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Costs of In-Vehicle Information Systems and Associated Infrastructure

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ENERGY DIVISION

COSTS OF IN-VEHICLE INFORMATION SYSTEMS AND ASSOCIATED INFRASTRUCTURE

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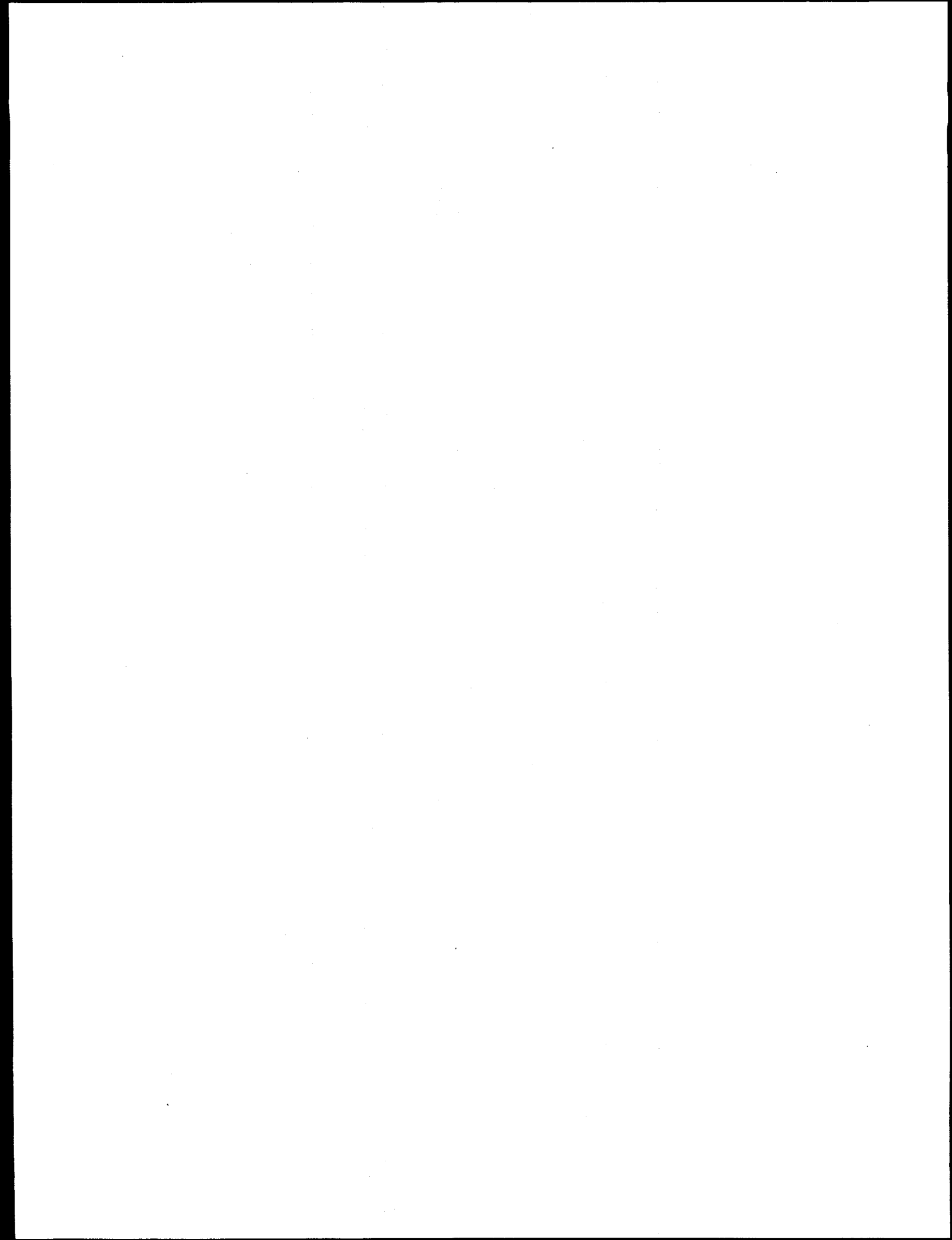
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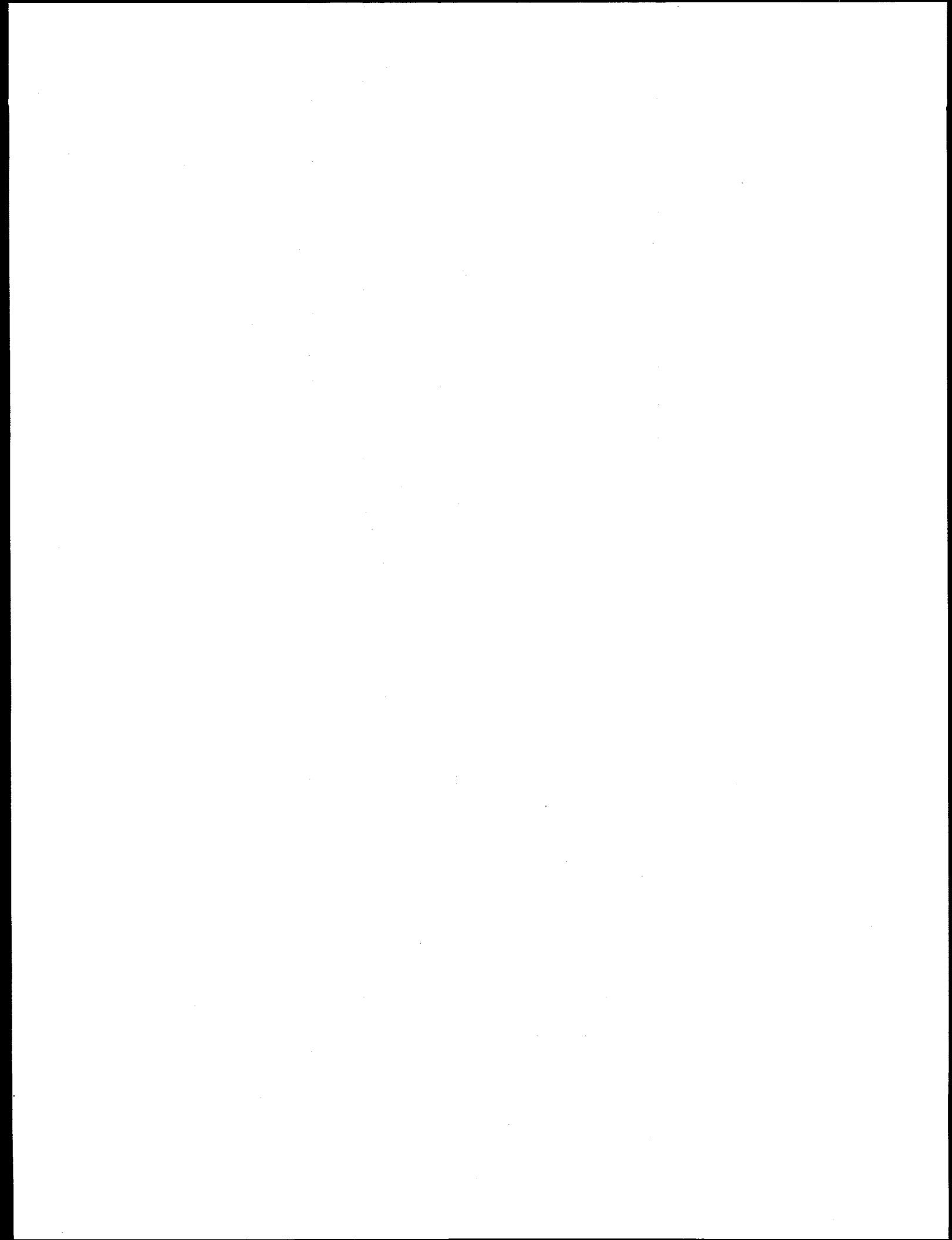
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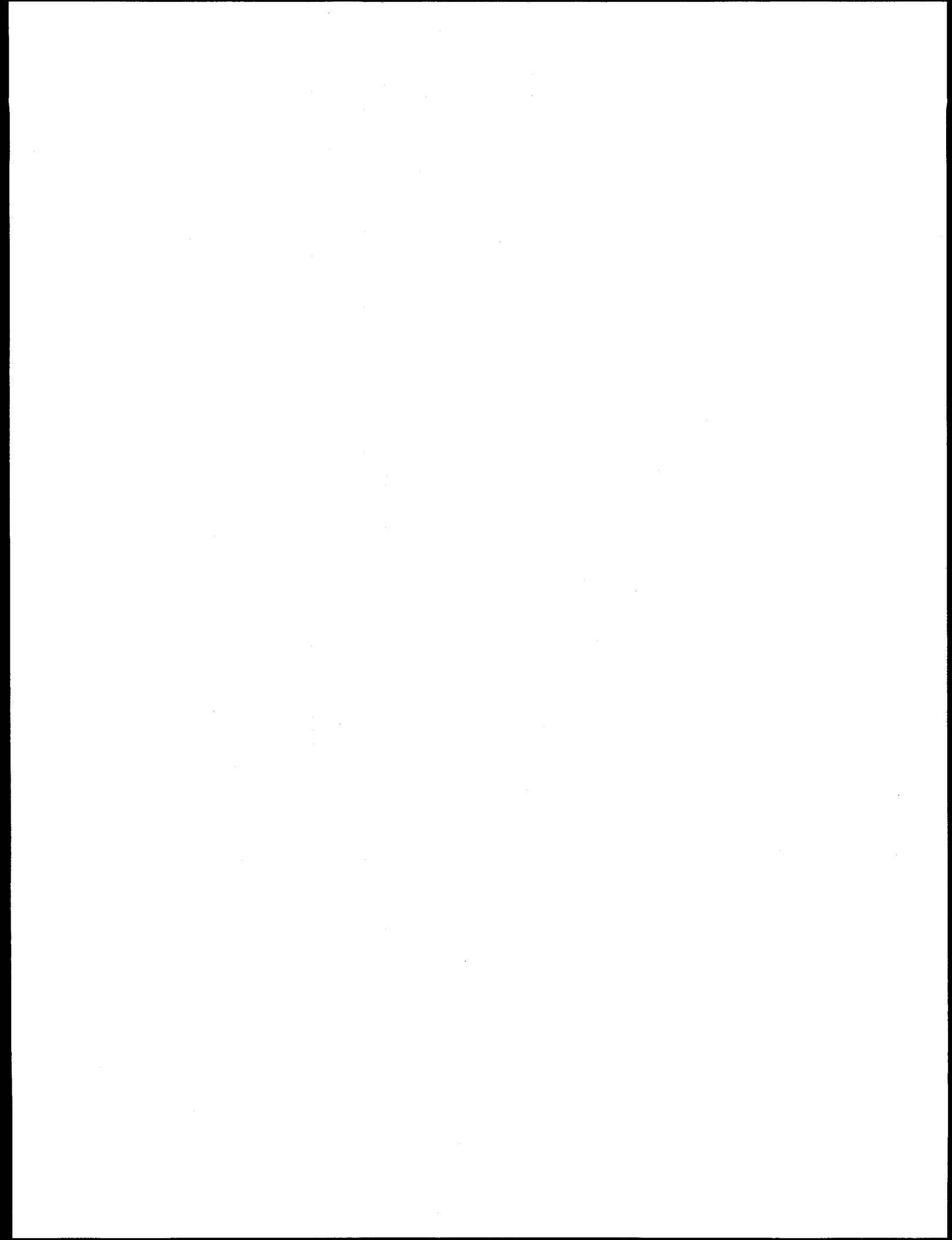
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EXECUTIVE SUMMARY

A keystone of intelligent transportation systems (ITS) are in-vehicle information systems (IVIS), which are designed to acquire, filter, prioritize, and display information about the driving environment to the driver of a road vehicle. Currently, many of the IVIS in the U.S. are Advanced Traveler Information Systems (ATIS) services, but further development of IVIS is envisioned to extend in the future toward dynamic and real-time vehicle control. Although the benefits of IVIS are expected to be sizeable, the costs of implementing these systems nationwide are expected to be significant as well. Because of the potential of IVIS to transform transportation, and the anticipated magnitude of their costs, better projections of the benefits and costs of these systems are needed. The purposes of this report are to develop a cost estimation methodology that makes projections of the costs of IVIS and associated infrastructure, and to illustrate the application of this methodology. The illustration of this methodology is limited to personal vehicles, but it can easily be adapted to commercial and transit IVIS, and to ITS in general.

The methodology developed here for estimating the costs of IVIS-related systems is a “bottom up” approach that calculates the costs of these systems based on the costs (i.e., prices) of their basic equipment components. The methodology takes the national ITS architecture as a fundamental starting point. In this architecture, ITS technologies provide services to their users through the deployment and use of *market packages* of technologies (such as interactive traveler information). Each market package consists of *equipment packages* (such as vehicle route guidance), which in turn consist of *components* (such as geographic information system). The market package cost is thus estimated as the sum of the cost of individual components in the equipment packages that comprise the market package, both inside and outside (i.e., infrastructure) the vehicle. Costs at the market package level are estimated for a specific deployment in a *life cycle* context. For infrastructure-related equipment packages, the life cycle cost includes the total capital, operating, and maintenance cost of individual components over a pre-determined deployment period. For in-vehicle equipment packages, the costs are estimated over the life of the vehicle (typically 14 years). The corresponding annualized, or *levelized*, cost is calculated as well. Since deployment of an IVIS is typically a multi-year endeavor, projections

of the future costs of the components are based on the historical price trends of electronic and other components available from the Bureau of Labor Statistics (BLS).

IVIS-related market package costs are estimated for user-defined deployment scenarios. Since infrastructure has a spatial aspect, the highway mileage, as well as other characteristics of the region in which a system is to be deployed, are parameters that are used to calculate the number of each component that is needed for region-wide deployment, given some assumptions about the market penetration rate (i.e., extent of deployment) of the system. Estimates are made of how much of this total regional deployment cost is likely to be paid by personal vehicle owners, private firms, the federal government, and state and local governments, based on simple fractional splits. To gain insight into the total size of the U.S. market and of the total funds needed by different parties (e.g., the federal government), the *regional* cost estimates are scaled to calculate *national* totals. This scaling is based on “expansion factors,” which are defined using the parameters used to estimate the number of units needed of each component within a region (e.g., highway mileage). The expansion factors are simply the ratio of the national value to the regional value.

