tables 5-1 and 5-2 in this section show the *new values for national ITS deployment costs*, and the impacts of the *various factors* that have been examined*.* in the changes. Table 5-1 shows this information for capital costs and Table 5-2 for O&M costs.

There are fairly large increases in the costs for the three generic geographic areas in both Capital and Annual O&M Costs, however, these are offset by a reduction in the number of metropolitan areas in each size class. The net result is almost no change in total costs. Nationally, the estimate for the capital costs of fully deploying ITS in metropolitan areas has *changed from $74.4 billion to $73.0 billion, a decrease of 2 percent*. The estimate for O&M costs *increased from $7.3 billion to 7.6 billion, or 4 percent.* These changes account for all of the modifications to the cost estimates, which were listed above, except for the modifications to the market size for full deployment.

A different view of the summary data can be taken, where the interest is on the *cost of the 75 largest metropolitan areas.* In this case, the change in the number of MSAs that are considered is ignored, as are the costs for the medium and small areas. These results are shown in Tables 5-3 and 5-4. The capital cost for the top 75 is estimated to *increase by 20 percent*, from $31.5 billion to $37.7 billion. Annual O&M costs for the top 75 areas *increase 33 percent*, from $3.3 billion to $4.3 billion per year.

The major difference between the small changes in Tables 5-1 and 5-2, and the larger ones, in Tables 5-3 and 5-4, is that the first two tables involve a *major decrease in the number of metropolitan areas that are being considered*, while the latter two keep the number of areas constant, at 75.

To summarize, the new numerical results are as follows:

- National capital costs for 300 MSAs $73.0 billion
- National annual O&M costs for 300 MSAs $7.6 billion
- Capital costs for 75 largest MSAs $37.7 billion
- Annual O&M costs for 75 largest MSAs $4.3 billion

Table 5-1
Comparison of 1995 and Final Revised Capital Cost Estimates With Percentage Changes Due to Each Updated Factor

Geo-graphic Descriptor	Capital Costs Estimated in FHWA 1995 Report	% Change Due to Updated Unit Costs	% Change Due to Updated Cost Elements	% Change Due to Updated MSAs	% Change Due to Using 1997 Deploy-ment	Final Revised Capital Costs	Total % Change From FHWA 1995 Report
Generic Large Area	$420M	1	39	0	-15	$502M	20%
Generic Medium Area	$278M	2	31	0	-7	$348M	25%
Generic Small Area	$40.8M	4	18	0	-3	$48.3M	18%
Large Areas	$31.5B	1	39	-20	-15	$30.1B	-4%
Medium Areas	$34.8B	2	31	-16	-7	$36.5B	5%
Small Areas	$8.2B	4	18	-34	-3	$6.4B	-22%
National Total	**$74.4B**	2	33	-20	-12	**$73.0B**	**-2%**

Note: Numbers are rounded

Table 5-2
Comparison of 1995 and Final Revised O&M Cost Estimates
With Percentage Changes Due to Each Updated Factor

Geo-graphic Descriptor	O&M Costs Estimated in FHWA 1995 Report	% Change Due to Updated Unit Costs	% Change Due to Updated Cost Elements	% Change Due to Updated MSAs	% Change Due to Using 1997 Deploy-ment	Final Revised O&M Costs	Total % Change From FHWA 1995 Report
Generic Large Area	$44M	9.5	21	0	0	$58M	33%
Generic Medium Area	$26M	11	20	0	0	$33M	27%
Generic Small Area	$4M	11	8	0	0	$5M	25%
Large Areas	$3.3B	9.5	21	-20	0	$3.5B	6%
Medium Areas	$3.2B	11	20	-16	0	$3.5B	9%
Small Areas	$0.8B	16	8	-33	0	$0.64B	-20%
National Total	**$7.3B**	11	19	-20	0	**$7.6B**	**4%**

Note: Numbers are rounded

Table 5-3
For 75 Large Metropolitan Statistical Areas (SMAs): Comparison of 1995 and Final Revised Capital Cost Estimates With Percentage Changes Due to Each Updated Factor

Geographic Descriptor	Capital Costs Estimated in FHWA 1995 Report	% Change Due to Updated Unit Costs	% Change Due to Updated Cost Elements	% Change Due to Using 1997 Deployment	Final Revised Capital Costs	Total % Change From FHWA 1995 Report
Generic Large Area	$420M	1%	39%	-15%	$502M	+20%
75 Large MSAs	$31.5B	1%	39%	-15%	$37.7B	+20%

Note: Numbers are rounded

Table 5-4
For 75 Large Metropolitan Statistical Areas (SMAs): Comparison of 1995 and Final Revised O&M Cost Estimates With Percentage Changes Due to Each Updated Factor

Geographic Descriptor	O&M Costs Estimated in FHWA 1995 Report	% Change Due to Updated Unit Costs	% Change Due to Updated Cost Elements	% Change Due to Using 1997 Deployment	Final Revised O&M Costs	Total % Change From FHWA 1995 Report
Generic Large Area	$43.5M	9.5	21	0	$57.8M	+33%
75 Large MSAs	$3.26B	9.5	21	0	$4.33B	+33%

Note: Numbers are rounded

To investigate how the level of *full deployment* might affect the estimate of investment needs, a *parametric analysis* was performed for the generic large and medium areas. This analysis was performed for three different constant values – 50%, 67%, and 80% – for the percent that the deployment levels might be of the quantities used in the remainder of the paper. The 100% level was defined as the “could” case, while the lower percentages were defined as possible “should” cases.

For example, for “Should” deployment levels equal to 67% of the Could levels, the generic large area would only need $393 million, on average, instead of $589 million. Furthermore, if we take into account that, on average, 14.8% of the “should” case full deployment has already occurred, then only $334 million would be required. Hence, it can be seen that making an estimate of the investment needed at the national level depends quite heavily on the values estimated for the Should Case and Base Case (1997) deployment levels.

5B. Next Steps

Detailed investigation of two major factors will be carried out to extend this working paper. First will be an assessment of how the market penetration percentages depend on the metropolitan area definitions and their geographic extent.

Second will be further coordination with ORNL and FHWA concerning the ITS deployment tracking data, to ensure that the terminologies used here and in that study are used in a consistent fashion, and that the quantities of ITS infrastructure elements that have been reported are used correctly in the current study.

Based on our examinations of the costing literature, Mitretek will also provide suggestions to FHWA and ORNL on important ITS elements and sub-systems to add to the next ITS deployment survey.

As more ITS cost information becomes available, the unit cost estimates will be updated, allowing this paper to be revised as appropriate.

APPENDIX A
ASSUMPTIONS FOR THE CORE INFRASTRUCTURE COST ESTIMATE
AUGUST 1995

The following document contains the assumptions necessary to develop representative costs to deploy a core infrastructure of Intelligent Transportation Systems (ITS) strategies. Some elements (i.e., surveillance, communication, emergency vehicle management) do not lend themselves to a one-to-one correspondence with the seven core infrastructure areas but are listed under the most logical areas. To obtain the cost figures, information from systems in Texas, Virginia, Massachusetts, Washington, Georgia, Minnesota, Maryland, Delaware and California was gathered and discussions with experts in the area of traffic management systems were held. In the attached spreadsheet, the cost for deploying various ITS strategies nationwide is also estimated. The costs are a "worst case scenario" (unless otherwise noted) and reflect areas that are assumed to have no existing infrastructure. In this manner, areas with an existing infrastructure may scale back their costs accordingly. The general assumptions for each size (large, medium, and small) of metropolitan system follow.

Before the assumptions are discussed, it should be mentioned that technology for traffic management strategies is in a state of continual advancement. As technological advancements are made, technologies which were once considered state-of-the-art will be considered state-of-the-practice, and competition will adjust the costs accordingly. For example, as the use of non-intrusive detection methods (i.e., video image processing, acoustic detection, infrared technology) increases, the use of pavement loop detectors will decrease. This document represents state-of-the practice technologies (and their associated costs) which could instrument a core infrastructure of ITS technologies if they were procured and deployed in 1995.

DEFINITIONS

Capital costs refer to the one-time procurement cost of the elements.

Operations and Maintenance costs are annual costs associated with operating and maintaining the necessary elements. Personnel costs are listed separately and are not included under O&M. Maintenance is 5% of the non-recurring costs, unless otherwise noted, and does not include personnel costs. Maintenance work for surveillance, traveler information, communication, and transportation management centers is done by the same operations and maintenance personnel.

LARGE METROPOLITAN SYSTEM

The large metropolitan area will be the size of Detroit, Michigan with 400 miles of freeway assumed. Interchanges are at 1- mile spacings with all ramps metered. There are 4 lanes in each direction on the large metropolitan area's freeways. There are 12 approach lanes for each signalized intersection. There are assumed to be 2500 signalized intersections. Five additional TMCs (6 total) were included in the costs. For the purposes of this document, metropolitan statistical areas with populations over 750,000 were assumed as large.

MEDIUM METROPOLITAN SYSTEM

The medium metropolitan area will be the size of Knoxville, Tennessee with 300 miles of freeway assumed. Interchanges are at 1-mile spacings with all ramps metered. There are 3 lanes in each direction on the medium metropolitan area's freeways. There are 10 approaches per signalized intersection, and 1500 signalized intersections are assumed. Three additional TMCs (4 total) were included in the costs. For the purposes of this document, metropolitan statistical areas with populations between 200,000 - 750,000 were assumed as medium.

SMALL METROPOLITAN SYSTEM

The small area is the size of Cheyenne, Wyoming with 50 miles of freeway assumed. Interchanges are at 2-mile spacings with no ramps metered. There are 2 lanes in each direction on the small freeways. There are 10 approach lanes for each signalized intersection, and 50 signalized intersections are assumed. For the purposes of this document, metropolitan statistical areas with populations between 50,000 - 200,000 were assumed as small.

GENERAL ASSUMPTIONS

- Freeway mileage is given in centerline miles.
- One center each was assumed for traveler information, emergency management, and transit management. In actuality, some areas may co-locate their facilities.

Computers

The elements under computers include video switches, graphical user interfaces, high capacity storage, cable television access, audio interface, computer monitors, video monitors, video cassette recorder and workstations. The costs for the medium, and small, metropolitan areas were scaled down to 0.8 and 0.7, respectively, of the cost of a large system's computer needs.

Software for the Various Centers is as Follows:

Transportation Management Center (Highway Advisory Radio library, traffic management, automated traffic control, HOV management, lane management, CMS library)
Traveler Information Center (route planning, traffic measurement, data fusion)
Transit Management Center (ride share, transit scheduling, dispatch and fleet management)
Emergency Management Center (emergency management, vehicle tracking)

Communications

This includes the communications equipment internal to the facility such as equipment racks, Sonet System, mulitplexers, modems, etc.

Facilities

The facilities costs were based on purchasing as opposed to leasing space. A building of 23,000 square feet was assumed in the costs for a large system. The costs were scaled accordingly to 0.8 for medium and 0.7 for small. Some of the centers may be co-located.

Field Hardware

- CCTV is at every mile of freeway and at 1/10th of the signalized intersections (trouble spots).
- Environmental Sensors detect road conditions (ice, fog, precipitation, pumping stations, tunnel ventilation, etc.)
- HOV Lane Monitoring and control includes the gates and hardware.
- Loop detectors are placed at half-mile spacings on the freeways across all lanes. They are also placed at every approach lane of signalized intersections and at intermediate locations.
- Call boxes are spaced at half-mile intervals in each direction.
- Video image processing (VIPS) is used at 1/10th of the signalized intersections for the large and medium metropolitan areas.
- Fiber-Optic cable costs include trenching, conduit, installation, and cable.
- Kiosk costs widely vary, depending on the level of integration with various transportation modes, the level of security required, and the type of installation (wall-mounted, free-standing indoor, outdoor). A mid-range system was assumed. Capital costs include procurement of the kiosks, alarms, software adjustments, technical assistance. Annual costs include kiosk and software maintenance, training, leased dedicated phone lines, supplies, and software license fees.

Incident Management Equipment

The vehicles mentioned in this section are pick-up trucks which have the materials necessary to change tires, direct traffic, make minor repairs, provide nominal amounts of fuel, push vehicles from the road, radio for help, and clean up minor accidents from the roads. They are not heavy-duty towing trucks.

System Design & Integration

The costs for system design and integration were based on a large system. The costs for the medium and small areas were scaled accordingly to 0.8 for medium and 0.7 for a small system.