To demonstrate the IVIS-cost estimation methodology, a multicriteria method was used to select five IVIS-related market packages from among all such packages:

- (1) Broadcast Traveler Information
- (2) Dynamic Route Guidance
- (3) Interactive Traveler Information
- (4) ISP-based Route Guidance, and
- (5) Intersection Collision Avoidance

The selected market packages provide a range of user-services currently being considered in the marketplace, and a varying degree of technology maturity.

Costs estimates for each component are compiled in a user-friendly information system. This information system provides price data, equipment descriptions, and data-source documentation for all of the components of the five market packages; and users of the software can edit this information. In addition, there are user-interfaces for other modules that allow users to “build” their own deployment scenarios and to calculate their costs.

In this study, we consider Urbansville and Thruville, as defined in the national ITS architecture study for a ten-year deployment period (i.e., 1997-2007), as representative urban

and interurban deployment scenarios, respectively. The national cost estimate of the Urbansville scenario is based on the largest 75 metropolitan areas targeted for implementation of Intelligent Transportation Infrastructure (ITI) within the next 10 years. The remaining 316 urbanized areas, of the total of 391 urbanized areas having a population greater than 50,000, were used to estimate the cost of nationwide implementation in Thruville regions. The market penetration rates of in-vehicle equipment packages are assumed to be considerably lower (i.e., less than 10%) and to penetrate the market much more gradually, compared to the extensive infrastructure deployment.

Projected regional costs of five IVIS-related market packages for a ten-year deployment period are shown in Table 1. Life cycle costs of in-vehicle equipment packages are assumed to be the greatest (i.e., \$10,000/vehicle) for ISP-based route guidance market packages, compared to the lowest cost of \$600/vehicle for the broadcast traveler information market package. The corresponding levelized costs of these in-vehicle equipment packages are estimated to be \$1,200/vehicle and \$68/vehicle, respectively. High annual recurring costs contribute greatly to the overall costs of the higher-cost packages. Furthermore, a significant reduction in the price of in-vehicle equipment package components is not assumed to occur within the next ten years.

Table 1. Projected Regional Costs of Five IVIS-Related Market Packages for a Ten-Year Deployment Period (1997-2007)

Market packages	Ten-year deployment cost (1996 dollars)					
	In-vehicle (per vehicle)		Infrastructure			
	Life cycle (\$)	Levelized (\$/yr)	Urban		Interurban	
			Life cycle (\$M)	Levelized (\$M/yr)	Life cycle (\$M)	Levelized (\$M/yr)
Broadcast Traveler Information	598	68	86.6	12.9	24.7	3.5
Interactive Traveler Information	5,294	605	115.7	17.0	32.3	4.5
Dynamic Route Guidance	5,704	652	87.6	13.0	25.1	3.5
ISP-Based Route Guidance	10,400	1,189	116.3	17.1	32.6	4.6
Intersection Collision Avoidance	4,854	555	96.4	13.7	20.4	2.9

Life cycle costs of infrastructure for various market packages range from \$87M to \$120M for the urban region, as shown in Table 1. The corresponding costs of infrastructure for the

interurban region are about 3 to 6 times lower than the urban region. Nationwide deployment of intersection collision avoidance (ICA) market packages is estimated to cost \$5,500M for the 75 largest urban regions and \$480M for the 316 interurban regions (due in large part to lower market penetration) as shown in Figure 1. Except for the ICA, the infrastructure required by different market packages has many equipment packages in common. Thus, the incremental infrastructure cost for implementing several market packages at the same time would be minimal (e.g., \$0.6M between interactive traveler information and ISP-based route guidance). The cost of nationwide infrastructure to support ISP-based route guidance is estimated to be \$5,400M for the 75 largest urban regions and \$1,300M for the 316 interurban regions. The infrastructure cost of this market package includes most of the infrastructure necessary for other market packages, i.e., dynamic route guidance, interactive traveler information, and broadcast traveler information.

Projected regional costs of five IVIS-related market packages are tabulated at the equipment package level by parties "likely" to pay in Tables 2 and 3, for single urban and interurban regions, respectively. The allocation of costs among parties is based on an assumption of very high federal involvement in ITS deployment during the next ten years. The *actual* allocation might reflect a much greater state (and local) split, as in current highway disbursements (FHWA 1996). In Tables 2 and 3 the federal government share of total life cycle costs is projected to be the greatest for roadway basic surveillance and roadway signal controls equipment packages (i.e., \$46M and \$45M, respectively, for the urban region). Similarly, for these two equipment packages, the state and local government share is calculated to be \$28M and \$25M, respectively. For interactive infrastructure information, the private sector is likely to pay the greatest cost, estimated to be \$31M and \$8.6M for urban and interurban regions, respectively. Since costs in interurban regions are anticipated to be considerably lower than in urban regions, the public sector share of total costs is also considerably lower in interurban regions. For nationwide implementation of IVIS market packages, it is estimated that the share of federal government spending is likely to be the greatest for roadway basic surveillance and roadway signal controls equipment packages (e.g., \$2,500M and \$2,000M, respectively for the urban region). The federal shares of the corresponding levelized (annual) costs of these equipment packages are \$360M and \$290M, respectively. Similarly, the private sector is likely to pay the entire life cycle costs of \$1,600M and \$260M for urban and interurban regions,

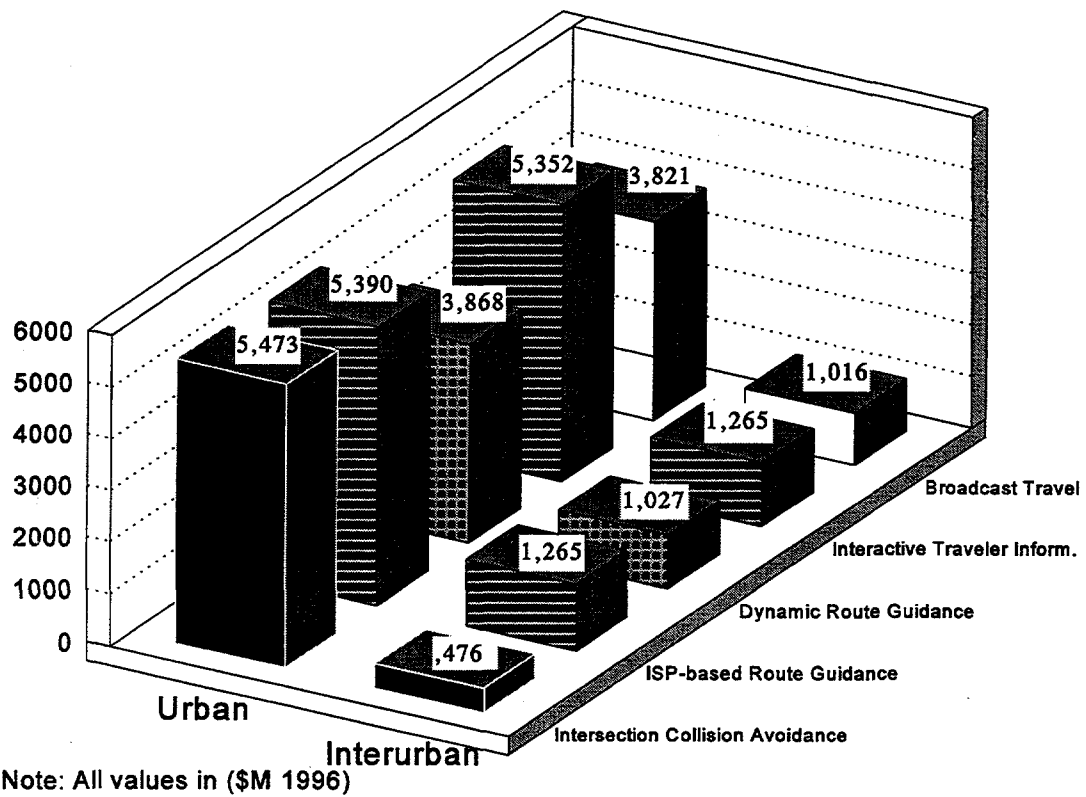


Fig. 1. Projected national deployment costs of the infrastructure for five IVIS-related market packages for a ten-year deployment period.

Table 2. Projected *Urban Region* Costs of the Infrastructure-Related Equipment Packages for Five IVIS-Related Market Packages for a Ten-Year Deployment Period, by *Parties Likely to Pay*

Equipment package	Ten-year deployment cost (\$M 1996)							
	Life cycle				Annual levelized			
	Fed	Stat	Pvt	Tot	Fed	Stat	Pvt	Tot
Basic Information Broadcast			2.9	2.9			0.4	0.4
Collect Traffic Surveillance	0.4	2.8		3.2	0.05	0.45		0.5
Infrastructure Provided Route Selection			0.6	0.6			0.08	0.08
Interactive Infrastructure Information			31	31			4.4	4.4
Roadway Basic Surveillance	46.2	27.8		74	6.6	4.4		11
Roadway Intersection Collision	0.02	0.01		0.03	0.002	0.002		0.004
Roadway Signal Controls	45.0	25		70	6.4	3.6		10
Roadway Signal Priority	6.5	4.1		10.6	0.9	0.6		1.5
TMC Multi-Modal Coordination	12.0	3.8		15.8	1.7	0.5		2.2
Transit Center Demand Responsive Operations	0.1	0.9		1.0	0.02	0.08		0.1
Transit Center Fare & Load Mgmt.	0.9	1.1		2.0	0.1	0.2		0.3
Transit Center Fixed Route Operations	0.3	0.9		1.2	0.05	0.15		0.2
Transit Center Tracking & Dispatch	0.6	2.7		3.3	0.1	0.4		0.5

Note: Fed: Federal Stat: State or Local Pvt: Private Sector Tot: Total

Table 3. Projected *Interurban Region* Costs of the Infrastructure-Related Equipment Packages for Five IVIS-Related Market Packages for a Ten-Year Deployment Period, by *Parties Likely to Pay*

Equipment packages	Ten-year deployment cost (\$M 1996)							
	Life cycle				Annual leveled			
	Fed	Stat	Pvt	Tot	Fed	Stat	Pvt	Tot
Basic Information Broadcast			1.4	1.4			0.2	0.2
Collect Traffic Surveillance	0.1	0.7		0.8	0.02	0.08		0.1
Infrastructure Provided Route Selection			0.3	0.3			0.04	0.04
Interactive Infrastructure Information			8.6	8.6			1.2	1.2
Roadway Basic Surveillance	12.3	7.7		20	1.7	1.1		2.8
Roadway Intersection Collision	0.007	0.003		0.01	0.001	0.0		0.001
Roadway Signal Controls	9.1	5.2		14.3	1.3	0.7		2.0
Roadway Signal Priority	1.8	1.1		2.9	0.3	0.1		0.4
TMC Multi-Modal Coordination	2.4	0.8		3.2	0.3	0.2		0.5
Transit Center Demand Responsive Operations	0.05	0.35		0.4	0.007	0.053		0.06
Transit Center Fare & Load Mgmt.	0.4	0.4		0.8	0.05	0.05		0.1
Transit Center Fixed Route Operations	0.1	0.3		0.4	0.02	0.04		0.06
Transit Center Tracking & Dispatch	0.3	1.0		1.3	0.04	0.16		0.2

Note: Fed: Federal Stat: State or Local Pvt: Private Sector Tot: Total

respectively, for the nationwide implementation of interactive infrastructure information equipment packages.

The projected cost estimates for the five IVIS-related market packages discussed in this report probably represent the high end because they are based on the assumption that none of the ITS technology currently deployed can be retrofitted or used. Also the estimates reflect some double-counting of costs in the "private" and "consumer" categories, and for components used in more than one equipment package (the costs of equipment packages are estimated as if they are stand-alone systems, independent of their intended use with specific market packages). Costs of different market packages should *not* be added to estimate the total cost due to double-counting of infrastructure costs common to several of these market packages.

IVIS technologies are still under development. Uncertainty about future technologies makes it difficult to project their costs. Thus, the estimates in this report should be regarded as order-of-magnitude projections that reflect specific assumptions about market penetration and other factors.

1. INTRODUCTION

1.1 GENERAL DESCRIPTION OF IVIS

The nation's surface transportation system is on the brink of an information technology revolution that will enhance the safety, mobility and efficiency of its roadways. A keystone of these intelligent transportation systems (ITS) are in-vehicle information systems (IVIS), which are designed to acquire, filter, prioritize, and display information about the driving environment to the driver of a road vehicle. For travel on roadways, the information included in an IVIS system comprises the set of services called Advanced Traveler Information Systems (ATIS), as well as other information systems being developed under the U.S. Department of Transportation's (DOT's) ITS program, as well as by many firms.

Currently, many of the IVIS in the U.S. are ATIS services. ATIS products are being sold through retail, car rental, and direct sale channels. ATIS products and services currently fall into one of two categories: (a) live traffic information; and (b) location, route guidance, and navigation products. Traffic information is generally available to consumers free of additional charge via existing broadcast and communications services, such as radio, cellular phones and the internet. Location, route guidance, and navigation products are sold through direct mail and audio and computer retail channels. These products may require separate purchase of global positioning system (GPS) and interface hardware, in addition to digitized maps and navigation and routing software. A recent study by Volpe (1996) provides an excellent update of the commercial ATIS market. In the longer term, further development of IVIS is envisioned to extend toward dynamic and real-time vehicle control. These advanced technologies will support the display of real-time data and information to the driver for eventual translation into a vehicle control activity.

1.2 MOTIVATION

Although the benefits of IVIS are expected to be sizeable, the costs of implementing these systems nationwide are expected to be significant as well. Because of the potential of IVIS to transform transportation, and the anticipated magnitude of their costs, better projections of the benefits and costs of these systems are needed. Such estimates will enhance the efficient deployment of IVIS, by reducing uncertainty about the financial risks and rewards of these systems. To date, most studies have concentrated on ITS benefits and only a few on costs. No

specific IVIS cost estimates are currently available. A few cost studies are generally related to intelligent transportation infrastructure (ITI) (e.g., Stevens and Chin 1992). For the most part, they are neither sufficiently detailed nor publicly available. Although price information is available for commercial ATIS products and services that operate inside vehicles, few attempts have been made to estimate total IVIS costs by combining in-vehicle and infrastructure costs.

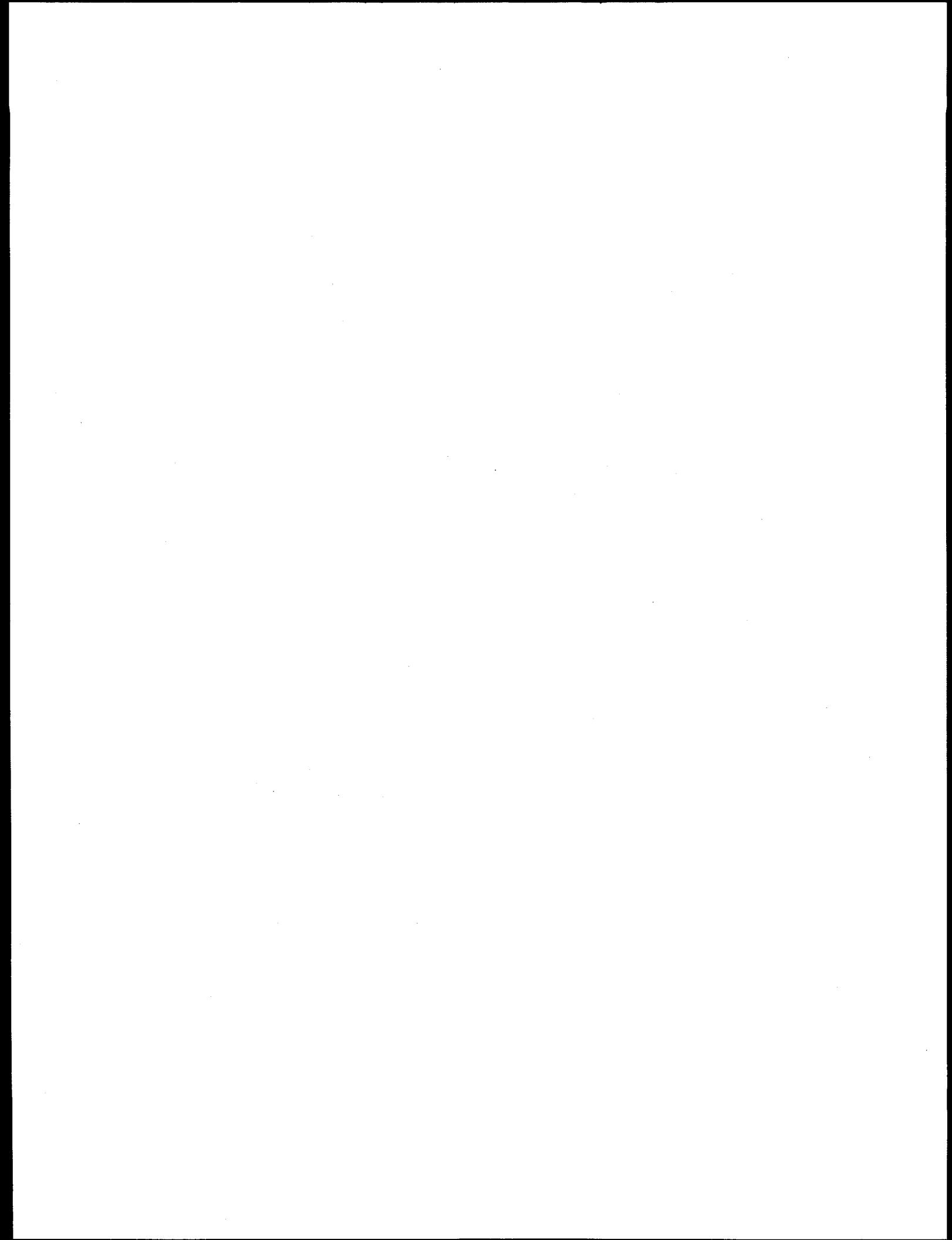
One of the few ITS cost studies done thus far was for the national ITS architecture study (DOT 1996b). This study updated the 1994 Phase I national ITS architecture study by Rockwell International, Inc. This updated study provides estimates of the costs (i.e., expenditures) of implementing ITS services by using information on the unit prices and quantities of various ITS technologies. An evaluation of expenditures for sample deployments of ITS services is also included in this study. However, most of the underlying assumptions on cost information are not detailed, and IVIS costs are not explicitly estimated. Other studies available in the literature, such as on ITS operational tests and model deployments, do not provide any detailed, comprehensive cost information.

Ongoing studies are expected to provide more information, and their findings will complement the estimates made in this report. Intelligent Transportation Systems of America (ITS America) is currently co-funding two studies on ITS national investment and markets.¹ The first of these studies is co-sponsored by the US DOT Joint Program Office. It is analyzing the public and private investments that will be needed to realize the national goals of ITS deployment, along with its costs, benefits, and economic impacts. The costs are being estimated by taking the ITS architecture study's (DOT's 1996b) cost estimates for an urban region, and by using expansion factors, based on the numbers and sizes of U.S. cities, to calculate a national total. The Electronics Industry Association is the co-sponsor of the other study. Its aim is to forecast the expected U.S. and international markets for ITS technologies, products, and services over the next 5, 10, and 20 years.

¹ The reports from these two studies were not published at the time that our study was done. These other reports are now available (ITSA 1997).

1.3 PURPOSE

The purposes of this report are to develop a cost estimation methodology that makes projections of the costs of IVIS and associated infrastructure systems, and to illustrate the application of this methodology. The illustration of the methodology is limited to personal vehicles, but it can easily be adapted to commercial and transit IVIS, and to ITS in general. The next section of this report gives an overview of each major step of the methodology. The remaining sections of the report individually describe each step and tabulate the numerical results.



2. OVERVIEW OF METHODOLOGY

The methodology for estimating the costs of IVIS-related systems is a "bottom up" approach that calculates the costs of these systems based on the costs (i.e., prices) of their basic equipment components. The method consists of the following steps:

- (1) *Define market package configurations:* The methodology takes the national ITS architecture as its fundamental starting point. In this architecture, ITS technologies provide services to their users through the deployment and use of integrated *market packages* of technologies (such as interactive traveler information). Each market package consists of *equipment packages* (such as vehicle route guidance), which in turn consist of *components* (such as a geographic information system). The first step of the methodology is to identify the relevant market packages and to define their constituent equipment packages, and their components, consistent with the national ITS architecture. This analysis is described in Section 3.
- (2) *Determine prices of components:* The next step is to compile individual-component cost information. This information is obtained from various industry sources. The ITS architecture study's cost estimates serve as a starting point for a more detailed compilation of these estimates. These costs are then used to calculate a total *life cycle cost*, which represents the total capital, operating, and maintenance cost of the equipment over a pre-determined deployment period (of say 10 years). The corresponding annualized, or *levelized*, cost is calculated as well. Section 4 describes the meaning of these costs, describes the sources of data, and tabulates the component prices.
- (3) *Make projections of future costs:* Since deployment of any system is typically a multi-year endeavor, it is necessary to make projections of the future costs of the equipment. Various methods may be used, such as assuming no change in costs, or assuming a fixed percentage annual increase or decrease. Section 5 discusses this issue and describes how costs were projected in this study. The approach is to use recent historical data on the *price trends* of electronic and other components, and to assume that these price trends will continue. Each component is categorized into one of four categories of components, the price trends of each category are statistically estimated, and the estimated equations are applied to project the future prices of each component.

- (4) *Define deployment scenarios:* After the prices of each component are compiled and future prices projected, it is necessary to define the scenario(s) under study. In this study, we report on calculations for the Urbansville and Thruville scenarios defined in the national architecture study. These scenarios are intended as being representative of large urban and interurban deployments, respectively. The highway mileage, as well as other characteristics of the region in which a system is to be deployed, are parameters that are used to calculate the number of units of each component that are needed for region-wide deployment, given some assumptions about the market penetration (i.e., extent of deployment) of the system. Section 6 describes the deployment scenarios considered in this study.
- (5) *Make cost estimates:* The next step is to calculate the total costs of a regionwide (i.e., Urbansville or Thruville) deployment. Data on the current and projected costs of each component are multiplied by estimates of the number of units of each component needed each year to calculate the costs of regionwide deployment. Then, estimates are made of how much of this total is likely to be paid by personal vehicle owners, private firms, the federal government, and state and local governments, based on simple fractional splits. Section 7 describes these results.
- (6) *Scale estimates to calculate national totals:* To gain insight into the total size of the U.S. market and of the total funds needed by different parties (e.g., the federal government), the region-wide cost estimates are scaled to estimate national totals. This scaling is based on "expansion-factors." These expansion factors are defined by the ratio of the expected national deployment to the size of the regional deployment, based on the parameters used to estimate the numbers of units needed of each component for regional deployment (e.g., highway mileage). Thus, the ratio of, for example, total highway mileage in the largest 75 metropolitan areas in the U.S. to the highway mileage in Urbansville is used as an expansion factor to calculate the total costs of deployment in these cities. Similarly, data on the next 316 largest areas having a population of more than 50,000 in the U.S. are used to calculate ratios to scale up the cost estimates for Thruville to estimate the total costs in the U.S. for interurban corridor deployments. Section 8 describes this analysis in more detail.

Together, these steps provide a simple, yet systematic, approach for estimating the costs of IVIS-related systems.

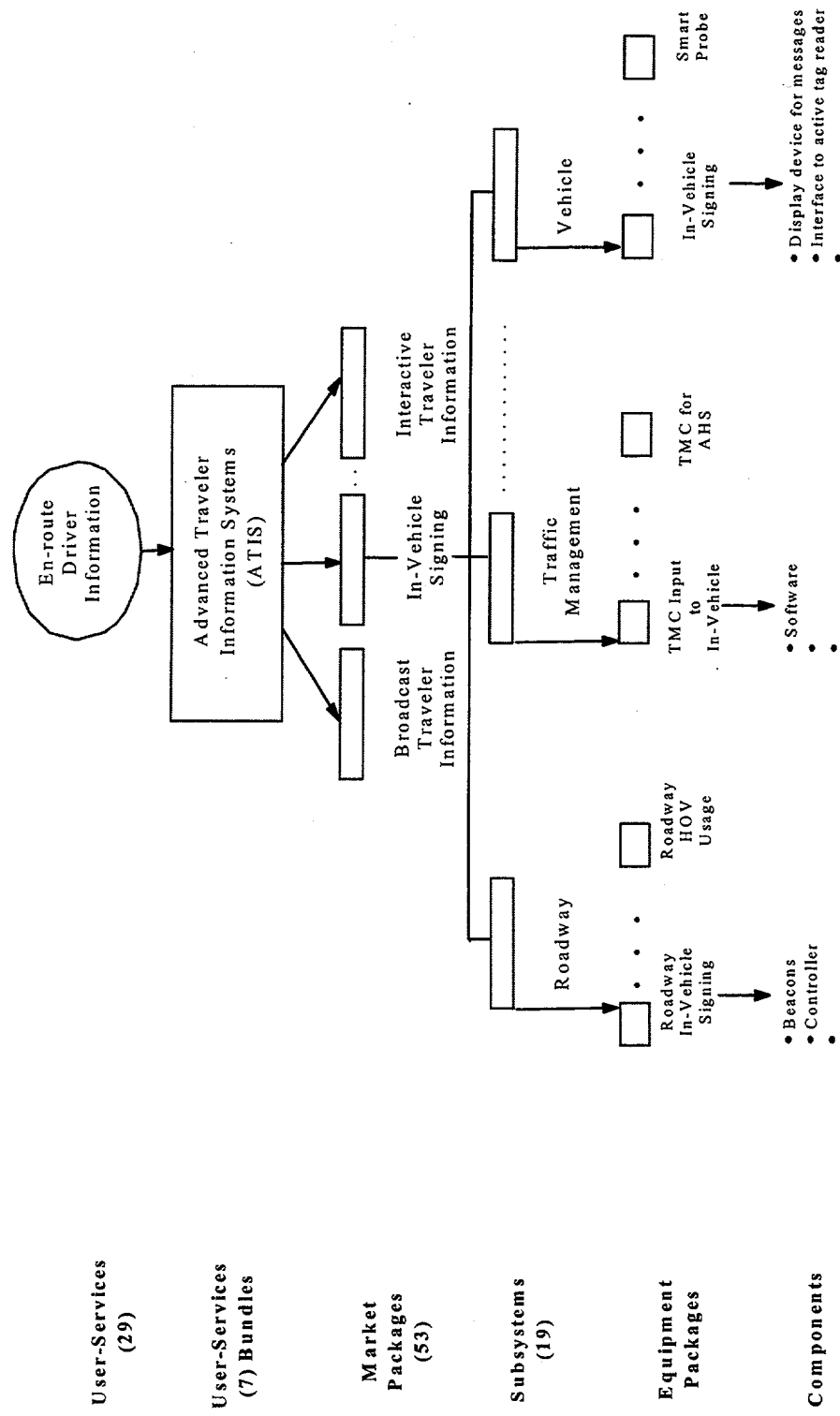
3. IVIS-RELATED MARKET PACKAGES, SUBSYSTEMS, AND EQUIPMENT

3.1 DEFINING IVIS WITHIN THE FRAMEWORK OF THE ITS ARCHITECTURE

The IVIS defined here are based on the recently completed national ITS architecture study (DOT 1996a). The national ITS architecture provides a framework for designing transportation systems that implement the ITS user services and that create opportunity for interoperability across diverse nationwide deployments, while preserving flexibility and choice for the many implementors. The architecture can be implemented to achieve these benefits in three principal ways: (1) adaptation or development of consensus standards for transportation products based on architecture requirements, (2) development of regional architectures that interpret the national architecture and that tailor it to support integrated regional ITS solutions, and (3) incremental deployment of architecture compatible systems (DOT 1996a). The modular design concept of the national ITS architecture allows the incremental deployment of ITS services, taking advantage of mature ITS technologies to establish an early market for ITS products and services. In addition, a subset of the national architecture maps well with the Intelligent Transportation Infrastructure (ITI), designed to be implemented in the 75 largest metropolitan areas within the next 10 years. ITI will provide the essential ITS infrastructure for the full range of ITS services.

Figure 3.1 defines IVIS based on the national ITS architecture, using the in-vehicle signing market package as a specific example. ITS services are defined in terms of *user services* that are provided by specific ITS technologies. The *market packages* provide user services that might be required by traffic managers, transit operators, travelers, and other ITS stakeholders. A market package often includes capabilities that span more than one user service. For example, the in-vehicle signing market package provides two kinds of user services (i.e., en-route driver information and traffic control). A set of market packages comprises an *IVIS system*.

The market packages are grouped into seven *user-services bundles*. IVIS market packages fall under four of these bundles, i.e., Advanced Traveler Information Systems (ATIS), Advanced Traffic Management Systems (ATMS), Advanced Vehicle Safety Systems (AVSS), and Emergency Management (EM). A total of sixteen IVIS market packages have been identified, nine of which belong to ATIS. ATIS market packages provide information on current and near-future traffic conditions, road hazards on intended routes, and weather conditions, as well as accommodations, services, and recreation.