Other

Under "Road Communication," costs are listed as per intersection. These costs include codecs, leased lines, video switches, and interconnection of signal.

Electronic Toll Collection Systems

For large metropolitan areas, 15 lanes are assumed per toll plaza. For medium and small areas, 10 and 6 lanes are assumed, respectively. Large areas have 20 toll plazas and medium and small have 10 and 2, respectively. It is assumed that 40 percent of the lanes in the large and medium toll plazas use AVI technologies. The small metropolitan areas are assumed not to use AVI technology.

Electronic Fare Payment Systems

The cost of proximity (smart) cards and related detection/communication equipment is not high, relatively speaking. Implementing a system, however, requires an extensive equipment base, communications infrastructure, and data processing center. These cost figures assume that the electronic fare payment system is installed on an existing transit infrastructure.

Software allows the smart cards to be used as a conventional stored value card, an employee pass, a discount value card (student or handicapped), a bus transfer, a bus farecard, and a parking lot farecard. As the use of the smart cards expands, additional software will be required to allow account reconciliation between different transportation providers accepting the same card, expanded control measures for a larger card population base, and specific operational requirements for both new and existing users.

APPENDIX B

DETAILED TABLE OF
COST ELEMENTS, UNIT COSTS, FULL DEPLOYMENT SIZE,
AND NATIONAL ITS METROPOLITAN INFRASTRUCTURE COSTS
(AS DESCRIBED IN SECTION 2, FROM FHWA REPORT [REFERENCE 1])

Table B-1
Number of ITS Infrastructure Cost Elements in Each of the Three Size Classes

ELEMENTS	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL
SURVEILLANCE			
Point Detection (loops)	40,000	25000	1500
CCTV Cameras	650	450	110
Video Image Processing/intersection	250	150	0
Environmental Sensors	100	70	40
HOV lane control & monitoring equip.	10	8	0
TRAVELER INFORMATION			
Fixed CMS & Controllers	100	75	25
Fixed HAR & Controllers	10	7	2
Hybrid CMS	100	80	0
Ramp Meter Systems (per interchange)	400	300	0
Signal Upgrades	2500	1500	50
COMMUNICATION			
Callboxes	1600	1200	0
Fiber-Optic Cable/mile	400	300	50
Signal Communication per intersection	2500	1500	50
TMCs	6	4	1
Computers & Hardware/TMC	1	0.8	0.7
Software (various)/TMC	1	1	1
Facilities and Communications/TMC	1	0.8	0.7
O & M Personnel/TMC	36	24	15
TRAVELER INFO CENTERS			
Computers and Hardware	1	0.8	0.7
Software (various)	1	1	1
Facilities & Communication	1	0.8	0.7
Kiosks	200	150	50
O & M Personnel	30	25	10
TRANSIT MANAGEMENT CENTER			
Computers & Hardware	1	0.8	0.7
Software (various)	1	1	1
Facilities & Communication	1	0.8	0.7
O & M Personnel	3	2	1
TRANSIT VEHICLE INTERFACES			
Kiosks, cellular radio, etc per vehicle	2000	1200	100

Table B-1
Number of ITS Infrastructure Cost Elements in Each of the Three Size Classes

ELEMENTS	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL
EMERGENCY MANAGEMENT CENTERS			
Computers & Hardware	1	0.8	0.7
Software (various)	1	1	1
Facilities & Communications	1	0.8	0.7
O & M Personnel	3	2	1
EMERGENCY VEHICLE SERVICES			
Cellular radio, Communications /vehicle	3300	2500	500
INCIDENT MANAGEMENT EQUIPMENT			
Vehicles	40	25	0
Portable HAR	10	5	3
Portable CMS	15	10	10
O & M Personnel	40	30	5
SYSTEM DESIGN & INTEGRATION			
TMC, TIC, EMC, TRANSIT MC	1	0.8	0.7
ELECTRONIC TOLL COLLECTION SYSTEM			
Manual AVI (per lane)	30	10	0
Automatic AVI (per lane)	15	5	0
Manual Automatic AVI (per lane)	15	5	0
AVI Dedicated (per lane)	30	10	0
Express AVI (per lane)	30	10	0
AVI Plaza Computer equipment	20	10	0
ELECTRONIC FARE PAYMENT SYSTEM			
Central Computer System	1	1	0
Ticket Vending Machines	500	300	0
Sys Engr. Program Mgt., Installation	1	0.6	0
Training & Documentation	1	1	0
Bus Farebox	2000	1200	0
Station Controller	65	35	0
Turnstile	600	400	0
Ticket Office Machine & Validator	100	80	0
Smart Card	2,000,000	1,000,000	0

Table B-2
Cost Elements, Unit Costs, Full Deployment Size, and National ITS Metropolitan Infrastructure Costs from FHWA Report (Reference 1)

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

Table B-2
Cost Elements, Unit Costs, Full Deployment Size, and National ITS Metropolitan Infrastructure Costs from FHWA Report (Reference 1)

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

Table B-2

Cost Elements, Unit Costs, Full Deployment Size, and National ITS Metropolitan Infrastructure Costs from FHWA Report (Reference 1)

ELEMENTS	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	UNIT COST O & M ($K)	UNIT COST CAPITOL ($K)	O & M COST LARGE ($K)	CAPITOL LARGE ($K)	O & M COST MEDIUM ($K)	CAPITOL MEDIUM ($K)	O & M COST SMALL ($K)	CAPITOL SMALL ($K)
SUBTOTAL ($K)						7310	8675	2460	3325	0	0
ELECTRONIC FARE PAYMENT SYS											
Central Computer System	1	1	0	150	3000	150	3000	150	3000	0	0
Ticket Vending Machines	500	300	0	3	60	1500	30000	900	18000	0	0
Sys Engr. Program Mgmt, Installation	1	0.6	0	0	16000	0	16000	0	9600	0	0
Training & Documentation	1	1	0	4	80	4	80	4	80	0	0
Bus Farebox	2000	1200	0	0.35	7	700	14000	420	8400	0	0
Station Controller	65	35	0	1	20	65	1300	35	700	0	0
Turnstile	600	400	0	1.375	27.5	825	16500	550	11000	0	0
Ticket Office Machine & Validator	100	80	0	1.22	24.4	122	2440	97.6	1952	0	0
Smart Card	2000000	1000000	0	0.0005	0.01	1000	20000	500	10000	0	0
SUBTOTAL ($K)						4366	103320	2656.6	62732	0	0
TOTAL PER METRO AREA						$43,515	$420,167	$24,825	$278,039	$3,874	$40,753
NUMBER OF LARGE METRO AREAS	75										
NUMBER OF MEDIUM METRO AREAS		125									
NUMBER OF SMALL METRO AREAS			200								
NATIONAL TOTALS FOR EACH SIZE CLASS											
CAPITAL COSTS ($B)							$31.5		$34.8		$8.2
ANNUAL O&M COSTS ($B)						$3.26		$3.10		$0.77	
NATIONAL TOTALS	CAPITAL COSTS ($B)					$74.4					
	ANNUAL O&M COSTS ($B)					$7.14					

APPENDIX C

DETAILED TABLES OF
CHANGES TO COST ELEMENTS, UNIT COSTS, FULL DEPLOYMENT SIZE, AND NATIONAL ITS METROPOLITAN INFRASTRUCTURE COSTS
(AS DESCRIBED IN SECTION 3)

Table C-1: ITS Unit Cost Estimates from Three Sources: Core Infrastructure, TransCore ITS Planning Handbook, and Mitretek ITS Planning Seattle Case Study

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	Seattle 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	Seattle				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	Seattle				0.5
CCTV Cameras/Site	$20	Core			1	
CCTV	$25	TransC, Seattle	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 vehicles/intersection	$40	TransCore	10%	4		
AVI equip. to identify priority vehicles/intersection	$25	Seattle				1.5
AVL equip to supplement GPS/site	$250	TransCore	10%	25		
AVL equip to supplement GPS/site	$300	Seattle				6
COMMUNICATION						
Fiber-Optic Cable/mile	$240	Core			12	
Fiber-Optic Cable/mile	$290	Seattle				0.8
Fiber-Optic Hub (Interchange) (1 per 5 miles of fiber)	$110	Seattle				8
Wireless Radio	$15	TransCore				
Twisted-pair to Signals (per intersection)	$10	Core			0.50	
Twisted-pair to Signals (per intersection)	$19.4	Seattle				
Leased lines to signals	.04/month	TransCore	0%	0		
Leased lines to roadside video	.30/month	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	Seattle				0.5
Coordinated/Adaptive Master (1 per 20-25 Locals)	$10	Seattle				0.5
Signal Controller Upgrade	$5	Core			0.25	
Emergency Vehicle Preemption	$2.0	TransCore				
Transit Vehicle Preemption	$2.0	TransCore				
Railroad Preemption	$0.5	TransCore				
FREEWAY MANAGEMENT						
Ramp Meter System (per interchange)	$40	Core	10%	4	2	
Ramp Meter System (per interchange)	$30	Seattle				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	Seattle				170
Software (various)	$220	Core			11	
Software (various)	$225	Seattle				34
Central Dispatch/Tracking Software (Incident Mgmt.)	$600	Seattle				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	

Table C-1: ITS Unit Cost Estimates from Three Sources: Core Infrastructure, TransCore ITS Planning Handbook, and Mitretek ITS Planning Seattle Case Study

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	Seattle Infrastr. O&M Cost $1,000
Small Area (<250,000 population)	$2,800	Core	15%	420	140	
O & M Personnel		Core			50	
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	Seattle				4
Full Matrix VMS & Controllers (without structure)	$80	TransCore	5%	4		
Mid Range Fixed VMS & Controllers (without structure)	$60	TransCore	5%	3		
Cantilever 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, Seattle	10%	2	1	1
Kiosks	$30	Core			10	
Kiosks	$15	TransCore	10%	1.5		
Kiosks	$18	Seattle				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	Seattle				$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						

Table C-1: ITS Unit Cost Estimates from Three Sources: Core Infrastructure, TransCore ITS Planning Handbook, and Mitretek ITS Planning Seattle Case Study

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	Seattle Infrastr. O&M Cost $1,000
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	Seattle				45
Software (various)	$90	Core			4.5	
Software (various)	$150	Seattle				3
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	160	
Small Area (<250,000 population)	$2,800	Core	15%	420	140	
Facilities & Communication	$500	Seattle				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	Seattle				0.01
In-Vehicle AVL Equipment per vehicle	$9.0	Seattle				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	
System Engr. Program Mgmt, Installation						
TRAVELER SERVICES						
Smart Card (Electronic Fare Payment)	$0.01	Core	0%	0	0	
Pre-Trip Planning Service per subscription	$0	Seattle				0.12
Personal Dynamic Route Guidance per subscription	$0.80	Seattle				0.12

Table C-2
Updated National ITS Metropolitan Infrastructure Costs Based on Updated Unit Costs, Only

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
SURVEILLANCE - ARTERIALS											
Loop Detectors per signal per approach lane	1.10	0.07	30,000	15,000	500	33,000	2160	16500	1080	550	36
Other arterial loop detectors	1.10	0.07	3,600	6,400	600	3960	259.2	7040	460.8	660	43.2
Overhead Point Detectors [NEW]	2.25	0.11	0	0	0						
Processor (170 series), 1 per direction per half mile (Arterials) [NEW]	6.25	0.31	10,000	4,000	200						
CCTV Cameras per signalized intersection	25	1.7	250	150	60	6250	425	3750	255	1500	102
CCTV pole and foundation [NEW]	18	0.9	250	150	60						
Video Image Processing/intersection	40	3	250	150	0	10,000	750	6000	450	0	0
AVI equip. to identify priority veh./intersection [NEW]	33	2.6	2500	1500	50						
AVL equip (to supplement GPS)/site [NEW]	275	16.5	3	0	0						
SUBTOTAL ($K)						$53,210	$3,594	$33,290	$2,246	$2,710	$181
SURVEILLANCE - FREEWAYS											
Loop Detectors per fwy lane per half mile	1.10	0.07	6,400	3,600	400	7040	460.8	3960	259.2	440	28.8
Overhead Point Detectors [NEW]	2.25	0.11	0	0	0						
Data Station (Fwy), 1 per half mile [NEW]	25.00	0.50	800	600	100						
CCTV Cameras per freeway mile	25	1.7	400	300	50	10,000	680	7500	510	1250	85
CCTV pole and foundation [NEW]	18	0.9	400	300	50						
Emissions & Environmental Sensors	4	0.2	100	70	20	400	20	280	14	80	4
SUBTOTAL ($K)						$17,440	$1,161	$11,740	$783	$1,770	$118
COMMUNICATION - ARTERIALS											
Twisted-pair to Signals (per intersection)	15	0.75	2500	1500	50	37,500	1875	22,500	1125	750	37.5
Wireless radio [NEW]	15	?									
Leased line to signals [NEW]	0	0.48									
Leased line to video [NEW]	0	3.6									
SUBTOTAL ($K)						$37,500	$1,875	$22,500	$1,125	$750	$38
COMMUNICATION - FREEWAYS											
Fiber-Optic Cable/ freeway mile	265	13.25	400	300	50	106,000	5300	79,500	3975	13250	662.5
Fiber-optic hub - 1 per 5 mi. of fiber [NEW]	110	8									
Leased line to video [NEW]	0	3.6									
SUBTOTAL ($K)						$106,000	$5,300	$79,500	$3,975	$13,250	$663
TRAFFIC SIGNAL CONTROL											
Central Computer System (Closed Loop) NEW	10	0.5									
Central Computer System (Distributed) NEW	30	1.5									
Master controllers for distributed system (1 per 25 intersections) [NEW]	10	0.5	100	60	2						

Table C-2
Updated National ITS Metropolitan Infrastructure Costs Based on Updated Unit Costs, Only

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
Signal controller replacement per intersection [NEW]	17.5	0.9									
Signal controller upgrade (per intersection)	5	0.25	2500	1500	50	12,500	625	7500	375	250	12.5
Signal Preemption: Transit, Emergency Vehicle, RR [NEW]	2	0.1	125	0	0			0	0	0	0
SUBTOTAL ($K)						$12,500	$625	$7,500	$375	$250	$13
FREEWAY MANAGEMENT @ ROADSIDE											
HOV lane control & monitoring equip.	250	18.8	10	8	0	2500	188	2000	150.4	0	0
Ramp Meter Systems (per interchange)	35	3.5	400	300	0	14,000	1400	10500	1050	0	0
SUBTOTAL ($K)						$16,500	$1,588	$12,500	$1,200	$0	$0
TRAVELER INFORMATION @ ROADSIDE/SITE											
Full Matrix VMS & Controllers (without structure)	70	3.5	100	75	25	7,000	350	5250	262.5	1750	87.5
Overhead Structure[Separated out]	105	5	100	75	25	10,500	500	7875	375	2625	125
Hybrid VMS with structure (Arterials)	20	1	100	80	0	2000	100	1600	80	0	0
Fixed HAR & Controllers	20	1	10	7	2	200	10	140	7	40	2
Callboxes: each direction per half-mile	5	0.5	1600	1200	0	8000	800	6000	600	0	0
Kiosks	21	5.5	200	150	50	4200	1100	3150	825.0	1050	275
SUBTOTAL ($K)						$31,900	$2,860	$24,015	$2,150	$5,465	$490
INCIDENT MANAGEMENT EQUIPMENT											
Portable VMS	40	2	15	10	10	600	30	400	20	400	20
Portable HAR	45	3.3	10	5	3	450	33	225	16.5	135	9.9
Special Pickup Trucks (w. Dyn. Route Guidance)	50	5	40	25	0	2000	200	1250	125	0	0
O & M Personnel	0	50	40	30	5	0	2000	0	1500	0	250
SUBTOTAL ($K)						$3,050	$2,263	$1,875	$1,662	$535	$280
TRANSP. MGMT CTRS (Number per metro area)			6	4	1						
Central Dispatch/Routing Equip (I per area) [NEW]	600	30	1	1	0						
Computers & Hardware/TMC	680	68	100%	80%	70%	680	68	544	54.4	476	47.6
Software (various)/TMC	220	22	1	1	1	220	22	220	22	220	22
Facilities & Communications/TMC	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel/TMC	0	50	36	24	15	0	1800	0	1200	0	750
SUBTOTAL ($K)						$29,400	$13,740	$15,856	$6,386	$3,496	$1,100
TRAVELER INFORMATION CENTER											
Computers and Hardware	102	10.2	100%	80%	70%	102	10.2	81.6	8.16	71.4	7.14

Table C-2
Updated National ITS Metropolitan Infrastructure Costs Based on Updated Unit Costs, Only

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
Software (various)	300	15	1	1	1	300	15	300	15	300	15
Facilities & Communication (stand-alone)	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel	0	50	30	25	10	0	1500	0	1250	0	500
SUBTOTAL ($K)						4,402	1,925	3,582	1,593	3,171	802
EMERGENCY RESPONSE CENTER											
Computers & Hardware	400	20	100%	80%	70%	400	20	320	16	280	14
Software (various)	70	3.5	1	1	1	70	3.5	70	3.5	70	3.5
Facilities & Communications (stand-alone)	4000	400	1	0.8	0.7	4000	400	3200	320	2800	280
O & M Personnel	0	50	3	2	1	0	150	0	100	0	50
SUBTOTAL ($K)						$4,470	$574	$3,590	$440	$3,150	$348
EMERGENCY SERVICES EQUIPMENT											
Cellular radio, comm. services per vehicle	0.3	0.02	3300	2500	500	990	49.5	750	37.5	150	7.5
SUBTOTAL ($K)						$990	$50	$750	$38	$150	$8
TRANSIT MANAGEMENT CENTER											
Computers & Hardware	340	51	100%	80%	70%	340	51	272	40.8	238	35.7
Software (various)	120	6	1	1	1	120	6	120	6	120	6.0
Facilities & Communication (stand-alone)	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel	0	50	3	2	1	0	150	0	100	0	50
SUBTOTAL ($K)						4460	607	3592	466.8	3158	371.7
TRANSIT VEHICLE INTERFACES											
Cellular radio, display, etc per vehicle	6.3	0.473	2000	1200	100	12,600	946	7560	567.6	630	47.3
AVI Transponder (on Signal Priority routes) [NEW]	0.6	0.01	0	0	0	0	0	0	0	0	0
In-vehicle AVL equip. per vehicle [NEW]	9	1.5	0	0	0	0	0	0	0	0	0
SUBTOTAL ($K)						$12,600	$946	$7,560	$568	$630	$47
ELECTRONIC FARE PAYMENT SYS											
In Transit Mgmt Center											
Central Computer System	3000	150	1	1	0	3000	150	3000	150	0	0
Training & Documentation	80	4	1	1	0	80	4	80	4	0	0
At ticketing site											
Station Controller [DELETE]	20	1	65	35	0	1300	65	700	35	0	0
Ticket Office Machine & Validator	24.4	1.22	100	80	0	2440	122	1952	97.6	0	0
Ticket Vending Machines	60	3	500	300	0	30,000	1500	18000	900	0	0
Turnstile [DELETE]	27.5	1.375	600	400	0	16,500	825	11000	550	0	0

Table C-2

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Unit Costs, Only

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
On Transit Vehicles											
Bus Farebox	7	0.35	2000	1200	0	14,000	700	8400	420	0	0
Smart Card	0.003	0	2,000,000	1,000,000	0	6,000	0	3000	0	0	0
Sys Engineering. Etc. [MOVED]											
SUBTOTAL ($K)						$73,320	$3,366	$46,132	$2,157	$0	$0
ELECTRONIC TOLL COLLECTION SYS											
AVI Plaza Computer equipment	130	7	20	10	0	2600	140	1300	70	0	0
Manual AVI (per lane)	73	147	30	10	0	2190	4410	730	1470	0	0
Automatic AVI (per lane)	70	48	15	5	0	1050	720	350	240	0	0
Manual Automatic AVI (per lane)	125	116	15	5	0	1875	1740	625	580	0	0
AVI Dedicated (per lane)	16	5	30	10	0	480	150	160	50	0	0
Express AVI (per lane)	16	5	30	10	0	480	150	160	50	0	0
SUBTOTAL ($K)						$6,075	$7,170	$2,025	$2,390	$0	$0
SYS DESIGN & INTEGRATION											
TMC, TIC, EMC, Transit MC	5400	0	100%	80%	70%	5400	0	4320	0	3780	0
Electronic Fare Payment Sys	5400	0	100%	60%	0%	5400	0	3240	0	0	0
SUBTOTAL ($K)						$10,800	$0	$7,560	$0	$3,780	$0
TOTAL PER METRO AREA						**$424,617**	**$47,643**	**$283,567**	**$27,552**	**$42,265**	**$4,457**
NUMBER OF LARGE METRO AREAS			75								
NUMBER OF MEDIUM METRO AREAS				125							
NUMBER OF SMALL METRO AREAS					200						
NATIONAL TOTALS FOR EACH SIZE CLASS											
CAPITAL COSTS ($B)						$31.8		$35.4		$8.5	
ANNUAL O&M COSTS ($B)							$3.57		$3.44		$0.89
NATIONAL TOTALS			**CAPITAL COSTS ($B)**			**$75.7**					
			ANNUAL O&M COSTS ($B)			**$7.91**					

Table C-3

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements and Unit Costs

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
SURVEILLANCE - ARTERIALS											
Loop Detectors per signal per approach lane	1.10	0.07	30,000	15,000	500	33,000	2160	16500	1080	550	36
Other arterial loop detectors	1.10	0.07	3,600	6,400	600	3960	259	7040	461	660	43
Overhead Point Detectors [NEW]	2.25	0.11	0	0	0	0	0	0	0	0	0
Processor (170 series), 1 per direction per half mile (Arterials) [NEW]	6.25	0.31	10,000	4,000	200	62500	3125	25000	1250	1250	62.5
CCTV Cameras per signalized intersection	25	1.7	250	150	60	6250	425	3750	255	1500	102
CCTV pole and foundation [NEW]	18	0.9	250	150	60	4500	225	2700	135	1080	54
Video Image Processing/intersection	40	3	250	150	0	10,000	750	6000	450	0	0
AVI equip. to identify priority veh./intersection [NEW]	33	2.6	2500	1500	50	82500	6600	49500	3960	1650	132
AVL equip (to supplement GPS)/site [NEW]	275	16.5	3	0	0	825	49.5	0	0	0	0
SUBTOTAL ($K)						$203,535	$13,594	$110,490	$7,591	$6,690	$430
SURVEILLANCE - FREEWAYS											
Loop Detectors per fwy lane per half mile	1.10	0.07	6,400	3,600	400	7040	461	3960	259	440	29
Overhead Point Detectors [NEW]	2.25	0.11	0	0	0	0	0	0	0	0	0
Data Station (Fwy), 1 per half mile [NEW]	25.00	0.50	800	600	100	20000	400	15000	300	2500	50
CCTV Cameras per freeway mile	25	1.7	400	300	50	10,000	680	7500	510	1250	85
CCTV pole and foundation [NEW]	18	0.9	400	300	50	7,200	360	5400	270	900	45
Emissions & Environmental Sensors	4	0.2	100	70	20	400	20	280	14	80	4.0
SUBTOTAL ($K)						$44,640	$1,921	$32,140	$1,353	$5,170	$213
COMMUNICATION - ARTERIALS											
Twisted-pair to Signals (per intersection)	15	0.75	2500	1500	50	37,500	1875	22,500	1125	750	37.5
Wireless radio [NEW]	15	?	0	0	0	0	0	0	0	0	0
Leased line to signals [NEW]	0	0.48	0	0	0	0	0	0	0	0	0
Leased line to video [NEW]	0	3.6	0	0	0	0	0	0	0	0	0
SUBTOTAL ($K)						$37,500	$1,875	$22,500	$1,125	$750	$38
COMMUNICATION - FREEWAYS											
Fiber-Optic Cable/ freeway mile	265	13.25	400	300	50	106,000	5300	79,500	3975	13250	662.5
Fiber-optic hub - 1 per 5 mi. of fiber [NEW]	110	8	0	0	0	0	0.0	0	0.0	0	0.0
Leased line to video [NEW]	0	3.6	0	0	0	0	0	0	0	0	0
SUBTOTAL ($K)						$106,000	$5,300	$79,500	$3,975	$13,250	$663
TRAFFIC SIGNAL CONTROL											
Central Computer System (Closed Loop) NEW	10	0.5	0	0	0	0	0.00	0	0.00	0	0.00
Central Computer System (Distributed) NEW	30	1.5	0	0	0	0	0	0	0	0	0
Master controllers for distributed system (1 per 25 intersections) [NEW]	10	0.5	100	60	2	1,000	50	600	30	20	1.0