Note: Numbers within parenthesis indicate the total number of given ITS architecture elements defined in the national ITS architecture study.

Fig. 3.1. Definition of IVIS (In-Vehicle Signing market package is shown as an example).

Subsystems define the architecture necessary for the implementation of market packages. Subsystems consist of *equipment packages* that have specific functions. A combination of interrelated equipment packages is generally necessary for the implementation of a market package. Equipment packages may be purchased and operated by different stakeholders. An equipment package represents a set of equipment/capabilities that are purchased by an end-user to achieve a desired capability and thus are also termed “units of deployment.” For the example of the in-vehicle signing market package in Fig. 3.1, Roadway, Traffic Management, and Vehicle are the three architecture subsystems. Roadway In-Vehicle Signing, Traffic Management Center (TMC) Input to In-Vehicle, and In-Vehicle Signing, respectively, are the corresponding equipment packages within these subsystems for this market package. The vehicle subsystem encompasses the equipment package inside the vehicle; whereas, the other two subsystems are outside the vehicle and thus are infrastructure-related. The in-vehicle equipment package will be purchased by the vehicle-user (i.e., owner); whereas, the other two equipment packages provide information.

Components are the specific hardware and/or software that constitute an equipment package. Examples of components are beacons, controllers, and in-vehicle display monitors. When equipment packages are purchased and deployed or installed, specific component *models* are either directly assembled into an equipment package or indirectly selected as part of a pre-bundled equipment package.

3.2 IVIS-RELATED SYSTEMS

Table 3.1 lists sixteen market packages identified for personal IVIS based on the national ITS architecture. Note that these market packages involve significant interaction with the driver of the vehicle in some form, i.e., physical/visual/audio. Also listed in Table 3.1 are the equipment packages, which are for both inside and outside the vehicle, for each market package. Equipment packages necessary inside the vehicle belong to the personal vehicle subsystem; whereas, most of the infrastructure-related equipment packages outside the vehicle belong to traffic management and transit management subsystems..

Table 3.2 lists market packages and equipment packages for commercial and transit IVIS. As indicated previously, this report focuses on personal IVIS, so that the packages listed in

Table 3.1. List of Market Packages and Equipment Packages for Personal In-Vehicle Information Systems

PERSONAL VEHICLE SYSTEM						
	Market Package	Equipment Packages (In-Vehicle)	Equipment Packages (Outside)	Equipment Packages (Outside)	Equipment Packages (Outside)	Equipment Packages (Outside)
ATIS	Broadcast Traveler Information	Basic Vehicle Reception	Basic Info. Broadcast (ISP)	Collect Traffic Surveillance (TMS)	Roadway Basic Surveillance (RS)	Transit Center Fare & Load Mgmt (TRMS)
			Transit Center Fixed-Route Operations (TRMS)	Transit Center Tracking & Dispatch (TRMS)		
	Interactive Traveler Information	Interactive Vehicle Reception	Interactive Infrastructure Info.(ISP)	Collect Traffic Surveillance (TMS)	Roadway Basic Surveillance (RS)	Transit Center Fare & Load Mgmt (TRMS)
		Vehicle Route Guidance	Transit Center Fixed-Route Operations (TRMS)	Transit Center Tracking & Dispatch (TRMS)	Transit Center Demand Responsive Operations (TRMS)	
	Autonomous Route Guidance	Vehicle Route Guidance				
	Dynamic Route Guidance	Basic Vehicle Reception	Basic Info. Broadcast (ISP)	Collect Traffic Surveillance (TMS)	Roadway Basic Surveillance (RS)	Transit Center Fare & Load Mgmt (TRMS)
		Vehicle Route Guidance	Transit Center Fixed-Route Operations (TRMS)	Transit Center Tracking & Dispatch (TRMS)		
		In-Vehicle Signing				
	ISP-Based Route Guidance	Interactive Vehicle Reception	Infrastructure Provided Rte. Selection (ISP)	Interactive Infrastructure Info.(ISP)	Collect Traffic Surveillance (TMS)	Roadway Basic Surveillance (RS)
		Vehicle Route Guidance	Transit Center Fixed-Route Operations (TRMS)	Transit Center Tracking & Dispatch (TRMS)	Transit Center Demand Responsive Operations (TRMS)	
	Integrated Transp. Management/Rte. Guidance	Interactive Vehicle Reception	Interactive Infrastructure Info.(ISP)	ISP Advanced Integr. Control Support (ISP)	TMC Advanced Signal Control (TMS)	
		Vehicle Route Guidance	Transit Center Fixed-Route Operations (TRMS)	Transit Center Tracking & Dispatch (TRMS)	Transit Center Demand Responsive Operations (TRMS)	
			Collect Traffic Surveillance (TMS)	Roadway Basic Surveillance (RS)	Transit Center Fare & Load Mgmt (TRMS)	
	Yellow Pages and Reservation	Interactive Vehicle Reception	Infra. Provided Yellow Pages & Reservn. (ISP)	interactive Infrastructure Info.(ISP)		
	Vehicle Route Guidance					
Dynamic Ridesharing	Interactive Vehicle Reception	Infra. Provided Dynamic Ride Sharing (ISP)	Interactive Infrastructure Info.(ISP)	Transit Center Fare & Load Mgmt (TRMS)		
	Vehicle Route Guidance	Transit Center Fixed-Route Operations (TRMS)	Transit Center Tracking & Dispatch (TRMS)	Transit Center Demand Responsive Operations (TRMS)		
In-Vehicle Signing	In-Vehicle Signing	Roadway In-Vehicle Signing (RS)	TMC Input to In-Vehicle Signing (TMS)			
ATMS	Dynamic Toll/Parking Fee Management	Vehicle Toll/Parking Interface	TMC Toll/Parking Coordination (TMS)	Toll Plaza Toll Collection (TCS)	Toll Administration (TAS)	Parking Management (PMS)
EM	Mayday Support	Vehicle Mayday I/F	Emergency Mayday & E-911 Interface (EM)			
		Vehicle Route Guidance				
AVSS	Vehicle Safety Monitoring	Vehicle Safety Monitoring				
		Vehicle Route Guidance				
	Longitudinal Safety Monitoring	Vehicle Longitudinal Warning				
	Lateral Safety Warning	Vehicle Lateral Warning				
	Intersection Safety Warning	Vehicle Intersectn. Coll. Warning	Roadway Intersection Collision (RS)	Roadside Signal Priority (RS)	Roadway Signal Controls (RS)	TMC Multi-Modal Coordination (TMS)
	Intersection Collision Avoidance	Vehicle Intersection Control	Roadway Intersection Collision (RS)	Roadside Signal Priority (RS)	Roadway Signal Controls (RS)	

Note: Text within the parenthesis indicates subsystems to which each equipment package (outside the vehicle) belongs.

LEGEND: ATIS: Automated Traveler Information System ATMS: Advanced Traffic Management Systems AVSS: Advanced Vehicle Safety Systems
 EM: Emergency Management ISP: Information Service Provider Subsystem PMS: Parking Management Subsystem
 RS: Roadway Subsystem TAS: Toll Administration Subsystem TCS: Toll Collection Subsystem
 TMS: Traffic Management Subsystem TRMS: Transit Management Subsystem

Table 3.2. List of Market Packages and Equipment Packages for Commercial and Transit In-Vehicle Information Systems

COMMERCIAL VEHICLE SYSTEM						
	Market Package	Equipment Packages (In-Vehicle)	Equipment Packages (Outside)	Equipment Packages (Outside)	Equipment Packages (Outside)	Equipment Packages (Outside)
CVO	Fleet Administration	On-board Trip Monitoring	Fleet Administration (FMS)	Fleet Maintenance Mgmt. (FMS)	Infrastructure Provided Rte. Selection (ISP)	
	Freight Administration	On-board Cargo Monitoring	Freight Admin. & Management (FMS)			
	Electronic Clearance	On-board CV Electronic Data	CV Informn. Exchange (CVAS)	Roadside Electronic Screening (CVCS)		
	Intl. Border Electronic Clearance	On-board CV Electronic Data	Fleet Credentials & Taxes Mgmt. & Reporting (FMS)	Intl. Border Crossing (CVCS)	CV Informn. Exchange (CVAS)	Intl. CV Admin. (CVAS)
	Weigh-In-Motion	On-board CV Electronic Data	Roadside WIM (CVCS)			
	Roadside CVO Safety	On-board CV Electronic Data	Citation and Accident Electronic Recording (CVAS)	Roadside Safety Inspection (CVCS)	CV Informn. Exchange (CVAS)	CV Safety Admin. (CVAS)
	On-Board CVO Safety	On-board CV Safety	Citation and Accident Electronic Recording (CVAS)	CV Informn. Exchange (CVAS)	CV Safety Admin. (CVAS)	
		On-board Trip Monitoring				
	CVO Fleet Maintenance	On-board CV Safety	Fleet Maintenance Mgmt. (FMS)			
		On-board Trip Monitoring				
	HAZMAT Management	On-board CV Electronic Data	CV Safety Admin. (CVAS)	Emergency Mayday and E-911 I/F (EM)	Emergency Response Mgmt. (EM)	Emergency & Incident Mgmt. Comm. (EM)
		Vehicle Mayday I/F	TMC Incident Dispatch Coordn./Comm. (TMS)	Fleet HAZMAT Mgmt. (FMS)		
	On-board Cargo Monitoring					
TRANSIT VEHICLE SYSTEM						
	Market Package	Equipment Package (In-Vehicle)	Equipment Packages (Outside)	Equipment Packages (Outside)	Equipment Packages (Outside)	Equipment Packages (Outside)
APTS	Transit Vehicle Tracking	On-board Trip Monitoring	Transit Center Tracking and Dispatch (TRMS)			
	Transit Fixed-Route Operations	Vehicle Dispatch Support	Transit Center Fixed-Route Operations (TRMS)			
	Demand Response Transit	On-board Transit Driver I/F	Transit Center Paratransit Operations (TRMS)	Interactive Infrastructure Info (ISP)		
	Transit Passenger and Fare Mgmt.	On-board Transit Fare and Load Mgmt.	Transit Center Fare and Load Mgmt. (TRMS)			
	Transit Security	On-board Transit Security	Transit Center Security (TRMS)	Emergency Response Mgmt. (EM)		
	Transit Maintenance	On-board Maintenance	Fleet Maintenance Mgmt. (TRMS)			
	Multi-modal Coordination	On-board Vehicle Signal Coordination	Transit Center Multi-Modal Coordination (TRMS)	TMC Multi-Modal Coordn. (TMS)	Roadside Signal Priority (RS)	

Note: Text within the parenthesis indicates subsystems to which each equipment package (outside the vehicle) belongs.

LEGEND: APTS: Advanced Public Transit Systems
EM: Emergency Management Subsystem
TMS: Traffic Management Subsystem

CVAS: Commercial Vehicle Administration Subsystem
FMS: Fleet Management Subsystem
TRMS: Transit Management Subsystem

CVCS: Commercial Vehicle Check Subsystem
ISP: Information Provider Subsystem

CVO: Commercial Vehicle Opern
RS: Roadway Subsystem

Table 3.2 are not included in the calculations in this report. However, the general methodology is applicable to these systems as well.

3.3 SELECTION OF MARKET PACKAGES

It was necessary to reduce the scope of the study from the sixteen market packages listed in Table 3.1 to about four or five market packages. The following criteria were used to make this selection:

- a) If the market package is one of the early market packages identified by the national ITS architecture study, then it was given priority. Early market packages have been highlighted as important for early deployment if they meet at least three of the following five criteria: enabling function (i.e., enables future deployments of more advanced services), technology available, standards not required, few institutional issues, and established benefits.
- b) If infrastructure for the market package is to be developed as a part of implementation of the Intelligent Transportation Infrastructure in the 75 largest metropolitan areas within the next 10 years, then the package was given priority.
- c) If federal funding is likely to be available to deploy this market package, then it is given priority.
- d) If there are market packages with functions in common, creating market package synergy, then such packages were given priority.
- e) Packages with a greater number of different types of benefits (in terms of the six ITS system goals discussed in the national ITS architecture study) were given priority.

A multicriteria method using the five criteria was used to select from among the various market packages. Table 3.3 shows the ranking of the market packages using the multicriteria method. Each market package was evaluated separately on each criterion (a 0–10 scale was used). A 50% weight was assigned to the “Benefits” criterion. The remaining 50% weight was distributed equally among the remaining four criteria.

The top-four ranked market packages, as indicated in Table 3.4, were selected for more detailed consideration in this study. Also, the last-ranked market package was selected to afford greater diversity to the set of market packages studied. Thus, the following market packages were selected: i.e., (i) broadcast traveler information, (ii) interactive traveler information, (iii) dynamic route guidance (iv) ISP-based route guidance, and (v) intersection collision avoidance.