Table C-3

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements and Unit Costs

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
Signal controller replacement per intersection [NEW]	17.5	0.9	0	0	0	0	0	0	0	0	0
Signal controller upgrade (per intersection)	5	0.25	2500	1500	50	12,500	625	7500	375	250	12.5
Signal Preemption: Transit, Emergency Vehicle, RR [NEW]	2	0.1	125	0	0	250	12.5	0	0	0	0
SUBTOTAL ($K)						$13,750	$688	$8,100	$405	$270	$14
FREEWAY MANAGEMENT @ ROADSIDE											
HOV lane control & monitoring equip.	250	18.8	10	8	0	2500	188	2000	150.4	0	0
Ramp Meter Systems (per interchange)	35	3.5	400	300	0	14,000	1400	10500	1050	0	0
SUBTOTAL ($K)						$16,500	$1,588	$12,500	$1,200	$0	$0
TRAVELER INFORMATION @ ROADSIDE/SITE											
Full Matrix VMS & Controllers (without structure)	70	3.5	100	75	25	7,000	350	5250	262.5	1750	87.5
Overhead Structure[Separated out]	105	5	100	75	25	10,500	500	7875	375	2625	125
Hybrid VMS with structure (Arterials)	20	1	100	80	0	2000	100	1600	80	0	0
Fixed HAR & Controllers	20	1	10	7	2	200	10	140	7.0	40	2.0
Callboxes: each direction per half-mile	5	0.5	1600	1200	0	8000	800	6000	600	0	0
Kiosks	21	5.5	200	150	50	4200	1100	3150	825.0	1050	275
SUBTOTAL ($K)						$31,900	$2,860	$24,015	$2,150	$5,465	$490
INCIDENT MANAGEMENT EQUIPMENT											
Portable VMS	40	2	15	10	10	600	30	400	20	400	20
Portable HAR	45	3.3	10	5	3	450	33	225	16.5	135	9.9
Special Pickup Trucks (w. Dyn. Route Guidance)	50	5	40	25	0	2000	200	1250	125	0	0
O & M Personnel	0	50	40	30	5	0	2000	0	1500	0	250
SUBTOTAL ($K)						$3,050	$2,263	$1,875	$1,662	$535	$280
TRANSP. MGMT CTRS (Number per metro area)			6	4	1						
Central Dispatch/Routing Equip (I per area) [NEW]	600	30	1	1	0	600	30	600	30	0	0
Computers & Hardware/TMC	680	68	100%	80%	70%	680	68	544	54.4	476	47.6
Software (various)/TMC	220	22	1	1	1	220	22	220	22	220	22
Facilities & Communications/TMC	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel/TMC	0	50	36	24	15	0	1800	0	1200	0	750
SUBTOTAL ($K)						$30,000	$13,770	$16,456	$6,416	$3,496	$1,100
TRAVELER INFORMATION CENTER											

Table C-3
Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements and Unit Costs

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
Computers and Hardware	102	10.2	100%	80%	70%	102	10.2	81.6	8.16	71.4	7.14
Software (various)	300	15	1	1	1	300	15	300	15	300	15
Facilities & Communication (stand-alone)	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel	0	50	30	25	10	0	1500	0	1250	0	500
SUBTOTAL ($K)						4,402	1,925	3,582	1,593	3,171	802
EMERGENCY RESPONSE CENTER											
Computers & Hardware	400	20	100%	80%	70%	400	20	320	16	280	14
Software (various)	70	3.5	1	1	1	70	3.5	70	3.5	70	3.5
Facilities & Communications (stand-alone)	4000	400	1	0.8	0.7	4000	400	3200	320	2800	280
O & M Personnel	0	50	3	2	1	0	150	0	100	0	50
SUBTOTAL ($K)						$4,470	$574	$3,590	$440	$3,150	$348
EMERGENCY SERVICES EQUIPMENT											
Cellular radio, comm. services per vehicle	0.3	0.02	3300	2500	500	990	49.5	750	37.5	150	7.5
SUBTOTAL ($K)						$990	$50	$750	$38	$150	$8
TRANSIT MANAGEMENT CENTER											
Computers & Hardware	340	51	100%	80%	70%	340	51	272	40.8	238	35.7
Software (various)	120	6	1	1	1	120	6	120	6	120	6.0
Facilities & Communication (stand-alone)	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel	0	50	3	2	1	0	150	0	100	0	50
SUBTOTAL ($K)						4460	607	3592	466.8	3158	371.7
TRANSIT VEHICLE INTERFACES											
Cellular radio, display, etc per vehicle	6.3	0.47	2000	1200	100	12,600	946	7560	567.6	630	47.3
AVI Transponder (on Signal Priority routes) [NEW]	0.60	0.01	0	0	0	0	0	0	0	0	0
In-vehicle AVL equip. per vehicle [NEW]	9	1.5	0	0	0	0	0	0	0	0	0
SUBTOTAL ($K)						$12,600	$946	$7,560	$568	$630	$47
ELECTRONIC FARE PAYMENT SYS											
<u>In Transit Mgmt Center</u>											
Central Computer System	3000	150	1	1	0	3000	150	3000	150	0	0
Training & Documentation	80	4	1	1	0	80	4	80	4	0	0
At ticketing site											
Station Controller [DELETE]	20	1	65	35	0	0	0	0	0	0	0
Ticket Office Machine & Validator	24.4	1.22	100	80	0	2440	122	1952	97.6	0	0

Table C-3

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements and Unit Costs

ELEMENTS	UNIT COST CAPITOL ($K)	UNIT COST O & M ($K)	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE ($K)	O & M COST LARGE ($K)	CAPITOL MEDIUM ($K)	O & M COST MEDIUM ($K)	CAPITOL SMALL ($K)	O & M COST SMALL ($K)
Ticket Vending Machines	60	3	500	300	0	30,000	1500	18000	900	0	0
Turnstile [DELETE]	27.5	1.375	600	400	0	0	0	0	0	0	0
On Transit Vehicles											
Bus Farebox	7	0.35	2000	1200	0	14,000	700	8400	420	0	0
Smart Card	0.003	0	2,000,000	1,000,000	0	6,000	0	3000	0	0	0
Sys Engineering. Etc. [MOVED]											
SUBTOTAL ($K)						$55,520	$2,476	$34,432	$1,572	$0	$0
ELECTRONIC TOLL COLLECTION SYS											
AVI Plaza Computer equipment	130	7	20	10	0	2600	140	1300	70	0	0
Manual AVI (per lane)	73	147	30	10	0	2190	4410	730	1470	0	0
Automatic AVI (per lane)	70	48	15	5	0	1050	720	350	240	0	0
Manual Automatic AVI (per lane)	125	116	15	5	0	1875	1740	625	580	0	0
AVI Dedicated (per lane)	16	5	30	10	0	480	150	160	50	0	0
Express AVI (per lane)	16	5	30	10	0	480	150	160	50	0	0
SUBTOTAL ($K)						$8,675	$7,310	$3,325	$2,460	$0	$0
SYS DESIGN & INTEGRATION											
TMC, TIC, EMC, Transit MC	5400	0	100%	80%	70%	5400	0	4320	0	3780	0
Electronic Fare Payment Sys	5400	0	100%	60%	0%	5400	0	3240	0	0	0
SUBTOTAL ($K)						$10,800	$0	$7,560	$0	$3,780	$0
TOTAL PER METRO AREA						**$588,792**	**$57,745**	**$371,967**	**$33,012**	**$49,665**	**$4,801**
NUMBER OF LARGE METRO AREAS			75								
NUMBER OF MEDIUM METRO AREAS				125							
NUMBER OF SMALL METRO AREAS					200						
NATIONAL TOTALS FOR EACH SIZE CLASS											
CAPITAL COSTS ($B)						$44.2		$46.5		$9.9	
ANNUAL O&M COSTS ($B)							$4.33		$4.13		$0.96
NATIONAL TOTALS			**CAPITAL COSTS ($B)**			**$100.6**					
			ANNUAL O&M COSTS ($B)			**$9.42**					

Table C-4

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements, Unit Costs and Number of Metropolitan Statistical Areas

ELEMENTS	UNIT COST CAPITOL	UNIT COST O & M	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE	O & M COST LARGE	CAPITOL MEDIUM	O & M COST MEDIUM	CAPITOL SMALL	O & M COST SMALL
SURVEILLANCE - ARTERIALS											
Loop Detectors per signal per approach lane	1.10	0.07	30,000	15,000	500	33,000	2160	16500	1080	550	36
Other arterial loop detectors	1.10	0.07	3,600	6,400	600	3960	259	7040	461	660	43
Overhead Point Detectors [NEW]	2.25	0.11	0	0	0	0	0	0	0	0	0
Processor (170 series), 1 per direction per half mile (Arterials) [NEW]	6.25	0.31	10,000	4,000	200	62500	3125	25000	1250	1250	62.5
CCTV Cameras per signalized intersection	25	1.7	250	150	60	6250	425	3750	255	1500	102
CCTV pole and foundation [NEW]	18	0.9	250	150	60	4500	225	2700	135	1080	54
Video Image Processing/intersection	40	3	250	150	0	10,000	750	6000	450	0	0
AVI equip. to identify priority veh./intersection [NEW]	33	2.6	2500	1500	50	82500	6600	49500	3960	1650	132
AVL equip (to supplement GPS)/site [NEW]	275	16.5	3	0	0	825	49.5	0	0	0	0
SUBTOTAL ($K)						$203,535	$13,594	$110,490	$7,591	$6,690	$430
SURVEILLANCE - FREEWAYS											
Loop Detectors per fwy lane per half mile	1.10	0.07	6,400	3,600	400	7040	461	3960	259	440	29
Overhead Point Detectors [NEW]	2.25	0.11	0	0	0	0	0	0	0	0	0
Data Station (Fwy), 1 per half mile [NEW]	25.00	0.50	800	600	100	20000	400	15000	300	2500	50
CCTV Cameras per freeway mile	25	1.7	400	300	50	10,000	680	7500	510	1250	85
CCTV pole and foundation [NEW]	18	0.9	400	300	50	7,200	360	5400	270	900	45
Emissions & Environmental Sensors	4	0.2	100	70	20	400	20	280	14	80	4.0
SUBTOTAL ($K)						$44,640	$1,921	$32,140	$1,353	$5,170	$213
COMMUNICATION - ARTERIALS											
Twisted-pair to Signals (per intersection)	15	0.75	2500	1500	50	37,500	1875	22,500	1125	750	37.5
Wireless radio [NEW]	15	?	0	0	0	0	0	0	0	0	0
Leased line to signals [NEW]	0	0.48	0	0	0	0	0	0	0	0	0
Leased line to video [NEW]	0	3.6	0	0	0	0	0	0	0	0	0
SUBTOTAL ($K)						$37,500	$1,875	$22,500	$1,125	$750	$38
COMMUNICATION - FREEWAYS											
Fiber-Optic Cable/ freeway mile	265	13.25	400	300	50	106,000	5300	79,500	3975	13250	662.5
Fiber-optic hub - 1 per 5 mi. of fiber [NEW]	110	8	0	0	0	0	0.0	0	0.0	0	0.0
Leased line to video [NEW]	0	3.6	0	0	0	0	0	0	0	0	0
SUBTOTAL ($K)						$106,000	$5,300	$79,500	$3,975	$13,250	$663
TRAFFIC SIGNAL CONTROL											
Central Computer System (Closed Loop) NEW	10	0.5	0	0	0	0	0.00	0	0.00	0	0.00
Central Computer System (Distributed) NEW	30	1.5	0	0	0	0	0	0	0	0	0
Master controllers for distributed system (1 per 25 intersections) [NEW]	10	0.5	100	60	2	1,000	50	600	30	20	1.0
Signal controller replacement per intersection [NEW]	17.5	0.9	0	0	0	0	0	0	0	0	0
Signal controller upgrade (per intersection)	5	0.25	2500	1500	50	12,500	625	7500	375	250	12.5

Table C-4

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements, Unit Costs and Number of Metropolitan Statistical Areas

ELEMENTS	UNIT COST CAPITOL	UNIT COST O & M	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE	O & M COST LARGE	CAPITOL MEDIUM	O & M COST MEDIUM	CAPITOL SMALL	O & M COST SMALL
Signal Preemption: Transit, Emergency Vehicle, RR [NEW]	2	0.1	125	0	0	250	12.5	0	0	0	0
SUBTOTAL ($K)						$13,750	$688	$8,100	$405	$270	$14
FREEWAY MANAGEMENT @ ROADSIDE											
HOV lane control & monitoring equip.	250	18.8	10	8	0	2500	188	2000	150.4	0	0
Ramp Meter Systems (per interchange)	35	3.5	400	300	0	14,000	1400	10500	1050	0	0
SUBTOTAL ($K)						$16,500	$1,588	$12,500	$1,200	$0	$0
TRAVELER INFORMATION @ ROADSIDE/SITE											
Full Matrix VMS & Controllers (without structure)	70	3.5	100	75	25	7,000	350	5250	262.5	1750	87.5
Overhead Structure[Separated out]	105	5	100	75	25	10,500	500	7875	375	2625	125
Hybrid VMS with structure (Arterials)	20	1	100	80	0	2000	100	1600	80	0	0
Fixed HAR & Controllers	20	1	10	7	2	200	10	140	7.0	40	2.0
Callboxes: each direction per half-mile	5	0.5	1600	1200	0	8000	800	6000	600	0	0
Kiosks	21	5.5	200	150	50	4200	1100	3150	825.0	1050	275
SUBTOTAL ($K)						$31,900	$2,860	$24,015	$2,150	$5,465	$490
INCIDENT MANAGEMENT EQUIPMENT											
Portable VMS	40	2	15	10	10	600	30	400	20	400	20
Portable HAR	45	3.3	10	5	3	450	33	225	16.5	135	9.9
Special Pickup Trucks (w. Dyn. Route Guidance)	**50**	5	40	25	0	2000	200	1250	125	0	0
O & M Personnel	0	50	40	30	5	0	2000	0	1500	0	250
SUBTOTAL ($K)						3050	2263	1875	1661.5	535	280
TRANSP. MGMT CTRS (Number per metro area)			6	4	1						
Central Dispatch/Routing Equip (I per area) [NEW]	600	30	1	1	0	600	30	600	30	0	0
Computers & Hardware/TMC	680	68	100%	80%	70%	680	68	544	54.4	476	47.6
Software (various)/TMC	220	22	1	1	1	220	22	220	22	220	22
Facilities & Communications/TMC	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel/TMC	0	50	36	24	15	0	1800	0	1200	0	750
SUBTOTAL ($K)						$30,000	$13,770	$16,456	$6,416	$3,496	$1,100
TRAVELER INFORMATION CENTER											
Computers and Hardware	102	10.2	100%	80%	70%	102	10.2	81.6	8.16	71.4	7.14
Software (various)	300	15	1	1	1	300	15	300	15	300	15
Facilities & Communication (stand-alone)	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel	0	50	30	25	10	0	1500	0	1250	0	500
SUBTOTAL ($K)						4,402	1,925	3,582	1,593	3,171	802
EMERGENCY RESPONSE CENTER											
Computers & Hardware	400	20	100%	80%	70%	400	20	320	16	280	14
Software (various)	70	3.5	1	1	1	70	3.5	70	3.5	70	3.5
Facilities & Communications (stand-alone)	4000	400	1	0.8	0.7	4000	400	3200	320	2800	280

Table C-4

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements, Unit Costs and Number of Metropolitan Statistical Areas

ELEMENTS	UNIT COST CAPITOL	UNIT COST O & M	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE	O & M COST LARGE	CAPITOL MEDIUM	O & M COST MEDIUM	CAPITOL SMALL	O & M COST SMALL
O & M Personnel	0	50	3	2	1	0	150	0	100	0	50
SUBTOTAL ($K)						$4,470	$574	$3,590	$440	$3,150	$348
EMERGENCY SERVICES EQUIPMENT											
Cellular radio, comm. services per vehicle	0.3	0.02	3300	2500	500	990	49.5	750	37.5	150	7.5
SUBTOTAL ($K)						$990	$50	$750	$38	$150	$8
TRANSIT MANAGEMENT CENTER											
Computers & Hardware	340	51	100%	80%	70%	340	51	272	40.8	238	35.7
Software (various)	120	6	1	1	1	120	6	120	6	120	6.0
Facilities & Communication (stand-alone)	4000	400	100%	80%	70%	4000	400	3200	320	2800	280
O & M Personnel	0	50	3	2	1	0	150	0	100	0	50
SUBTOTAL ($K)						4460	607	3592	466.8	3158	371.7
TRANSIT VEHICLE INTERFACES											
Cellular radio, display, etc per vehicle	6.3	0.47	2000	1200	100	12,600	946	7560	567.6	630	47.3
AVI Transponder (on Signal Priority routes) [NEW]	0.60	0.01	0	0	0	0	0	0	0	0	0
In-vehicle AVL equip. per vehicle [NEW]	9	1.5	0	0	0	0	0	0	0	0	0
SUBTOTAL ($K)						$12,600	$946	$7,560	$568	$630	$47
ELECTRONIC FARE PAYMENT SYS											
In Transit Mgmt Center											
Central Computer System	3000	150	1	1	0	3000	150	3000	150	0	0
Training & Documentation	80	4	1	1	0	80	4	80	4	0	0
At ticketing site											
Station Controller [DELETE]	20	1	65	35	0	0	0	0	0	0	0
Ticket Office Machine & Validator	24.4	1.22	100	80	0	2440	122	1952	97.6	0	0
Ticket Vending Machines	60	3	500	300	0	30,000	1500	18000	900	0	0
Turnstile [DELETE]	27.5	1.375	600	400	0	0	0	0	0	0	0
On Transit Vehicles											
Bus Farebox	7	0.35	2000	1200	0	14,000	700	8400	420	0	0
Smart Card	0.003	0	2,000,000	1,000,000	0	6,000	0	3000	0	0	0
Sys Engineering. Etc. [MOVED]											
SUBTOTAL ($K)						$55,520	$2,476	$34,432	$1,572	$0	$0
ELECTRONIC TOLL COLLECTION SYS											
AVI Plaza Computer equipment	130	7	20	10	0	2600	140	1300	70	0	0
Manual AVI (per lane)	73	147	30	10	0	2190	4410	730	1470	0	0
Automatic AVI (per lane)	70	48	15	5	0	1050	720	350	240	0	0
Manual Automatic AVI (per lane)	125	116	15	5	0	1875	1740	625	580	0	0
AVI Dedicated (per lane)	16	5	30	10	0	480	150	160	50	0	0
Express AVI (per lane)	16	5	30	10	0	480	150	160	50	0	0
SUBTOTAL ($K)						$8,675	$7,310	$3,325	$2,460	$0	$0

Table C-4

Updated National ITS Metropolitan Infrastructure Costs Based on Updated Cost Elements, Unit Costs and Number of Metropolitan Statistical Areas

ELEMENTS	UNIT COST CAPITOL	UNIT COST O & M	QUANTITY LARGE	QUANTITY MEDIUM	QUANTITY SMALL	CAPITOL LARGE	O & M COST LARGE	CAPITOL MEDIUM	O & M COST MEDIUM	CAPITOL SMALL	O & M COST SMALL
SYS DESIGN & INTEGRATION											
TMC, TIC, EMC, Transit MC	5400	0	100%	80%	70%	5400	0	4320	0	3780	0
Electronic Fare Payment Sys	5400	0	100%	60%	0%	5400	0	3240	0	0	0
SUBTOTAL ($K)						$10,800	$0	$7,560	$0	$3,780	$0
TOTAL PER METRO AREA						**$588,792**	**$57,745**	**$371,967**	**$33,012**	**$49,665**	**$4,801**
MODIFIED NO. OF METROPOLITAN STATISTICAL AREAS PER APOGEE COUNTS											
NUMBER OF LARGE METRO AREAS			60								
NUMBER OF MEDIUM METRO AREAS				105							
NUMBER OF SMALL METRO AREAS					132						
NATIONAL TOTALS FOR EACH SIZE CLASS											
CAPITAL COSTS ($B)						**$35.3**		**$39.1**		**$6.6**	
ANNUAL O&M COSTS ($B)							**$3.46**		**$3.47**		**$0.63**
NATIONAL TOTALS			**CAPITAL COSTS ($B)**			**$80.9**					
			ANNUAL O&M COSTS ($B)			**$7.56**					

Table C-5
Effect of Factoring in 1997 Deployment Estimates on Future National ITS Metropolitan Infrastructure Costs

	CAPITOL COST LARGE ($K)	% DEPLOYED BY 1997 LARGE	CAP COST EXPENDED BY '97 LARGE ($K)	UPDATED CAP COST LARGE ($K)	CAPITOL COST MEDIUM ($K)	% DEPLOYED BY 1997 MEDIUM	CAP COST EXPENDED BY '97 MEDIUM ($K)	UPDATED CAP COST MEDIUM ($K)
SURVEILLANCE - ARTERIALS								
Loop Detectors per signal per approach lane	$33,000	5%	$1,650		16500	2%	$330	
Other arterial loop detectors	$3,960	5%	$198		7040	2%	$141	
Overhead Point Detectors [NEW]	?	5%			0	2%	$0	
Processor (170 series), 1 per direction per half mile (Arterials) [NEW]	$62,500	5%	$3,125		25000	2%	$500	
CCTV Cameras per signalized intersection	$6,250	1%	$63		3750	0%	$0	
CCTV pole and foundation [NEW]	$4,500	1%	$45		2700	0%	$0	
Video Image Processing/intersection	$10,000	1%	$100		6000	0%	$0	
AVI equip. to identify priority veh./intersection [NEW]	$82,500	?	$0		49500		$0	
AVL equip (to supplement GPS)/site [NEW]	$825	?	$0		0		$0	
SURVEILLANCE - ARTERIALS	$203,535		$5,181	$198,355	$110,490		$971	$109,519
SURVEILLANCE - FREEWAYS								
Loop Detectors per fwy lane per half mile	$7,040	17%	$1,197		3960	3%	$119	
Overhead Point Detectors [NEW]	$0	17%	$0		0	3%	$0	
Data Station (Fwy), 1 per half mile [NEW]	$20,000	17%	$3,400		15000	3%	$450	
CCTV Cameras per freeway mile	$10,000	9%	$900		7500	0%	$0	
CCTV pole and foundation [NEW]	$7,200	9%	$648		5400	0%	$0	
Emissions & Environmental Sensors	$400	?	$0		280		$0	
SURVEILLANCE - FREEWAYS	$44,640		$6,145	$38,495	$32,140		$569	$31,571
COMMUNICATION - ARTERIALS								
Twisted-pair to Signals (per intersection)	$37,500	46%	$17,250		22,500	40%	$9,000	
Wireless radio [NEW]	$0	43%	$0		0	35%	$0	
Leased line to signals [NEW]	$0	46%	$0		0	40%	$0	
Leased line to video [NEW]	$0	1%	$0		0	0%	$0	
COMMUNICATION - ARTERIALS	$37,500		$17,250	$20,250	$22,500		$9,000	$13,500
COMMUNICATION - FREEWAYS								
Fiber-Optic Cable/ freeway mile	$106,000	9%	$9,540		79,500	3%	$2,385	
Fiber-optic hub - 1 per 5 mi. of fiber [NEW]	$0	9%	$0		0	3%	$0	
Leased line to video [NEW]	$0	9%	$0		0	3%	$0	
COMMUNICATION - FREEWAYS	$106,000	9%	$9,540	$96,460	$79,500	3%	$2,385	$77,115
TRAFFIC SIGNAL CONTROL								
Central Computer System (Closed Loop) NEW	$0				0			
Central Computer System (Distributed) NEW	$0				0			
Master controllers for distributed system (1 per 25 intersections) [NEW]	$1,000				600			
Signal controller replacement per intersection [NEW]	$0				0			
Signal controller upgrade (per intersection)	$12,500				7500			
Signal Preemption: Transit, Emergency Vehicle, RR [NEW]	$250	?			0			
TRAFFIC SIGNAL CONTROL	$13,750	46%	$6,325	$7,425	$8,100	40%	$3,240	$4,860

Table C-5

Effect of Factoring in 1997 Deployment Estimates on Future National ITS Metropolitan Infrastructure Costs