Table 3.3. Characteristics of Market Packages of IVIS for Personal Vehicles

	Market package	Early market package	ITI implementation	Federal funding necessary	Market packages with common functions	Benefits
A T I S	Broadcast Traveler Information (BTI)	Y	Y	F	ITI	1,2,3,6
	Interactive Traveler Information (ITI)	Y	Y	F	BTI, DR, YPR, IRG	1,2,3,6
	Autonomous Route Guidance (ARG)	Y	NA	NA	DRG	1,2,6
	Dynamic Route Guidance (DRG)	N	Y	F	ARG, IRG	1,2,3,4,6
	ISP-Based Route Guidance (IRG)	N	Y	F	ITRG, DRG, ITI	1,2,3,4,6
	Integrated Transportation Management/Route Guidance (ITRG)	N	N	F	IRG	1,2,3,4,6
	Yellow Pages and Reservation (YPR)	N	Y	F	ITI	2,6
	Dynamic Ridesharing (DR)	N	Y	P	ITI	1,2,3,6
A T M S	In-Vehicle Signing (IVS)	N	N	P	DTP	2,4,6
	Dynamic Toll/Parking Fee Management (DTP)	N	Y	P	IVS	5,6
E M	Mayday Support (MS)	Y	N	N	NA	4,5,6
A V S S	Vehicle Safety Monitoring (VSM)	Y	NA	NA	ISW, LSW	4,6
	Longitudinal Safety Monitoring (LSM)	N	NA	NA	NA	4,6
	Lateral Safety Warning (LSW)	N	NA	NA	VSM	4,6
	Intersection Safety Warning (ISW)	N	N	P	VSM	4,6
	Intersection Collision Avoidance (ICA)	N	N	N	ISW	4,6

Note: 1 = Increase Transportation System Efficiency 2 = Improve Mobility
 3 = Reduce Fuel Consumption and Environmental Cost 4 = Improve Safety
 6 = Create an Environment for an ITS Market
 F = Full Funding Necessary NA= Not Applicable
 P = Partial Funding Necessary (when both transit and traffic management architecture subsystems are not necessary)

Table 3.4. Ranking of Market Packages of IVIS for Personal Vehicles Based on the Multicriteria Method

	Market Package	Ranking Value
ATIS	Interactive Traveler Information (ITI)	9.0
ATIS	ISP-Based Route Guidance (IRG)	8.4
ATIS	Broadcast Traveler Information (BTI)	8.1
ATIS	Dynamic Route Guidance (DRG)	8.1
ATIS	Autonomous Route Guidance (ARG)	7.1
ATIS	Integrated Transportation Management/Route Guidance (ITRG)	6.6
AVSS	Vehicle Safety Monitoring (VSM)	6.4
ATIS	Dynamic Ridesharing (DR)	6.2
ATIS	Yellow Pages and Reservation (YPR)	4.8
AVSS	Lateral Safety Warning (LSW)	4.8
AVSS	Longitudinal Safety Monitoring (LSM)	4.5
EM	Mayday Support (MS)	4.3
ATMS	Dynamic Toll/Parking Fee Management (DTP)	4.2
ATIS	In-Vehicle Signing (IVS)	3.9
AVSS	Intersection Safety Warning (ISW)	2.9
AVSS	Intersection Collision Avoidance (ICA)	2.3

Calculations

No calculations

Assumptions for the scale used for each criterion (0-10 scale) :

- Early Market Package (No=0, Yes=10)
- ITI Implementation (No=0, Yes/NA=10)
- Federal Funding Necessary (No=0, Partial=5, Full/NA=10)
- Market Package w/ Common Functions (2.5 per Market Package)
- Benefits (2 per ITS Benefit Goal)

The selected market packages provide a range of user-services currently being considered in the IVIS marketplace, and a varying degree of technology maturity.

4. COST COMPILATION AND CALCULATIONS

4.1 DEFINITION OF LIFE CYCLE AND ANNUAL COSTS

The cost calculation methodology estimates costs at the market package level for a specific deployment period in a *life cycle* context. The market package cost is the sum of the costs of individual components in the equipment packages that comprise the market package, both inside and outside (i.e., infrastructure) the vehicle. For market packages that include infrastructure, the life cycle cost includes the initial capital (i.e., non-recurring) cost and the operation and maintenance (i.e., recurring) cost incurred over the deployment period under consideration. The life-cycle cost of in-vehicle equipment packages is estimated over the vehicle life (i.e., typically 14 years for personal vehicles). The cost referred to here is the "retail price" which includes overhead plus the manufacturer's cost of production. Thus, what are costs to buyers or consumers are potential revenues, or market, for vendors.

Life cycle costs are defined in one of three categories, based on which entity is most likely to pay the costs: vehicle users (i.e., in-vehicle equipment packages); private investors [e.g., Information Service Provider (ISP) equipment packages]; and the public sector (e.g. traffic and transit market packages). Since there exists so much uncertainty over the specifics of IVIS technologies, three estimates of costs are made based on engineering judgement and available information (i.e., High, Medium, and Low). Costs are calculated on an annual basis, including estimates of future costs at various stages of technology development (see Section 5). As an old component within an equipment package is replaced after its useful life, future costs are then applied to estimate the life cycle cost. Annual costs on a life cycle basis are estimated in constant (i.e., 1996) dollars. Present values and levelized costs are also estimated at the market package level, where a levelized cost is a constant annual cost that if paid over the life of the system would sum to an amount equal to the present value of the total cost. In its current stage of development, the methodology does not include the costs of disposing of the equipment, nor any "external" costs such as those that may occur from the discharge of wastes during the manufacture of equipment.

Figure 4.1 shows the cost methodology for the IVIS market packages. Two types of regions (i.e., urban and interurban) were considered. The nature of these market packages dictates

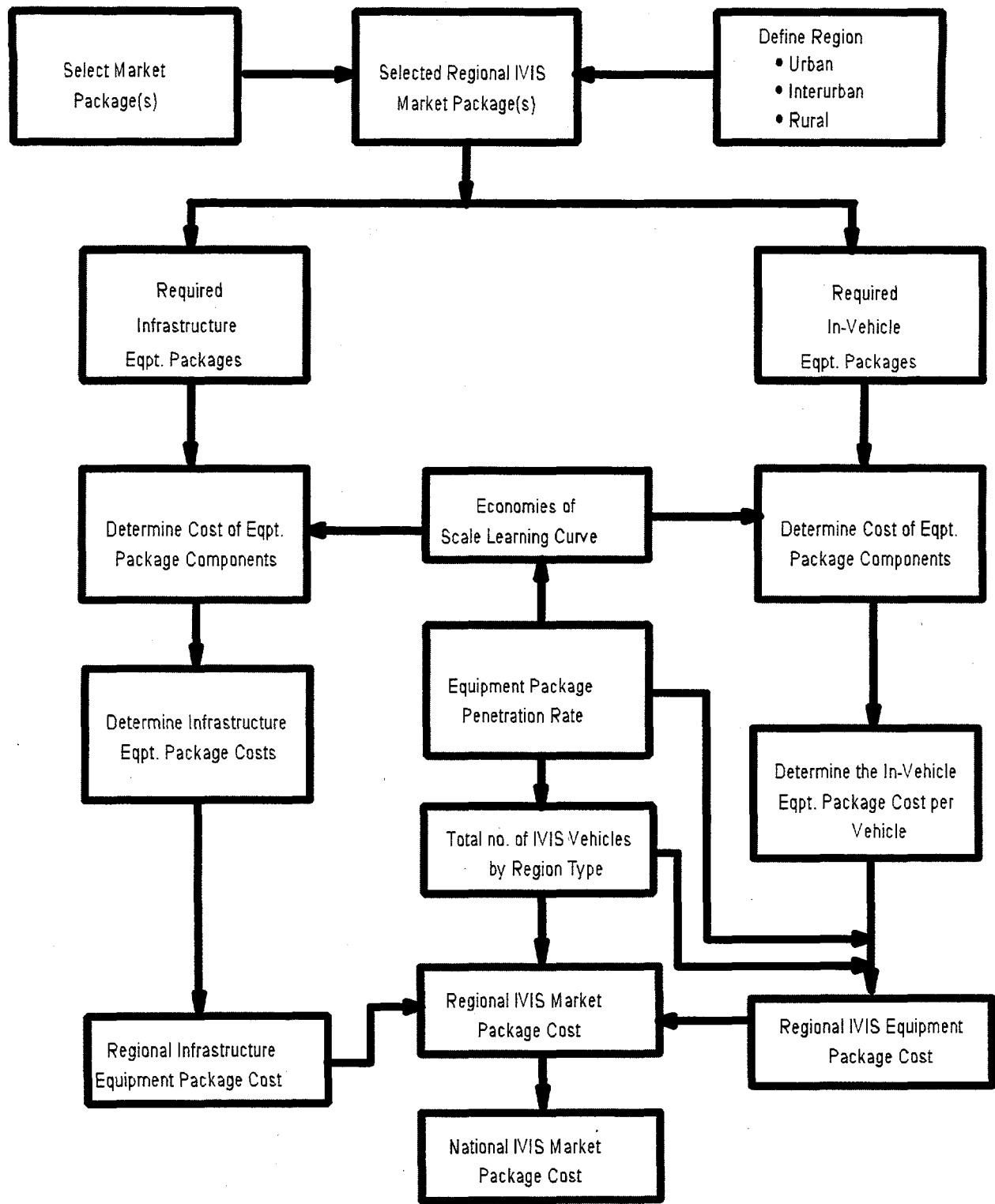


Fig. 4.1. IVIS cost estimation methodology.

the type of parameters to be used for the cost calculations for the components of the equipment package. For example, the number of inductive loops necessary for cost-effective basic road surveillance differs widely due to varying traffic patterns in different types of regions. The regions examined correspond respectively to the Urbansville and Thruville regions considered in the national ITS architecture study for its cost analysis (DOT 1996b). The Mountainville, or rural, region was not included in our study because market penetration and deployment were thought to be minimal over the next 10 years. The costs of in-vehicle equipment packages were estimated on a per vehicle basis, where economies of scale and industry-experience curves are taken into consideration based on the IVIS market penetration rate.

4.2 METHODOLOGY FOR COMPILATION OF COST INFORMATION

Listings of the components in each equipment package were compiled on the basis of information from functional equipment package descriptions in the national architecture study (DOT 1996b). Estimates of the costs (i.e., prices) of each component were compiled from the national architecture study, and from various ITS-related documents, technical papers, and product literature; and from communications with manufacturers, system integration suppliers, and consultants. The costs generally include installation and are in year 1996 dollars. The range of costs reflects variations in geographic markets, product capability, product quality, and vendor.

Intersection collision avoidance system costs, for example, were estimated based largely on information on program goals and plans provided by Calspan SRL about the Intersection Collision Avoidance Using ITS Countermeasures program sponsored by the National Highway Transportation Safety Administration (NHTSA) Office of Collision Avoidance Research. These costs are approximate goals for a system that will probably not be ready to deploy for at least 10 years into the future.

In general, the tabulated costs are upper-bound estimates. They do not explicitly reflect bulk-purchase discounts. Different organizational entities may purchase some of these components, and many components such as roadway sensors will be purchased over a number of years, thereby reducing somewhat any discounts for bulk purchases. Each equipment package is priced separately. When a combination of packages is purchased and installed, economic savings can be realized by design of an integrated system with fewer components and shared resources.

These savings were not incorporated into the calculations. Savings might also be realized if certain functions of an equipment package are dropped. For example, a vehicle route guidance system may function adequately without the capability to accept voice commands or to produce hardcopy. By reducing these requirements, a lower-cost equipment package can be deployed. These potential savings are not reflected in the cost estimates.

Although the costs of the individual components within in-vehicle equipment packages are listed, these costs were estimated based upon the expectation of an *integrated and complete* equipment package ready for installation in a vehicle. These costs are a highly sensitive competitive parameter and depend greatly on design and quantities produced. With only a few exceptions, each equipment package (for both in-vehicle and infrastructure-related) was costed as if it were developed to function without the use of another equipment package.

Tables 4.1 and 4.2 provide descriptions of the in-vehicle and infrastructure-related equipment packages considered and of the assumptions made about their technologies in compiling their cost information.

The estimated costs are for fully installed systems, and reflect consideration of factors that affect the number of units required for a system. For example, the Roadway Basic Surveillance (RBS) equipment package component costs include not only the cost of sensors and installation, but also all related electronic circuitry, data logging equipment, cabling, and their installation. The RBS equipment package is assumed to be consistent with the ITS architecture functional description and to include traffic sensors such as loops and video detection systems, surveillance camera systems that transmit traffic images to a manned facility for review, and tag readers. (Variable message signs, ramp meters, highway advisory radio, road probe beacons, in-vehicle signing beacons, environmental sensors, and emission sensors were not included as a part of this equipment package.) The number of RBS equipment package components required is indirectly linked to the density of traffic and to the number of IVIS users. Sensor density will be greater in areas with greater potential for traffic flow problems and with large numbers of vehicles. Sensor deployment will necessarily be gradual and costs may change as new sensor technologies develop and better traffic measurements are available from such sensors. These factors are additional reasons why estimates of equipment package costs and of the required quantity are imprecise, and this limitation should be borne in mind when viewing the results in this report.

Table 4.1. Description and Assumptions Made of In-Vehicle Equipment Packages

Equipment packages	Description	Assumptions
Basic Vehicle Reception (BVR)	Allows one way transfer of traffic and transit information from the ISP provider via BIB to the vehicle.	BIB uses FM subcarrier transmission; no other in-vehicle equipment packages are installed.
Interactive Vehicle Reception (IVR)	Allows two-way communications between ISP provider via III and the vehicle, with the vehicle's driver able to make specific queries and the ISP to respond directly to queries.	No other vehicle equipment packages installed.
Vehicle Route Guidance (VRG)	Provides autonomous route planning and guidance to location specified by vehicles driver; also has the capability of receiving traffic information from the ISP provider and optimizing the route chosen based on driver preferences and traffic conditions.	Specified system has the capability to receive traffic information from the infrastructure; for full functionality with ITS architecture descriptions, voice activation capability and hardcopy printout capability are also included in the component description.
Vehicle Intersection Control (VIC)	Provides the capability of detecting an impending collision at a RIC instrumented intersection and taking appropriate countermeasure control actions automatically.	Based on NHTSA project on collision avoidance, collision sensing capability is assumed to be located in vehicle not in the infrastructure; millimeter wave radar for collision sensing; no other in-vehicle equipment packages are installed.

Table 4.2. Description and Assumptions Made of Infrastructure-Related Equipment Packages

Equipment packages	Description	Assumptions
Basic Information Broadcast (BIB)	Collects, processes, stores, bills, and disseminates traveler information including traveler, transit, ridematching, traffic, and parking information.	FM subcarrier is used for transmission.
Collect Traffic Surveillance (CTS)	Collects, stores, and provides electronic access to the traffic surveillance data.	Based on the system setup to periodically poll various data collection points (RBS) for acquiring sensor data from the roadway; physical facilities already exist to house this system at a Traffic Management Center.
Infrastructure Provided Route Selection (IPRS)	Receives origin and destination requests from IVR equipped vehicles, generates route guidance instructions, and provides them to the vehicle driver.	Requires the presence of III equipment package already in the infrastructure and IVR in the vehicle; equipment package co-located with III.
Interactive Infrastructure Information (III)	Collects, processes, stores, bills, and disseminates traveler information including traveler, transit, ridematching, traffic, and parking information in direct response to interactive traveler request.	Assumes a distributed processing architecture with a central server and linked workstations whose primary function is to service the requests of individual users; assumes a standalone functionality not dependent on the presence of a BIB equipment package.