	CAPITOL COST LARGE ($K)	% DEPLOYED BY 1997 LARGE	CAP COST EXPENDED BY '97 LARGE ($K)	UPDATED CAP COST LARGE ($K)	CAPITOL COST MEDIUM ($K)	% DEPLOYED BY 1997 MEDIUM	CAP COST EXPENDED BY '97 MEDIUM ($K)	UPDATED CAP COST MEDIUM ($K)
FREEWAY MANAGEMENT @ ROADSIDE								
HOV lane control & monitoring equip.	$2,500	?	$0		2000		$0	
Ramp Meter Systems (per interchange)	$14,000	13%	$1,820		10500	1%	$105	
FREEWAY MANAGEMENT @ ROADSIDE	$16,500	13%	$1,820	$14,680	$12,500	1%	$105	$12,395
TRAVELER INFORMATION @ ROADSIDE/SITE								
Full Matrix VMS & Controllers (without structure)	$7,000				5250			
Overhead Structure[Separated out]	$10,500				7875			
Hybrid VMS with structure (Arterials)	$2,000				1600			
Fixed HAR & Controllers	$200				140			
Callboxes: each direction per half-mile	$8,000				6000			
Kiosks	$4,200				3150			
TRAVELER INFORMATION @ ROADSIDE/SITE	$31,900	22%	$7,018	$24,882	$24,015	9%	$2,161	$21,854
INCIDENT MANAGEMENT EQUIPMENT								
Portable VMS	$600	31%	$186		400	5%	$20	
Portable HAR	$450	31%	$140		225	5%	$11	
Special Pickup Trucks (w. Dyn. Route Guidance)	$2,000	1%	$20		1250	0%	$0	
O & M Personnel	$0	31%	$0		0	5%	$0	
INCIDENT MANAGEMENT EQUIPMENT	$3,050	31%	$346	$2,705	$1,875	5%	$31	$1,844
TRANSP. MGMT. CTRS								
Software (various)/TMC	$600				600			
Computers & Hardware/TMC	$680				544			
Software (various)/TMC	$220				220			
Facilities & Communications/TMC	$4,000				3200			
O & M Personnel/TMC	$0				0			
TRANSP. MGMT. CTRS	$30,000	17%	$5,100	$24,900	$16,456	5%	$823	$15,633
TRAVELER INFORMATION CENTER								
Computers and Hardware	$102				82			
Software (various)	$300				300			
Facilities & Communication (stand-alone)	$4,000				3200			
O & M Personnel	$0				0			
TRAVELER INFORMATION CENTER	$4,402	0%	$0	$4,402	3,582	0%	$0	$3,582
EMERGENCY RESPONSE CENTER								
Computers & Hardware	$400				320			
Software (various)	$70				70			
Facilities & Communications (stand-alone)	$4,000				3200			
O & M Personnel	$0				$0			
EMERGENCY RESPONSE CENTER	$4,470	43%	$1,922	$2,548	3590	40%	$1,436	$2,154
EMERGENCY SERVICES EQUIPMENT								
Cellular radio, comm. services per vehicle	$990				$750			

Table C-5
Effect of Factoring in 1997 Deployment Estimates on Future National ITS Metropolitan Infrastructure Costs

	CAPITOL COST LARGE ($K)	% DEPLOYED BY 1997 LARGE	CAP COST EXPENDED BY '97 LARGE ($K)	UPDATED CAP COST LARGE ($K)	CAPITOL COST MEDIUM ($K)	% DEPLOYED BY 1997 MEDIUM	CAP COST EXPENDED BY '97 MEDIUM ($K)	UPDATED CAP COST MEDIUM ($K)
EMERGENCY SERVICES EQUIPMENT	$990	43%	$426	$564	$750	40%	$300	$450
TRANSIT MANAGEMENT CENTER								
Computers & Hardware	$340				272			
Software (various)	$120				120			
Facilities & Communication (stand-alone)	$4,000				3200			
O & M Personnel	$0				0			
TRANSIT MANAGEMENT CENTER	$4,460	23%	$1,026	$3,434	$ 3,592	2%	$72	$3,520
TRANSIT VEHICLE INTERFACES								
Cellular radio, display, etc per vehicle	$12,600	16%	$2,016		7560	5%	$378	
AVI Transponder (on Signal Priority routes) [NEW]	$0	?	$0		0		$0	
In-vehicle AVL equip. per vehicle [NEW]	$0	23%	$0		0	2%	$0	
TRANSIT VEHICLE INTERFACES	$12,600		$2,016	$10,584	$7,560		$378	$7,182
ELECTRONIC FARE PAYMENT SYSTEM								
In Transit Mgmt Center								
Central Computer System	$3,000	30%	$900		3000			
Training & Documentation	$80	30%	$24		80			
At ticketing site								
Station Controller [DELETE]	$0				0			
Ticket Office Machine & Validator	$2,440	30%	$732		1952			
Ticket Vending Machines	$30,000	30%	$9,000		18000			
Turnstile [DELETE]	$0				0			
On Transit Vehicles								
Bus Farebox	$14,000	30%	$4,200		8400			
Smart Card	$6,000	1%	$60		3000	0%		
Sys Engineering. Etc. [MOVED]								
ELECTRONIC FARE PAYMENT SYSTEM	$55,520		$14,916	$40,604	$34,432	4%	$1,377	$33,055
ELECTRONIC TOLL COLLECTION SYSTEM								
AVI Plaza Computer equipment	$2,600	36%			1300	36%		
Manual AVI (per lane)	$2,190				730			
Automatic AVI (per lane)	$1,050				350			
Manual Automatic AVI (per lane)	$1,875				625			
AVI Dedicated (per lane)	$480				160			
Express AVI (per lane)	$480				160			
ELECTRONIC TOLL COLLECTION SYSTEM	$8,675	36%	$3,123	$5,552	$3,325	36%	$1,197	$2,128
SYS DESIGN & INTEGRATION								
TMC, TIC, EMC, Transit MC	$5,400	20%	$1,080		4320	9%	$389	
Electronic Fare Payment Sys	$5,400	30%	$3,240		3240	4%	$130	
SYS DESIGN & INTEGRATION	$10,800		$4,320	$6,480	$7,560		$518	$7,042
TOTAL PER METRO AREA	$588,792		**$86,472**	**$502,320**	$371,967		**$24,564**	**$347,403**

Table C-5

Effect of Factoring in 1997 Deployment Estimates on Future National ITS Metropolitan Infrastructure Costs

	CAPITOL COST LARGE ($K)	% DEPLOYED BY 1997 LARGE	CAP COST EXPENDED BY '97 LARGE ($K)	UPDATED CAP COST LARGE ($K)	CAPITOL COST MEDIUM ($K)	% DEPLOYED BY 1997 MEDIUM	CAP COST EXPENDED BY '97 MEDIUM ($K)	UPDATED CAP COST MEDIUM ($K)
Percent Capital Cost Expended Through 1997		**LARGE**	**14.7%**			**MEDIUM**	**6.6%**	
						SMALL	**3.0%**	
MODIFIED NO. OF METROPOLITAN STATISTICAL AREAS PER APOGEE COUNTS								
NUMBER OF LARGE METRO AREAS		60						
NUMBER OF MEDIUM METRO AREAS		105						
NUMBER OF SMALL METRO AREAS		132						
NATIONAL TOTAL CAPITAL COST FOR EACH SIZE CLASS								
LARGE				**$30.1**				
MEDIUM				**$36.5**				
SMALL				**6.4**				
NATIONAL TOTAL EXPENDED BY 1997 BY SIZE CLASS								
LARGE			**$5.2**					
MEDIUM			**$2.6**					
SMALL			**$0.2**					

Addendum to the
Working Paper National Costs of the Metropolitan ITS Infrastructure:
Update to the FHWA 1995 Report

Introduction

The purpose of this addendum to the "Working Paper National Costs of the Metropolitan ITS Infrastructure: Update to the FHWA 1995 Report" (hereafter referred to as the *National Costs Update*) is to update the estimates of the costs remaining to deploy Intelligent Transportation System (ITS) infrastructure elements in the 75 largest metropolitan areas in the United States. Specifically, this addendum provides estimates to the deployment costs expended through 1999 and then updates the remaining costs to deploy ITS infrastructures based on this 1999 deployment cost estimate. Sections of the *National Costs Update* affected are 3D, 4, and 5.

Although the *National Costs Update* addresses costs for medium and small metropolitan areas, data to support such an analysis for 1999 expenditures is not available. Hence, this addendum addresses cost estimates for large metropolitan areas only.

Background

The *National Costs Update* was prepared to provide new estimates of the costs to deploy Intelligent Transportation System (ITS) infrastructure elements in the largest metropolitan areas in the United States. It built upon estimates that were distributed in June 1995 by Federal Highway Administration (FHWA)[1]. In building upon these 1995 cost estimates, new cost elements were added and deleted, unit cost values were updated, and quantities for metropolitan areas were updated. These modifications were based on new sources of ITS cost estimates and were necessary to establish a base case for estimating the needed ITS investment. Estimates of the costs to reach full deployment were calculated and presented in detailed cost tables in the report. Since that time new cost data sources are again available; hence, it is useful to update the national deployment cost estimate. This addendum addresses new estimates of the costs to deploy ITS infrastructure elements in the largest metropolitan areas in the United States based on 1999 deployment data. The base case or total needed capital investment established in the *National Costs Update* remains unchanged.

Changes to Market Penetration in Base Year

As stated in section 3D, it is important to recognize and account for previous ITS investments in making estimates of the remaining costs to deploy ITS infrastructure. To account for these previous investments, the amount of market penetration for the various cost elements for the current time period must be known. The 1997 deployment

[1] Office of Traffic Management and Intelligent Transportation Systems (HTV-10), *Cost Estimate and Assumptions for the Core Infrastructure*, FHWA, June 1995. The ITS Infrastructure was called the Core Infrastructure in 1995.

percentages[2] were factored into the *National Costs Update* cost tables to produce estimates of the percentages of the needed capital investment that had already been spent and subtracted from the total needed capital to provide estimates of the investment still to be made. Since 1999 ITS deployment data[3] is now available, those estimates can be updated.

The same methodology used to develop the 1997 deployment estimates on future national ITS costs was used for this 1999 update with the following exceptions:

- The 1999 estimate is for large metropolitan areas only. The 1997 deployment report divided the 78 largest metropolitan areas (see footnote 21 and table 2-2 in the *National Costs Update*) into three size classes. A methodology was developed to use deployment data from the three class sizes to estimate the capital cost expended through 1997 for generic medium and small size metropolitan areas. (Note that the national-level deployment data was used to estimate the cost expended through 1997 for a generic large metropolitan area.) The 1999 report does not provide deployment data based on these size classes. Only deployment data at the national level is provided. Thus, 1999 cost estimates could not be calculated for generic medium and small size metropolitan areas.

- The 1999 cost estimate accounts for deployment of Traveler Information Centers. The 1997 cost estimate does not account for any deployment of these centers. Traveler Information Centers were not included because the deployment tracking indicators from the 1997 report did not adequately represent deployment of Traveler Information Centers. There are many examples of these centers deployed in the U.S. today. Although the indicators used in the 1999 report have not changed, to *not* account for them in the 1999 cost expenditures would seem to present an inaccurate cost estimate.

The 1999 *deployment percentages* can be factored into the cost tables to produce estimates of the *percentages of the needed capital investment that has already been spent*, and thus can be subtracted from the total needed capital to provide estimates of the investments that must still be made. The effects on the detailed cost estimates of using the 1999 deployment survey data are shown in table 1. The columns in this table are defined as follows:

- ITS ELEMENTS and CAPITAL COSTS LARGE – are reproduced from table C-5.

- % DEPLOYED BY 1999 LARGE – have been taken from the figures in reference 3.

[2] Gordon, Steve, and Trombly, Jeffrey, *Tracking the Deployment of the Integrated Metropolitan ITS Infrastructure in the USA: FY 1997 Results*, Report FHWA-JPO-99-001, September 1998.
[3] Gordon, Steve, and Trombly, Jeffrey, *Tracking the Deployment of the Integrated Metropolitan ITS Infrastructure in the USA: FY99 Results*, Report FHWA-OP-00-016, May 2000.

Table 1

Effect of Factoring in 1999 Deployment Estimates on Future National ITS Metropolitan Infrastructure Costs

ITS ELEMENTS	CAPITOL COSTS LARGE ($K)	% DEPLOYED BY 1999 LARGE	CAPITAL COSTS EXPENDED BY '99 LARGE ($K)	REMAINING CAPITAL COSTS LARGE ($K)
SURVEILLANCE - ARTERIALS				
Loop Detectors per signal per approach lane	$33,000	9%	$2,970	
Other arterial loop detectors	$3,960	9%	$356	
Overhead Point Detectors [NEW]		9%		
Processor (170 series), 1 per direction per half mile (Arterials) [NEW]	$62,500	9%	$5,625	
CCTV Cameras per signalized intersection	$6,250	1%	$63	
CCTV pole and foundation [NEW]	$4,500	1%	$45	
Video Image Processing/intersection	$10,000	1%	$100	
AVI equip. to identify priority veh./intersection [NEW]	$82,500		$0	
AVL equip (to supplement GPS)/site [NEW]	$825		$0	
SURVEILLANCE - ARTERIALS	$203,535	**4%**	$9,159	$194,376
SURVEILLANCE - FREEWAYS				
Loop Detectors per fwy lane per half mile	$7,040	22%	$1,549	
Overhead Point Detectors [NEW]	$0	22%	$0	
Data Station (Fwy), 1 per half mile [NEW]	$20,000	22%	$4,400	
CCTV Cameras per freeway mile	$10,000	14%	$1,400	
CCTV pole and foundation [NEW]	$7,200	14%	$1,008	
Emissions & Environmental Sensors	$400		$0	
SURVEILLANCE - FREEWAYS	$44,640	**19%**	$8,357	$36,283
COMMUNICATION - ARTERIALS				
Twisted-pair to Signals (per intersection)	$37,500	46%	$17,250	
Wireless radio [NEW]	$0	20%	$0	
Leased line to signals [NEW]	$0	46%	$0	
Leased line to video [NEW]	$0	1%	$0	
COMMUNICATION - ARTERIALS	$37,500	**46%**	$17,250	$20,250
COMMUNICATION - FREEWAYS				
Fiber-Optic Cable/ freeway mile	$106,000	14%	$14,840	
Fiber-optic hub - 1 per 5 mi. of fiber [NEW]	$0	14%	$0	
Leased line to video [NEW]	$0	14%	$0	
COMMUNICATION - FREEWAYS	$106,000	**14%**	$14,840	$91,160
TRAFFIC SIGNAL CONTROL				
Central Computer System (Closed Loop) NEW	$0			
Central Computer System (Distributed) NEW	$0			
Master controllers for distributed system (1 per 25 intersections) [NEW]	$1,000			
Signal controller replacement per intersection [NEW]	$0			
Signal controller upgrade (per intersection)	$12,500			
Signal Preemption: Transit, Emergency Vehicle, RR [NEW]	$250			
TRAFFIC SIGNAL CONTROL	$13,750	**46%**	$6,325	$7,425
FREEWAY MANAGEMENT @ ROADSIDE				
HOV lane control & monitoring equip.	$2,500		$0	
Ramp Meter Systems (per interchange)	$14,000	8%	$1,120	
FREEWAY MANAGEMENT @ ROADSIDE	$16,500	**7%**	$1,120	$15,380
TRAVELER INFORMATION @ ROADSIDE/SITE				
Full Matrix VMS & Controllers (without structure)	$7,000			
Overhead Structure[Separated out]	$10,500			
Hybrid VMS with structure (Arterials)	$2,000			
Fixed HAR & Controllers	$200			
Callboxes: each direction per half-mile	$8,000			
Kiosks	$4,200			
TRAVELER INFORMATION @ ROADSIDE/SITE	$31,900	**27%**	$8,613	$23,287
INCIDENT MANAGEMENT EQUIPMENT				
Portable VMS	$600	38%	$228	
Portable HAR	$450	38%	$171	

Table 1

Effect of Factoring in 1999 Deployment Estimates on Future National ITS Metropolitan Infrastructure Costs

ITS ELEMENTS	CAPITOL COSTS LARGE ($K)	% DEPLOYED BY 1999 LARGE	CAPITAL COSTS EXPENDED BY '99 LARGE ($K)	REMAINING CAPITAL COSTS LARGE ($K)
Special Pickup Trucks (w. Dyn. Route Guidance)	$2,000	2%	$40	
O & M Personnel	$0	38%	$0	
INCIDENT MANAGEMENT EQUIPMENT	$3,050	**14%**	$439	$2,611
TRANSP. MGMT. CTRS				
Software (various)/TMC	$600			
Computers & Hardware/TMC	$680			
Software (various)/TMC	$220			
Facilities & Communications/TMC	$4,000			
O & M Personnel/TMC	$0			
TRANSP. MGMT. CTRS	$30,000	**22%**	$6,600	$23,400
TRAVELER INFORMATION CENTER				
Computers and Hardware	$102			
Software (various)	$300			
Facilities & Communication (stand-alone)	$4,000			
O & M Personnel	$0			
TRAVELER INFORMATION CENTER	$4,402	**22%**	$968	$3,434
EMERGENCY RESPONSE CENTER				
Computers & Hardware	$400			
Software (various)	$70			
Facilities & Communications (stand-alone)	$4,000			
O & M Personnel	$0			
EMERGENCY RESPONSE CENTER	$4,470	**66%**	$2,950	$1,520
EMERGENCY SERVICES EQUIPMENT				
Cellular radio, comm. services per vehicle	$990			
EMERGENCY SERVICES EQUIPMENT	$990	**66%**	$653	$337
TRANSIT MANAGEMENT CENTER				
Computers & Hardware	$340			
Software (various)	$120			
Facilities & Communication (stand-alone)	$4,000			
O & M Personnel	$0			
TRANSIT MANAGEMENT CENTER	$4,460	**30%**	$1,338	$3,122
TRANSIT VEHICLE INTERFACES				
Cellular radio, display, etc per vehicle	$12,600	10%	$1,260	
AVI Transponder (on Signal Priority routes) [NEW]	$0		$0	
In-vehicle AVL equip. per vehicle [NEW]	$0	30%	$0	
TRANSIT VEHICLE INTERFACES	$12,600	**10%**	$1,260	$11,340
ELECTRONIC FARE PAYMENT SYSTEM				
In Transit Mgmt Center				
Central Computer System	$3,000	45%	$1,350	
Training & Documentation	$80	45%	$36	
At ticketing site				
Station Controller [DELETE]	$0			
Ticket Office Machine & Validator	$2,440	45%	$1,098	
Ticket Vending Machines	$30,000	45%	$13,500	
Turnstile [DELETE]	$0			
On Transit Vehicles				
Bus Farebox	$14,000	45%	$6,300	
Smart Card	$6,000	3%	$180	
Sys Engineering. Etc. [MOVED]				
ELECTRONIC FARE PAYMENT SYSTEM	$55,520	**40%**	$22,464	$33,056
ELECTRONIC TOLL COLLECTION SYSTEM				
AVI Plaza Computer equipment	$2,600			
Manual AVI (per lane)	$2,190			
Automatic AVI (per lane)	$1,050			
Manual Automatic AVI (per lane)	$1,875			

Table 1

Effect of Factoring in 1999 Deployment Estimates on Future National ITS Metropolitan Infrastructure Costs

ITS ELEMENTS	CAPITOL COSTS LARGE ($K)	% DEPLOYED BY 1999 LARGE	CAPITAL COSTS EXPENDED BY '99 LARGE ($K)	REMAINING CAPITAL COSTS LARGE ($K)
AVI Dedicated (per lane)	$480			
Express AVI (per lane)	$480			
ELECTRONIC TOLL COLLECTION SYSTEM	$8,675	**43%**	$3,730	$4,945
SYS DESIGN & INTEGRATION				
TMC, TIC, EMC, Transit MC	$5,400	35%	$1,890	$3,510
Electronic Fare Payment Sys	$5,400	45%	$4,860	$540
SYS DESIGN & INTEGRATION	$10,800	**63%**	$6,750	$4,050
TOTAL PER LARGE METRO AREA	**$588,792**		**$112,817**	**$475,975**
Percent Capital Cost Expended Through 1999:	**19.2%**			
NUMBER OF LARGE METRO AREAS:	**75**			
				($B)
TOTAL NATIONAL CAPITAL COST FOR ALL LARGE METRO AREAS				**$44.2**
TOTAL NATIONAL COST EXPENDED BY 1999 FOR ALL LARGE METRO AREAS				**$8.5**
TOTAL NATIONAL CAPITAL COST REMAINING FOR ALL LARGE METRO AREAS				**$35.7**

- CAPITAL COSTS EXPENDED BY ’99 LARGE – are the product of the CAPITAL COSTS LARGE and % DEPLOYED BY 1999 LARGE. This column gives the estimated dollar expenditure on ITS metropolitan deployment through 1999.

- REMAINING CAPITAL COSTS LARGE – provides estimate of the remaining investment needed for large metropolitan areas.

By comparing the detailed estimates in table 1 with those for 1997 in *National Costs Update* table C-5, it can be determined which cost elements have the largest reduction in future costs due to taking into account the investments that have already occurred. However, since some of the estimates in both tables are only for the cost element groups, the group-level will be used for this reporting. The largest increases in expenditures from 1997 to 1999 are 23% in Emergency Response Centers, 23% in Emergency Services Equipment, and 23% in System Design and Integration.

The comparison of the new summary cost estimates with those in the *National Costs Update* table 3-7 are shown in table 2. Table 2 indicates that approximately 19.2% of the needed capital cost for ITS for large metropolitan areas was expended through 1999. This is an increase of 4.5% from the 1997 expenditures of 14.7%. Although the 1997 summary cost estimate in table 3-7 is based on 60 as the number of large Metropolitan Statistical Areas (MSAs) (see section 3C for changes to the number of MSAs), the national summary results are reported based on large MSAs of 75. For comparative purposes, national summary cost estimates for large metropolitan areas of 60 are included in table 2. Because O&M costs for all ITS capital costs (both expended and remaining) must be accounted for, the estimates for annual O&M costs (see table C-4) remain unchanged.

Table 2
Comparison of 1999 Full Deployment Summary Costs: With and Without Addition of ORNL 1997 Deployment Levels

Geographic Descriptor	Capital Costs: Without Considering Deployment Levels	Capital Costs: With ORNL 1997 Deployment Levels	Capital Costs: With ORNL 1999 Deployment Levels	Annual O&M Costs: Unchanged by 1999 Deployment Levels
Generic Large Area	$589M	$502M	$476M	$58M
Large Metropolitan Areas:				
60	$35.3B	$30.1B	$28.6B	$3.5B
75	$44.2B	$37.7B	$35.7B	$4.3B
% Difference	N/A	-14.7%	-19.2%	N/A

Note: Numbers are rounded

Alternative Values of Full Market Penetration

Just as it was important in the previous section to use the current market penetration estimates to reduce the estimate of still-needed investments, it is also important to determine the *maximum* amount of needed infrastructure investment. Section 4 described four proposed maximum levels that generally fall into one of two categories: what *could be deployed* and what *should be deployed*. It is believed that cost estimates presented thus far reflect the maximum amount of deployment or what *could* be deployed (based on the current definitions of the metropolitan ITS infrastructure). To show how the level of full deployment might affect the estimate of investment needs, a simple *parametric analysis* of the values for full market penetration was performed for the *National Costs Update*. A similar parametric analysis has been performed for this addendum. This analysis was carried out for the generic large metropolitan area using four different constant values for all cost elements for the percent that the "should" deployment levels might be of the "could" level. The four values are 33%, 50%, 67%, and 80%. The lower parametric value of 33% was added to this analysis to broaden the range of possible "should" levels.

The approach for calculating the results for these various levels is to start with information in table 1, and then add the appropriate constant value for the "should" level.

It can be shown algebraically that as long as the percent for the "should" level is larger than the largest value for the 1999 percent deployment shown in table 1 (this value is 66%), then the calculations for estimating the remaining costs for alternative values of full market penetration can be carried out at the aggregate level. For the four "should" levels only the 80% and 67% can be carried out at the aggregate level. The calculations for the 50% and 33% "should" levels could not be carried out at the aggregate level because, at these lower deployment levels we need to account for instances where ITS expenditures to date are greater than the "should" level capital cost. To not account for these "over expenditures" would misrepresent the investment needed to reach the "should" level.

Simplified versions of this calculation have been carried out using only the top-level or major ITS cost elements with the "should" level set to 50% and 33% of the could level. The results are shown in tables 3 and 4, respectively. The expenditures through 1999 are the top-level values from table 1. By carrying out the calculations and summing the columns, it can be seen that the total investment needed is $294 million at 50% and $194 million at 33% for the generic large area instead of $589 million. Furthermore, taking into account that $113 million has already been deployed through 1999, only $183 million and $98 million is remaining, respectively. The calculations for the other values of the should level have been carried out at the aggregate level, and are presented in table 5 and figure 1 along with the results from tables 3 and 4.