Table 4.2. Description and Assumptions Made of Infrastructure-Related Equipment Packages (Cont'd)

Equipment packages	Description	Assumptions
Roadway Basic Surveillance (RBS)	Capabilities to monitor traffic flow through major intersections and on major arterials and highways in urban areas; and to monitor road conditions using fixed equipment such as loop detector and wireline communications.	Assumes the use of loops for point sensors, video processing systems for area sensors, and surveillance cameras for transmittal of live video images; sensor costs per mile stated include sensors, installation, detection and data logging equipment, and all cabling and necessary electronic components. No. of surveillance cameras and video processing systems is 2 per mile and the density of loops is 3 loops per mile. RBS sensors are covered only for 100% of freeway miles (fwy) and 75% of arterial miles (art). Distribution of sensors is as follows: Loops: 75% (fwy) and 50% (art); surveillance cameras: 10% (fwy) and 10% (art); and video processing systems: 15% (fwy) and 10% (art).
Roadway Intersection Collision (RIC)	Roadside hardware at an intersection necessary for implementation of an intersection collision avoidance countermeasures.	Assumed that the roadside hardware will just provide transmission data concerning the intersection; based on present programs sponsored by NHTSA, intersection collision sensors assumed to be only vehicle-based.
Roadway Signal Controls (RSC)	Provides the capability to control traffic signals at major intersections.	Sensors for assistance in optimizing the control function are already provided via the RBS equipment package.

Table 4.2. Description and Assumptions Made of Infrastructure-Related Equipment Packages (Cont'd)

Equipment packages	Description	Assumptions
Roadway Signal Priority (RSP)	Provides the signal controls with the capability of receiving and responding to priority requests from emergency or specialized vehicles.	Assumes the existence of the RSC package at that location.
TMC Multi-Modal Coordination (TMMC)	Determines the need for transit vehicle priority and requests priority treatment at RSP controlled intersections along the route.	Assumes existence of RSP, RSC, and the cooperation of the transit and traffic management facilities.
Transit Center Demand Responsive Operations (TCDRO)	Capability to automate the planning and scheduling for para transit vehicles.	Assumes the existence of TCFRO equipment package.
Transit Center Fare & Load Mgmt (TCF&LM)	Capability to accept collected data required to determine accurate ridership levels and implement variable and flexible fare structures.	Assumes the existence of TCFRO and TCT&D packages
Transit Center Fixed Route Operations (TCFRO)	Capability to automate the planning and scheduling for fixed-route operations (e.g., improvements in fixed-routes, printing and disseminating schedules, etc).	Cost of equipping individual transit vehicles is not included; the equipment package is assumed to handle data transfers to and from transit vehicles.
Transit Center Tracking & Dispatch (TCT&D)	Capabilities for monitoring transit vehicle locations in real time and determining vehicle structure adherence.	Cost of equipping individual transit vehicles for locating is not included; the equipment package is assumed to handle data transfers to and from transit vehicles and the use of GPS receivers on vehicle for vehicle location application.

In our study, loops were chosen as the primary point-detection sensors, based on present common practice. Video image processing systems were selected as representative of area sensors. Surveillance cameras that transmit images to a traffic management center were also selected as an important cost component for the RBS equipment package. Costs were estimated based on point sensors being predominant in deployment since they are the most common and best understood point of reference for traffic measurements. However, some camera detection systems were also included in the cost estimate.

Communications costs have a major impact on most of the equipment packages. Wireline communications estimates are based on leasing lines from a commercial vendor. Ultimately, communications costs could be a major system expense. A careful cost analysis should be performed for individual sites to determine whether to lease communications services or to install dedicated communications lines over the long term. Leased communications may be the best option during the ramp up phase of implementation. Communications links with the ISP, the traffic management system, and the transit management system are redundant for fail-safe operation with each facility carrying the cost of one of its links to the other two.

Costs will often depend on the type of wireless technology selected between the vehicle and the ISP. Costs calculated here assumed that the wireless equipment is already largely in place with access via some type of cellular service. If large quantities of data must pass between the ISP and the individual vehicle, dedicated communications media may be required to meet performance expectations, particularly since some of the media available for voice may be heavily loaded as wireless applications became more exploited. Implementation of dedicated communications media will increase costs dramatically due to limited bandwidth availability, legal costs for setup, installation and hardware maintenance costs. Costs will also vary widely depending on whether the computing architecture is distributed or concentrated in one or two facilities.

Because of this study's focus on personal vehicle systems and related infrastructure, estimates of transit systems costs did not include the cost of equipment which must be installed inside the transit vehicle itself. Costs for the individual equipment packages for transit operations may be reduced if designed and purchased as a single common system.

Systems control and data management costs are associated with parts of almost every equipment package with the exception of the in-vehicle packages. The selection of a distributed or central architecture can have a profound impact on these costs.

4.3 SOURCES OF COST INFORMATION

Information utilized in the selection of system components and subsequent cost estimates came from a variety of resources. Original equipment manufacturers (OEM) and systems integration representatives were consulted for cost information. Several ITS documents and technical publications were utilized to understand better the requirements for each equipment package and the technologies available to meet these requirements. Resources utilized in the cost analysis of in-vehicle systems include information from products like Zexel Navmate, Siemens TetraStar, Rockwell Pathmaster, Clarion TravInfo, Sony Telepak, and Trafficmaster Freeway; and companies such as Densitron, Oki Electronics, Phillips Business Information systems, Hyundai Electronics, and Dialogic. Additional information on Intersection Collision Avoidance equipment package costs were obtained from numerous other sources (Pierowicz 1996, Jocoy 1996, Guinand 1995).

Resources for calculations of sensor costs included manufacturers and integrators such as Econolite, Rockwell, Golden River, RGA, Cohu, Diamond, Burle, and Peak. Several other sources were referenced for the RBS estimates (DOT 1996b, Michalopoulos 1992, 1994, Stevens and Chin 1992). ORNL communications experts and several other sources were used for communications costs (DOT 1996b, CTIA 1995, Nemzow 1995, Barritt 1996, Kady, NTIA 95-22, Rickard, 1996). Resources used for transit costs include the following commercial products: Orbital Sciences Corporation - Orbtrac Systems, Raytheon Transportation Management Solutions, Harris - FleetLynx, and Rockwell Transportation - Transitmaster, Fleetmaster. Resources for ISP, TMC, and transit computational systems, software, etc. included PB Farradyne - Mist, ITS Architecture Cost Analysis - June 1996, ORNL systems experts, Sun Microsystems, Hewlett Packard, and Digital Equipment Corporation. Several publications from the literature (Chadwick 1995, Hamit 1996, DOT 1996b) were also used.

Although the cost analysis performed for the national architecture (i.e., DOT (1996b)) provided initial estimates for some system components, it is advisable to update the estimates due to the rapid changing nature of ITS technology. Commercial sources of information should

be used to the extent possible to validate the estimates available from published sources. Cost estimates for products not yet in the marketplace were projected based on the cost information of other currently-available products, that use similar technology.

4.4 COMPILED COSTS

A list of components identified for each of the equipment packages for the five IVIS-related market packages, along with their current unit costs, is shown in Table 4.3. For infrastructure-related equipment packages, these unit costs reflect a certain parameter value, based on which the number of components needed in a deployment region is calculated. A detailed functional description of these components has been compiled in the IVIS software, including the source of information (to be discussed under Sect. 4.5 and Appendix A). Since each equipment package (for both in-vehicle and infrastructure-related) was costed as if it were developed to function without the use of another equipment package, there are some common components among several equipment packages. Initial unit costs are assumed to be zero for those components which either already exist, or to be the part of the maintenance cost. Note that the projected future costs of components (to be discussed under Sect. 5) are used in the life cycle cost calculations after the useful life of the initial components expires.

4.5 IVIS SOFTWARE

Software was developed to implement the methodology in this report. The software is an information system that systematically lists the costs of IVIS related packages and that calculates their costs. The first of these two functions is currently operational; the second is under development and testing (the numerical results in this report were calculated using spreadsheets).

The software is PC-based and operates under Windows 95. The software is designed to facilitate a systematic approach for listing, documenting, retrieving, and using IVIS cost data. Users such as metropolitan planning organizations can apply the software to consider alternative IVIS (and other ITS) technology deployments. The software encourages the development of integrated, rather than piecemeal, ITS systems by taking the technology-package configurations, that the national ITS architecture defines, as starting points for user-defined scenarios. Each scenario consists of one or more market packages (possibly customized). The software calculates the costs of these market packages (and of the user-defined scenarios) based on region-

Table 4.3. List of Components of Equipment Packages and Their Current Unit Costs (1996 \$)

Equipment package	Market packages used in	Component name	Initial unit cost (\$)
BIB	BTL, DRG	BIB Server	60000
BIB	BTL, DRG	BIB information database	60000
BIB	BTL, DRG	BIB Staffing	100000
BIB	BTL, DRG	BIB Network Backbone	100000
BIB	BTL, DRG	BIB Communication Line leasing DS0	800
BIB	BTL, DRG	BIB Communication Line leasing DS1	1000
BIB	BTL, DRG	BIB Workstation	5000
BIB	BTL, DRG	BIB Map Database Software	20000
BIB	BTL, DRG	Broadcast Interface	0
BIB	BTL, DRG	BIB Traffic Analysis Software	300000
BVR	BTL, DRG	AM/FM radio with data subcarrier	200
BVR	BTL, DRG	BVR Dash Mounted LCD	200
BVR	BTL, DRG	BVR Existing Audio System	0
CTS	BTL, DRG, IRG, ITI	CTS processor	150000
CTS	BTL, DRG, IRG, ITI	CTS Network Backbone	20000
CTS	BTL, DRG, IRG, ITI	CTS database and software	40000
CTS	BTL, DRG, IRG, ITI	CTS Staff	100000
CTS	BTL, DRG, IRG, ITI	CTS Communications Line leasing DS0	800
CTS	BTL, DRG, IRG, ITI	CTS Communications Line leasing DS3	5000
CTS	BTL, DRG, IRG, ITI	CTS Workstation	5000
CTS	BTL, DRG, IRG, ITI	CTS Map Database software	20000
III	IRG, ITI	III Database	120000
III	IRG, ITI	III Server	650000
III	IRG, ITI	III Network Backbone	250000
III	IRG, ITI	III Real Time Traveler Information Software	400000
III	IRG, ITI	III Transit Payment Software	250000
III	IRG, ITI	III Staff	100000
III	IRG, ITI	III Communications Line leasing DS0	800
III	IRG, ITI	III Communications Line leasing DS3	5000
III	IRG, ITI	III Workstation	5000
III	IRG, ITI	III Traffic Analysis software	300000
III	IRG, ITI	III Map Database software	20000
IPRS	IRG	Route Selection software	300000
IPRS	IRG	Map Database Software Upgrade	20000
IPRS	IRG	IPRS processor	5000
IPRS	IRG	IPRS Staff	100000

Table 4.3. List of Components of Equipment Packages and Their Current Unit Costs (1996 \$) (Cont'd)

Equipment package	Market packages used in	Component name	Initial unit cost (\$)
IVR	IRG, ITI	IVR processor	1000
IVR	IRG, ITI	IVR Service Charge	0
IVR	IRG, ITI	IVR Dash Mounted LCD	200
IVR	IRG, ITI	IVR Wireless Data Transceiver	500
IVR	IRG, ITI	IVR Audio system	0
RBS	BTI, DRG, IRG, ITI	Point Sensor	40000
RBS	BTI, DRG, IRG, ITI	Surveillance cameras+ Mounting Hardware	110000
RBS	BTI, DRG, IRG, ITI	Area Sensor	70000
RBS	BTI, DRG, IRG, ITI	RBS Staff	100000
RIC	ICA	RIC Transmitter	700
RIC	ICA	RIC processor	500
RSC	ICA	Traffic controller and links	75000
RSP	ICA	Preemption capability	15000
TCF&LM	BTI, DRG, ITI	TCF&LM Network Backbone	100000
TCF&LM	BTI, DRG, ITI	TCF&LM processor	150000
TCF&LM	BTI, DRG, ITI	TCF&LM Transit Payment Software	300000
TCF&LM	BTI, DRG, ITI	TCF&LM Staff	100000
TCF&LM	BTI, DRG, ITI	TCF&LM Communications Line leasing DS0	800
TCF&LM	BTI, DRG, ITI	TCF&LM two way voice communications	600
TCFRO	BTI, DRG, IRG, ITI	Dispatch & Fleet Management Software	60000
TCFRO	BTI, DRG, IRG, ITI	TCFRO processor	150000
TCFRO	BTI, DRG, IRG, ITI	TCFRO Transit system Database	40000
TCFRO	BTI, DRG, IRG, ITI	TCFRO Communications Line leasing DS1	1000
TCFRO	BTI, DRG, IRG, ITI	TCFRO Communications Line leasing DS3	5000
TCFRO	BTI, DRG, IRG, ITI	TCFRO Map Database Software	20000
TCFRO	BTI, DRG, IRG, ITI	TCFRO Staff	100000
TCDRO	IRG, ITI	TCDRO processor	25000
TCDRO	IRG, ITI	TCDRO database and software	75000
TCDRO	IRG, ITI	TCDRO Staff	100000
TCT&D	BTI, DRG, IRG, ITI	Vehicle Location Interface	20000
TCT&D	BTI, DRG, IRG, ITI	Vehicle tracking and Scheduling	60000
TCT&D	BTI, DRG, IRG, ITI	Schedule Adjustment Software	50000
TCT&D	BTI, DRG, IRG, ITI	Real Time Travel Information Software	100000
TCT&D	BTI, DRG, IRG, ITI	TCT&D processor	100000
TCT&D	BTI, DRG, IRG, ITI	TCT&D network backbone	100000
TCT&D	BTI, DRG, IRG, ITI	TCT&D Staff	100000
TCT&D	BTI, DRG, IRG, ITI	TCT&D Workstation	5000
TCT&D	BTI, DRG, IRG, ITI	TCT&D Communications Line leasing DS1	1000
TCT&D	BTI, DRG, IRG, ITI	TCT&D Communications Line leasing DS3	5000

Table 4.3. List of Components of Equipment Packages and Their Current Unit Costs (1996 \$) (Cont'd)

Equipment package	Market packages used in	Component name	Initial unit cost (\$)
TCT&D	BTI, DRG, IRG, ITI	TCT&D Wireless Data Transceiver	500
TCT&D	BTI, DRG, IRG, ITI	TCT&D Two way voice communications	600
TMCMM	ICA	Signal control preemption software	20000
TMCMM	ICA	Interface to signal control	7500
VIC	ICA	VIC processor	1000
VIC	ICA	VIC Collision sensor	1500
VIC	ICA	Avoidance actuators	110
VIC	ICA	VIC Wireless Data Transceiver	500
VRG	DRG, IRG	Geographical Information System	300
VRG	DRG, IRG	Global Positioning System/Differential GPS	800
VRG	DRG, IRG	Navigation Processor	1100
VRG	DRG, IRG	VRG voice recognition system	230
VRG	DRG, IRG	VRG printer	150
VRG	DRG, IRG	VRG Dash Mounted LCD	200
VRG	DRG, IRG	VRG Wireless Data Transceiver	500

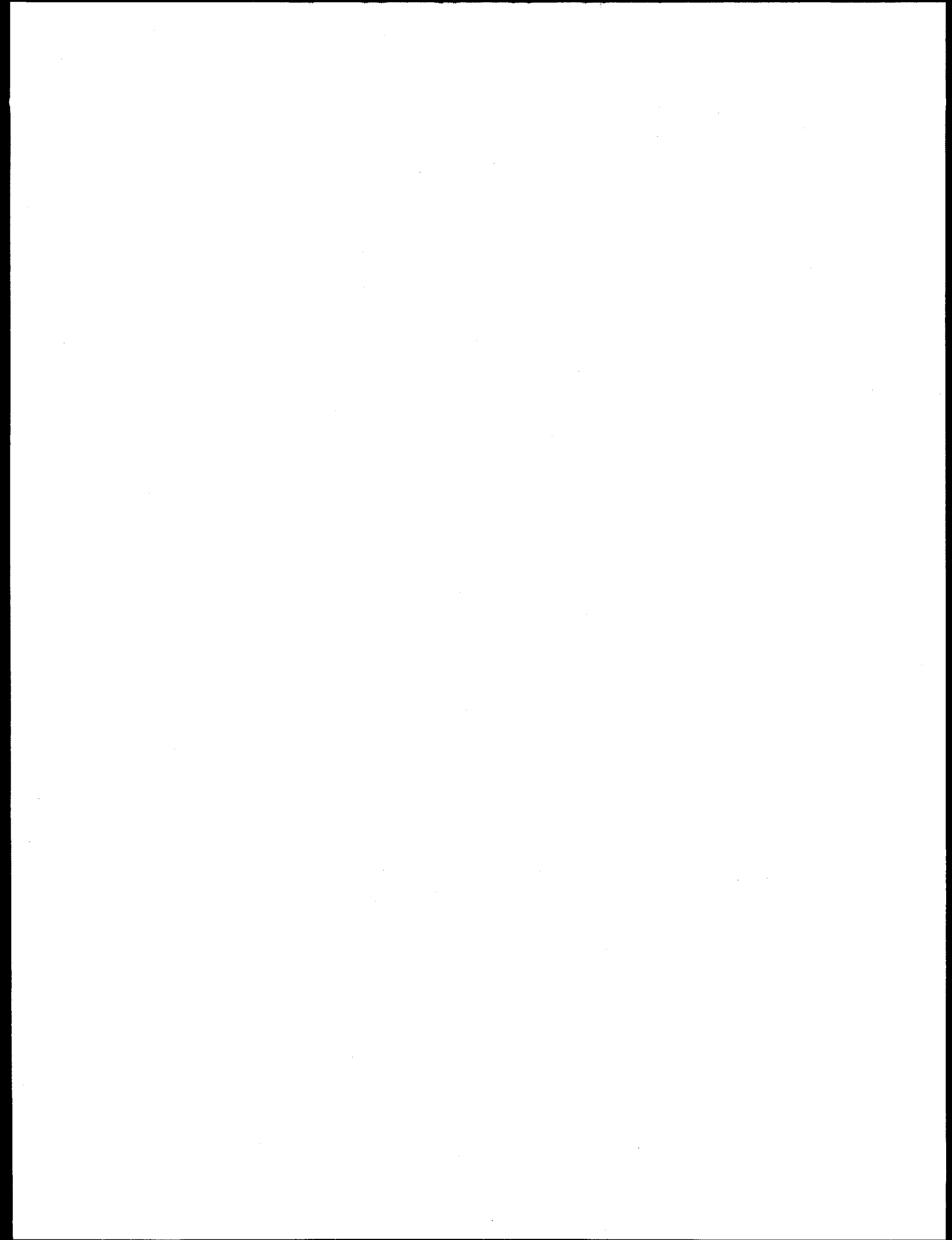
Legend:

- BIB: Basic Information Broadcast
- BTI: Broadcast Traveler Information
- BVR: Basic Vehicle Reception
- CTS: Collect Traffic Surveillance
- DRG: Dynamic Route Guidance
- ICA: Intersection Collision Avoidance
- III: Interactive Infrastructure Information
- IPRS: Infrastructure Provided Route Selection
- IRG: ISP-Based Route Guidance
- ITI: Interactive Traveler Information
- IVR: Interactive Vehicle Reception
- RBS: Roadway Basic Surveillance
- RIC: Roadway Intersection Collision
- RSC: Roadway Signal Controls
- RSP: Roadway Signal Priority
- TCDRO: Transit Center Demand Responsive Operations
- CF&LM: Transit Center Fare & Load Mgmt.
- TCFRO: Transit Center Fixed Route Operations
- TCT&D: Transit Center Tracking & Dispatch
- TMCMM: TMC Multi-Modal Coordination
- VIC: Vehicle Intersection Control
- VRG: Vehicle Route Guidance

and technology-specific parameters, and offers a variety of report formats for the results. These costs are listed separately for the different types of parties (i.e., consumers, private investors and government), who are likely to pay the costs of the different equipment packages that comprise each market package.

The software offers users several “automated” calculations such as the number of units that are needed for a particular regional deployment, infrastructure deployment rates, and projections of future component prices using alternative formulae. Users can override these automated estimates with their own estimates.

The software also allows users to add new model options as information becomes available on them; to select different alternative models for each component within an equipment package; and to change the price of each model. Besides providing IVIS cost estimates, the software provides a catalog of information on ITS technologies, including descriptions of various IVIS market packages and data sources. Appendix A provides more discussion on the IVIS software’s capabilities.



5. PROJECTIONS OF FUTURE COSTS

5.1 PRICE CHANGES OVER TIME

Infrastructure deployment will take place, and the market for in-vehicle systems will increase, over time. Therefore, to project the life cycle and annual costs of these systems, it is necessary to take into account changes over time in the unit costs of their components. As technologies develop, learning and economies of scale take place due to higher production volume. Competition increases, and unit costs generally decrease. As a technology matures, its unit costs stabilize and track the average rate of inflation. Some technologies' prices may increase slightly, net of inflation, while others continue to decline slightly. This section describes how these price trends were projected for this study. Section 5.2 describes the *experience concept*, which is applicable to new technologies. Section 5.3 describes empirical data and statistical estimates of the price trends of ITS-related commodities. The estimated price equations are subsequently used in the calculations, summarized in Sections 7 and 8. The results show that many ITS components are mature technologies, whose prices are slightly increasing over time.

5.2 EXPERIENCE CONCEPT FOR NEW TECHNOLOGIES

The decline in costs during a technology's early stages of commercialization can be modeled using the experience concept. This concept, originated by the Boston Consulting Group, generalizes the learning concept by encompassing all costs (including capital, administrative, research, and marketing) and tracing them through technological displacement and product evolution (BCG 1972). Unlike the learning concept, which applies to short-term improvements in labor productivity, the experience concept applies to *long-term* improvements and cost reductions from every conceivable source, including technological improvements, input substitution, economies of scale, new product design, and changing input prices, as well as labor productivity improvements. The dynamics of reductions in production cost with increases in cumulative production volume can be represented using the experience concept as follows:

$$C_f = C_o \left(\frac{CUM_f}{CUM_o} \right)^{\left[\frac{\ln PR}{\ln 2} \right]}$$

where CUM_f = final cumulative production level,
 CUM_o = initial cumulative production level,
 C_f = cost of producing the final unit,
 C_o = cost of producing the initial unit, and
 PR = progress ratio, expressed as a decimal fraction.

The progress ratio is similar to the factor "b" in the learning curve. It measures the rate of reduction in cost as cumulative production increases. A progress ratio value of 80% means a 20% reduction in cost for each doubling of cumulative production. Progress ratios typically range from 70% to 90%, and a value of about 80% has been found to characterize a wide number of industries. The lowest values of PR occur in highly competitive industries such as consumer electronics and semiconductors with major investment in research and development; the highest values of PR occur in mature industries with minimum investment in research and development such as beer and cement. Estimates of possible values of PR are determined from a review of the literature on the cost structure of newly developing technologies.

5.3 EMPIRICAL PRICE TRENDS

The components of the various equipment packages under consideration were grouped into four major ITS commodity categories, i.e., (i) communications and related equipment, (ii) electronic computers and equipment, (iii) commercial pole and line transmission, and (iv) process control instruments and optical instruments. Each of these four categories was matched with a Standard Industrial Classification (SIC) category, for which data are published by the Bureau of Labor Statistics (BLS). Price trends in these commodity categories were estimated statistically using historical data on the producer price indexes for the corresponding SIC commodity categories (BLS 1996). The majority of ITS components fall under either the SIC electronic computers and equipment category, or the SIC communications and related equipment category. For example, point sensors used in roadway basic surveillance and vehicle location interfaces in transit center tracking dispatch are grouped under the communications and related equipment category. Avoidance actuators used in the vehicle intersection control equipment package is an example of the commercial pole and line transmission category. Figure 5.1 shows the historical trend in the producer price indexes of the four SIC commodity categories during the past ten years. With the exception of the electronic computers and equipment category, all other

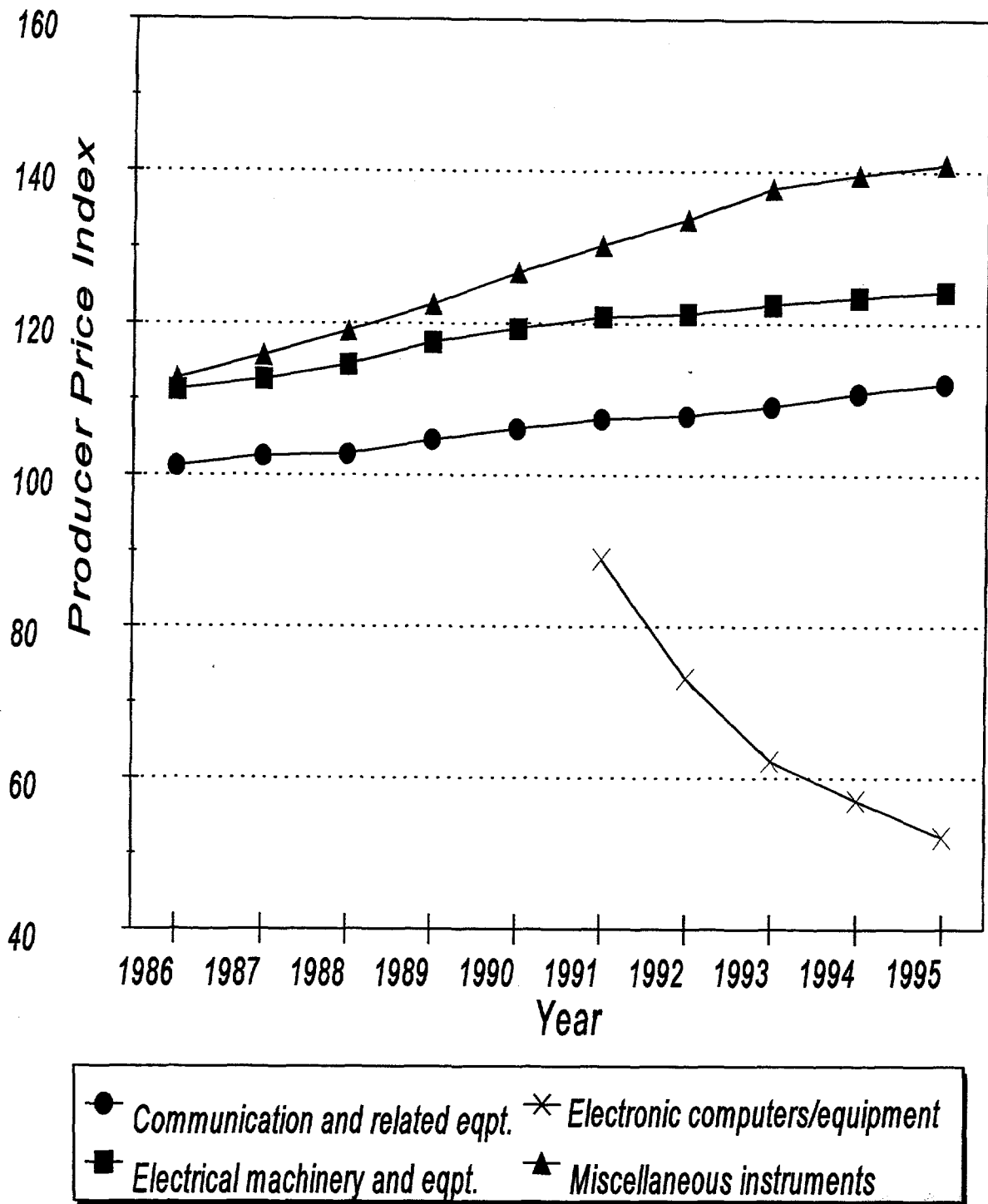


Fig. 5.1. Historical trend in the producer price indexes of the four SIC commodity categories over the past ten years.

commodity categories show an increasing trend in the producer price index, which seems to be leveling off during the past few years. These commodity categories with increasing prices are relatively mature technologies. Some (or all) of these price increases may be attributed to improved quality and functionality.

Table 5.1 shows the estimated cost equations for the different ITS commodity categories, each of which has an excellent fit to the historical data, as shown by its R^2 value. Since only the electronic computers and equipment category shows a decreasing cost trend, the experience curve (discussed in Section 5.2) was fitted to this category, but not to the other categories. A progress ratio value of 0.75 was used. The commercial pole and line transmission, and the process control instruments and optical instruments categories, were fitted to quadratic equations. Table 5.2 shows a few illustrative examples of the projected costs of components using the estimated equations.