Making estimates of the investment needed at the national level depends quite heavily on the values estimated for the "should" level and base year deployment levels. These

Table 3
Effect of Setting Full Deployment at 50% of "Could" Case for Generic Large Areas

GENERIC LARGE METRO AREA

Major ITS Cost Elements	Capital Cost for Could Case ($K)		Capital Cost Expended Through 1999 ($K)	Should Case at 50% of Could Case ($K)	Should Case - 1999 Expenditure ($K)
SURVEILLANCE - ARTERIALS	$203,535		$9,159	$101,768	$92,609
SURVEILLANCE - FREEWAYS	$44,640		$8,357	$22,320	$13,963
COMMUNICATION - ARTERIALS	$37,500		$17,250	$18,750	$1,500
COMMUNICATION - FREEWAYS	$106,000		$14,840	$53,000	$38,160
TRAFFIC SIGNAL CONTROL	$13,750		$6,325	$6,875	$550
Freeway Management @ Roadside	$16,500		$1,120	$8,250	$7,130
Traveler Information @ Roadside	$31,900		$8,613	$15,950	$7,337
INCIDENT MANAGEMENT EQUIPMENT	$3,050		$439	$1,525	$1,086
TRANSPORTATION MGMT CENTERS	$30,000		$6,600	$15,000	$8,400
TRAVELER INFORMATION CENTER	$4,402		$968	$2,201	$1,233
EMERGENCY RESPONSE CENTER	$4,470		$2,950	$2,235	
EMERGENCY SERVICES EQUIPMENT	$990		$653	$495	
TRANSIT MANAGEMENT CENTER	$4,460		$1,338	$2,230	$892
TRANSIT VEHICLE INTERFACES	$12,600		$1,260	$6,300	$5,040
ELECTRONIC FARE PAYMENT SYS	$55,520		$22,464	$27,760	$5,296
ELECTRONIC TOLL COLLECTION SYS	$8,675		$3,730	$4,338	$608
SYS DESIGN & INTEGRATION	$10,800		$6,750	$5,400	
TOTAL PER METRO AREA	**$588,792**		**$112,816**	**$294,396**	**$183,803**
Derived Percentage of Full Deployment Capital Cost Expended Through 1999		**19.2%**			
Aggregate Level Calculations Using Derived Percentage	$588,792	19.2%	$112,816	$294,396	$181,580

Table 4
Effect of Setting Full Deployment at 33% of "Could" Case for Generic Large Areas

GENERIC LARGE METRO AREA

Major ITS Cost Elements	Capital Cost for Could Case ($K)		Capital Cost Expended Through 1999 ($K)	Should Case at 33% of Could Case ($K)	Should Case - 1999 Expenditure ($K)
SURVEILLANCE - ARTERIALS	$203,535		$9,159	67,167	$58,008
SURVEILLANCE - FREEWAYS	$44,640		$8,357	14,731	$6,374
COMMUNICATION - ARTERIALS	$37,500		$17,250	12,375	
COMMUNICATION - FREEWAYS	$106,000		$14,840	34,980	$20,140
TRAFFIC SIGNAL CONTROL	$13,750		$6,325	4,538	
Freeway Management @ Roadside	$16,500		$1,120	5,445	$4,325
Traveler Information @ Roadside	$31,900		$8,613	10,527	$1,914
INCIDENT MANAGEMENT EQUIPMENT	$3,050		$439	1,007	$568
TRANSPORTATION MGMT CENTERS	$30,000		$6,600	9,900	$3,300
TRAVELER INFORMATION CENTER	$4,402		$968	1,453	$485
EMERGENCY RESPONSE CENTER	$4,470		$2,950	1,475	
EMERGENCY SERVICES EQUIPMENT	$990		$653	327	
TRANSIT MANAGEMENT CENTER	$4,460		$1,338	1,472	$134
TRANSIT VEHICLE INTERFACES	$12,600		$1,260	4,158	$2,898
ELECTRONIC FARE PAYMENT SYS	$55,520		$22,464	18,322	
ELECTRONIC TOLL COLLECTION SYS	$8,675		$3,730	2,863	
SYS DESIGN & INTEGRATION	$10,800		$6,750	3,564	
TOTAL PER METRO AREA	**$588,792**		**$112,816**	**$194,301**	**$98,145**
Derived Percentage of Full Deployment Capital Cost Expended Through 1999		**19.2%**			
Aggregate Level Calculations Using Derived Percentage	$588,792	19.2%	$112,816	$194,301	$81,485

Table 5
Parametric Analysis of Changing From the "Could" Case Full Deployment Level to Various "Should" Cases
For the Generic Large Areas

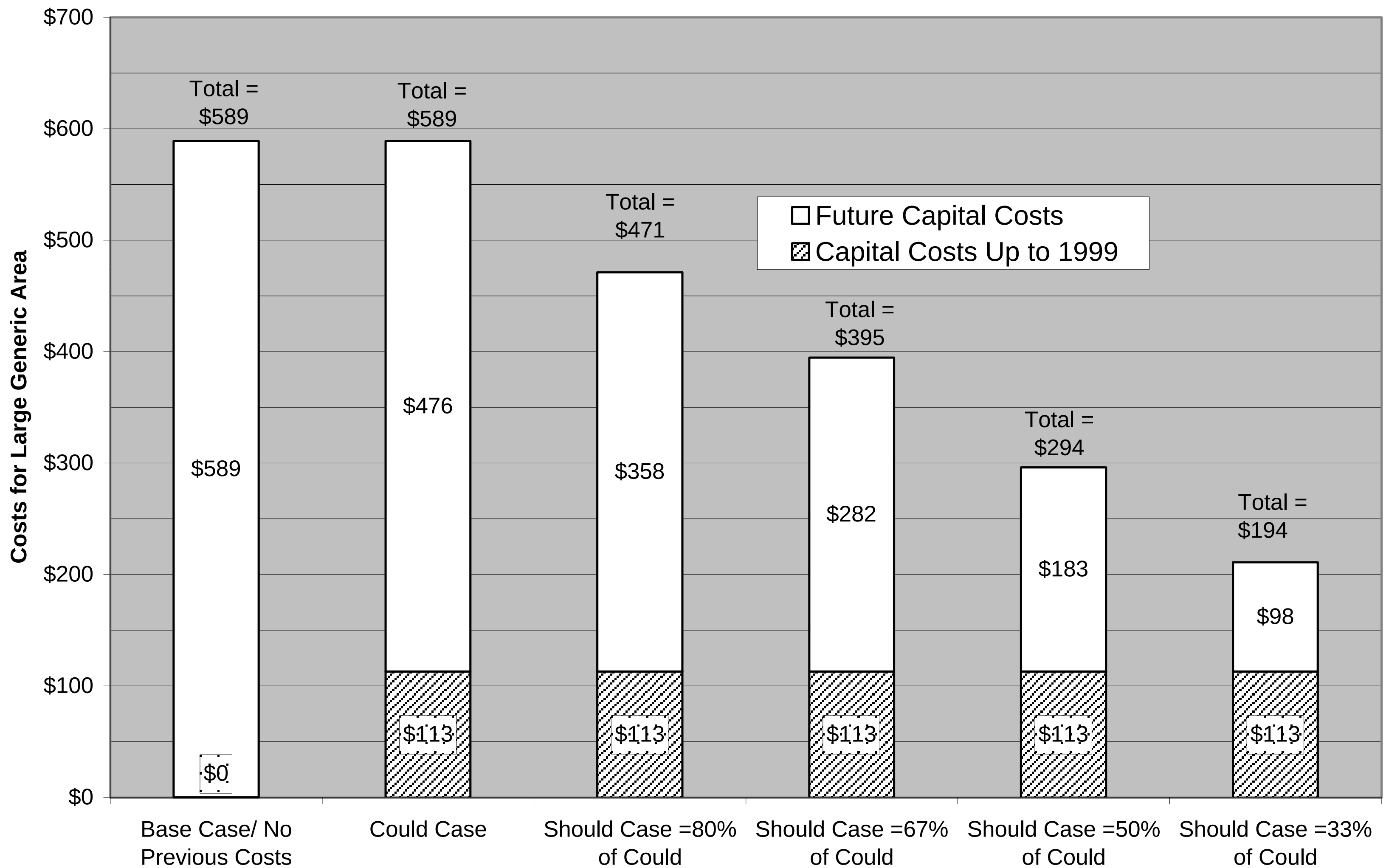
GENERIC LARGE METRO AREA

Capital Cost for "Could" Case Full Deployment ($M)	% Deployed Through 1999	Capital Costs Through 1999 ($M)	Parametrically Selected "Should" Case Capital Costs as % of "Could" Case	Capital Costs for "Should" Case Deployment ($M)	**Should Case Capital Costs - 1999 Capital Costs ($M)**
$589	19.2%	$113	*100%*	$589	**$476**
$589	19.2%	$113	*80%*	$471	**$358**
$589	19.2%	$113	*67%*	$395	**$282**
$589	19.2%	$113	*50%*	$294	**$183***
$589	19.2%	$113	33%	$194	**$98***

Note: The overall 1999 Deployment Percentage is derived in Table 1.

* Values are from tables 3 and 4, respectively.

Figure 1: Results of Parametric Analysis of Different Levels of Full Deployment Along With Previous Costs ($Millions)



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values will vary, not only by cost element, but by geographic region and transportation networks of each metropolitan area.

Summary and Conclusions

Applying the 1999 deployment data[4] to the cost tables provided in the *National Costs Update* provides a second set of data points with which to gauge the trend in ITS infrastructure deployment expenditures and to estimate the investment still to be made. The results show that progress is being made toward deployment of ITS infrastructure elements; hence, a reduction in the still-needed investment.

Table 6 shows ITS infrastructure trends from 1997 through 1999. To track trends from 1995 forward would portray unrealistic and inconclusive results because data on the extent of ITS deployment did not exist at that time. As shown in the *National Costs Update*, the update to the FHWA 1995 cost estimate resulted in a net increase in the needed ITS infrastructure investment (i.e., the base case needed investment). It is from this base case that the deployment tracking data was applied with 1997 deployment data and again in this addendum with 1999 deployment tracking data to determine the still-needed investment.

Table 6
ITS Infrastructure Costs Trends from 1997 through 1999

Geographic Descriptor	Capital Costs: Base Case	Capital Costs: With ORNL 1997 Deployment Levels	Capital Costs: With ORNL 1999 Deployment Levels	Annual O&M Costs: Unchanged by 1999 Deployment Levels
Generic Large Area	$589M	$502M	$476M	$58M
75 Largest Metropolitan Areas	$44.2B	$37.7B	$35.7B	$4.3B
% Difference	N/A	-14.7%	-19.2%	N/A

Note: Numbers are rounded

Approximately 19.2% of the needed capital costs for ITS large metropolitan areas has been expended through 1999. This value has increased by 4.5% from the 1997 expenditures of 14.7%. Accounting for expenditures through 1997, national capital costs for the largest 75 metropolitan areas were estimated at $37.7 billion. The same estimate accounting for expenditures through 1999 is approximately $35.7 billion. This equates to capital expenditures of approximately $1 billion per year over the two years. The estimate for annual O&M costs (see table C-4 of the *National Costs Update*) remains unchanged when the market penetration for the current time period is factored in.

[4] FHWA, 2000, ibid.

To investigate how the level of deployment might affect the estimate of investment needs, a parametric analysis similar to that performed in the *National Costs Update* was performed for the generic large metropolitan area. This analysis was performed for four different constant values – 33%, 50%, 67%, and 80% – with the constant values each representing the percent that the "should" deployment levels might be of the "could" (full deployment) level. The 100% level was defined as the "could" case, while the lower levels were defined as possible "should" cases. The lower value of 33% was included in this analysis to broaden the range of possible "should" cases.

Using a "should" case of 67% of the "could" case, the generic large area would need only $395 million, instead of $589 million. Furthermore, taking into account that $113 million has already been deployed through 1999, only $282 million is needed. Making estimates of the investment needed at the national level depends quite heavily on the values estimated for the "should" case and base year deployment levels. These values will vary, not only by cost element, but by geographic region and transportation networks of each metropolitan area.

Next Steps

As additional deployment tracking data become available, perhaps on an annual basis, the estimates of the still-needed investment can be updated. By receiving annual deployment data, ITS infrastructure deployment expenditures and trends can be better tracked and analyzed.