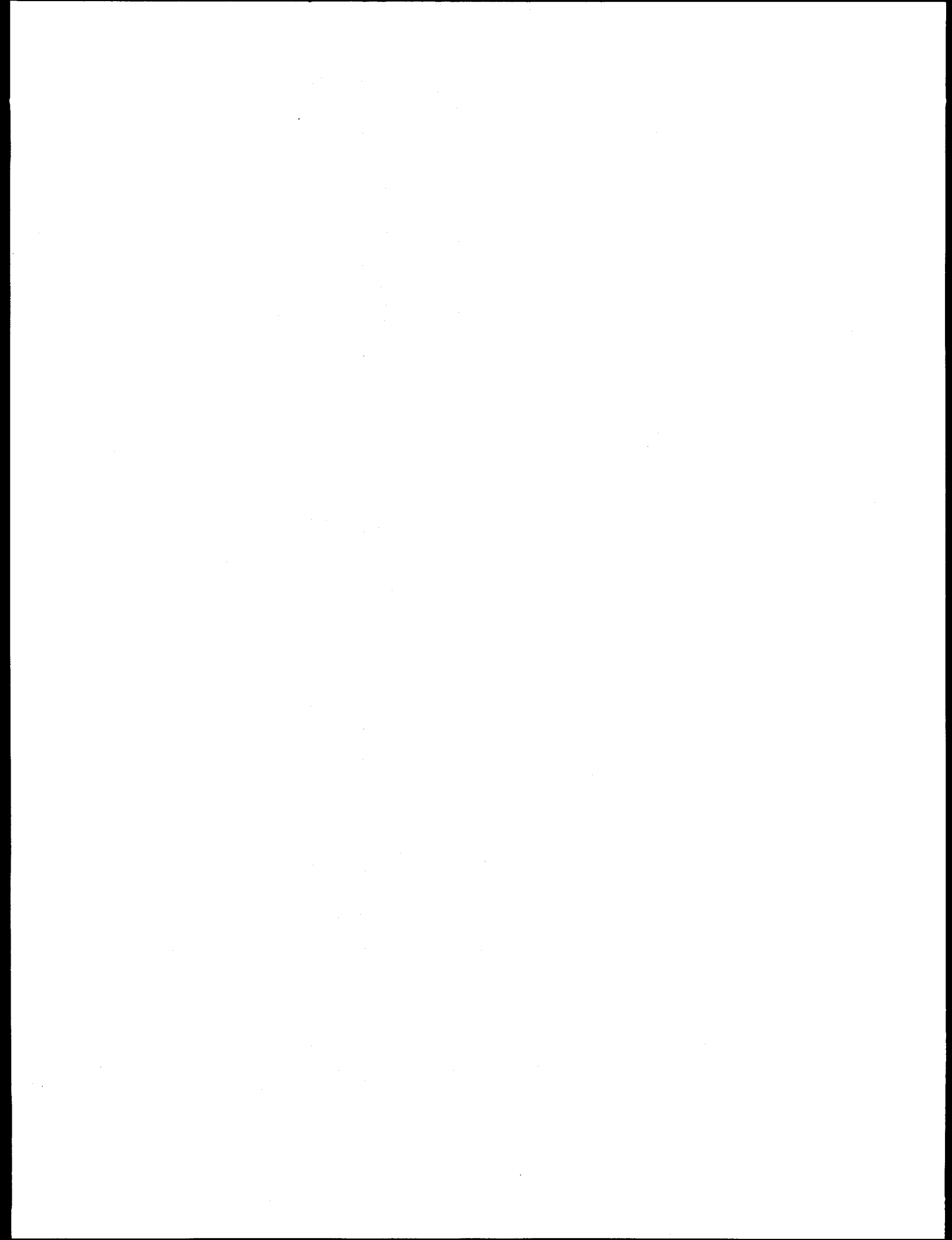
Table 5.1. Estimated Cost Equations for Different ITS Commodity Categories

SIC commodity category and code	ITS commodity category	Cost factor equation	R ²
Communications and related equipment (1176)	Communications and related equipment	$1+0.011t$	99.2%
Electronic computers and equipment (115)	Electronic computers and equipment	$1.695x (3.6044+0.6535t)^{-0.415}$	99.8%
Electrical machinery and equipment (117)	Commercial pole and line transmission	$1+0.0219t-0.0009t^2$	99.1%
Miscellaneous instruments (118)	Process control instruments and optical instruments	$1+0.0296t-0.0005t^2$	99.5%

Note: t is the number of years.

Table 5.2. Examples of Projected Costs (1996 \$) of ITS Components

ITS commodity category	ITS component	Projected unit cost (\$)		
		Current	5th year	10th year
Communications and related equipment	Point Sensor	12,000	12,660	13,320
Electronic computers and equipment	Workstation	5,000	3,808	3,241
Commercial pole and line transmission	Collision Avoidance Actuators	50,000	54,350	56,450
Process control instruments and optical instruments	Surveillance Cameras	40,000	45,420	49,840



6. DEPLOYMENT SCENARIOS

Costs of the IVIS market packages are estimated based on a user-defined deployment region for a ten-year deployment time frame (i.e., 1997–2007). Section 6.1 describes two regions for which deployment is assumed. Section 6.2 discusses the market penetration of the technologies; and Section 6.3 describes how the number of components is calculated.

6.1 DESCRIPTION OF DEPLOYMENT REGIONS

Two regions (i.e., urban and interurban) are considered. The characteristics of these regions dictate the specific values of the parameters that are used for the cost calculations. For example, the number of inductive loops necessary for cost-effective basic road surveillance differs depending on the traffic patterns in different types of regions. The regions examined correspond to the Urbansville (i.e., urban) and Thruville (i.e., interurban) regions considered in the national ITS architecture study for its cost analysis (DOT 1996b).

Urbansville is based on the southeast Michigan metropolitan area. The city of Detroit and portions of Wayne County, Oakland County, and Macomb County constitute the area of Urbansville. The Thruville area consists of portions of three Pennsylvania counties and four New Jersey counties, which comprise the I-95 corridor from the Delaware/Pennsylvania state line to the I-95/I-295 junction in New Jersey. By the year 2007, the Urbansville region is assumed to contain 2 million household vehicles and a population of 3.4 million people compared to 0.9 million household vehicles and 1.1 million people for the Thruville region. Table 6.1 lists the major parameters of Urbansville and Thruville used in the cost estimation. To reflect the particular year of the study under consideration (i.e., 2007), data from the national ITS architecture study were adjusted using the average annual growth rate calculated from the data given for the years 1992, 1997, and 2002.

6.2 MARKET PENETRATION RATES

The acceptance of ATIS marketplace offerings have been low thus far because they have not represented a sufficiently different service from competing products or services, given their price differential. The high price of ATIS products has been the main reason behind the low marketplace reception. They have largely been limited to date to the car rental market and business travelers. Traffic information is a laggard among early commercial ATIS offerings as the

Table 6.1. A List of Major Parameters of Urban and Interurban Regions for the Ten-Year Deployment Period

Parameter	Value	
	Urban	Interurban
No. of Household Vehicles	2,033,833	939,431
No. of Transit Vehicles	2,024	655
Population	3,430,019	1,109,283
Miles of Freeway	225	275
Miles of Arterial Surface Streets	1,701	700
Intersections	2,560	1,040

Source: (DOT 1996c).

existing market defines travelers' expectations for free and accessible traffic information. There is skepticism about whether traffic information will be more detailed, complete, action-oriented, or timely than that available at zero incremental cost from traditional sources, primarily radio stations. It is envisioned that traffic information will need to be packaged with other services on a multi-purpose platform to be saleable. Manufacturers of early location, navigation, and route guidance product offerings are exploring the optimal value trade-off among price, function, market penetration, and return on investment. In some cases, they are concentrating on a lower price with a lower function product. A recent report by Charles River Associates (1996) suggests that development of nationally consistent, good-quality traffic information and national/international communications standards are needed to provide a significant boost to ATIS market growth.

Charles River Associates has summarized early user acceptance research on ATIS products (CRA 1996). For private vehicle travel, users are more interested in ATIS information for long-distance trips than for local trips, and in en-route information than in pre-trip information. Personal and vehicular security and convenience are the two most favored ATIS features. For example, the user needs assessment program of the I-95 corridor project indicated that over 80% of the en-route survey respondents think that an in-vehicle system that warns of approaching hazards is either very important or somewhat important to have and that they are willing to pay up to \$500 and \$1,500, respectively, for in-vehicle emergency systems and automatic signal devices for summoning help ('mayday') (ICC 1995). Business people tend to be more interested in navigational and delay avoidance capabilities and relatively less interested in security features than are the people making mostly non-work trips. Similarly, a survey of

TravTek (an ITS operational test conducted in Orlando during 1990-1994) users indicated that people are willing to pay \$400 each for navigation and route guidance, \$300 for up-to-date information, and \$200 for motorist services and tourist information, almost five times less than the cost of products with lower quality currently available today (Perez, Golembiewski, and Dennard 1993).

Table 6.2 compares the assumed market penetration rates of urban and interurban regions for this study with the rates assumed in the national architecture study by the end of the ten-year deployment period. For the urban region, the assumed market penetration rate is the midpoint of the range used in the national architecture study; whereas, for the interurban region the lower range value of the national architecture study was used. The market penetration rates for interurban regions is in the range of 20–50% lower than those for urban regions.

The penetration rates given in the national ITS architecture study are mainly based on the 1991 study by the University of Michigan Transportation Research Institute (UMTRI 1991). A recent survey by Consumer Electronics Manufacturers Association (CEMA) on the need and acceptance of consumer navigation devices indicates that the ITS market has not changed significantly since the UMTRI survey, as shown in Table 6.3 (EIA 1995). Less than 1/3 of the total people surveyed are very interested in ITS features and they are willing to pay up to \$500, which is considerably lower than what is currently available in the market. Although there is significant interest in advanced vehicle safety systems (i.e., in our case intersection collision avoidance), significant technical development and potential liability issues related to any infrastructure control of vehicles need to be resolved before broad market acceptance will be realized. For the other two in-vehicle equipment packages (i.e., basic vehicle reception and interactive vehicle reception), the market penetration rates are assumed to be low, unless the quality of traffic information improves substantially to justify their costs. The vehicle route guidance equipment package is currently expensive and significant developments are required to increase the potential market for this technology. For infrastructure-related equipment packages, fewer barriers to implementation are assumed, so that infrastructure deployment is assumed to be completed to a large extent in ten years. Thus, rather high market penetration rates are used in our calculations for infrastructure packages (Table 6.2).

Table 6.2 shows the major parameter applied to the market penetration rate to estimate the magnitude of the deployment in a region. Note that the parameters to which the market

Table 6.2. Assumed Market Penetration Rates of Urban and Interurban Regions for the Ten-Year Deployment Period

Equipment packages	Major parameter	Market penetration rate (%)			
		Urban		Interurban	
		This study	Natl. architecture	This study	Natl. architecture
IN-VEHICLE					
Basic Vehicle Reception	Hhold Vehicles	7.5	5-10	5	5-10
Interactive Vehicle Reception	Hhold Vehicles	6.5	3-10	3	3-10
Vehicle Route Guidance	Hhold Vehicles	4.5	2-7	2	2-7
Vehicle Intersection Control	Hhold Vehicles	1	0	1	0
INFRASTRUCTURE					
Basic Information Broadcast	Miles	100	100	50	100
Collect Traffic Surveillance	Miles	100	100	50	0
Infrastructure Provided Route Selection	Miles	50	25-75	25	25-75
Interactive Infrastructure Information	Service Volume	6.5	100	3	100
Roadway Basic Surveillance	Miles	100	100	50	100
Roadway Intersection Collision	Intersections	1	0-1	1	0
Roadway Signal Controls	Intersections	40	30-50	20	0
Roadway Signal Priority	Intersections	37	25-50	25	25-50
TMC Multi-Modal Coordination	Intersections	100	100	50	100
Transit Center Demand Responsive Operations	Transit Vehicles	83	66-100	66	66-100
Transit Center Fare & Load Mgmt.	Transit Vehicles	83	66-100	33	33-66
Transit Center Fixed Route Operations	Transit Vehicles	83	66-100	66	66-100
Transit Center Tracking & Dispatch	Transit Vehicles	83	66-100	66	66-100

Note: Major Parameter: Hhold Vehicles: No. of Household Vehicles
Miles: No. of Freeway and Arterial Miles
Volume: Peak Service Volume
Intersections: No. of Intersections
Transit Vehicles: No. of Transit Vehicles

Table 6.3. Results of a Survey on Need and Acceptance of Consumer Navigation Devices

ITS feature	Very interested (% user)	Not interested (% user)
Step-by-step directions	32	29
Information about local businesses	17	34
Mileage information	25	27
Sending digital messages	15	44
Receiving messages	17	40
Up-to-the-minute traffic information	20	28
Showing current position on a map	30	27
Review of restaurants and hotels	18	29
Sending emergency distress signals	55	18
Likelihood of purchasing an ITS system	8	46
Amount willing to pay for a complete system (up to \$500)	50	36
Amount willing to pay per month for certain ITS features (up to \$10)	38	43

Source: EIA (1995).

penetration rates apply are different from the national ITS architecture study. That study, for example, applied the market penetration rates to the number of transit or traffic management centers calculated for a 100% penetration rate. It is not clear in that study whether there is a one-to-one correspondence between the market penetration rate and the extent of coverage in terms of major parameters (e.g., the number of transit vehicles and freeway miles).

6.3 NUMBER OF UNITS REQUIRED

To calculate the regional IVIS deployment cost, the number of components necessary within an equipment package is calculated at first based on the number of components required per given parameter (e.g., number of freeway miles, intersections etc.) and the market penetration rate (discussed in detail in Section 6.2). The deployment rate is assumed to increase uniformly throughout the deployment period and the assumed market penetration rate refers to the rate to be achieved in the last year of the deployment period. For example, a 10% market penetration rate in 2007 for the ten-year deployment period would result in a 1% increase annually in the market penetration rate, starting in 1997. The costs of in-vehicle equipment packages are estimated on a per vehicle basis and hence the number of components required is generally one per vehicle. When the market for in-vehicle equipment packages is calculated, the total number of

components are calculated as the product of the number of components required per vehicle, the total number of household vehicles in the region, and the market penetration rate of the equipment package.

Since infrastructure deployment has a spatial aspect, geographical parameters are used to calculate the number of units of each component required for a given region. For example, miles of roadway, peak service volume (i.e., in terms of number of IVIS vehicles), total number of transit vehicles, and number of intersections are the most commonly used parameters for the traffic management, information service provider, transit management, and roadway-related equipment packages, respectively. As an example, for a region with 900 transit vehicles, if a single workstation can handle 300 transit vehicles then the number of workstations needed is three. The number of components for each deployment year is calculated as the product of the number of components required per given parameter, the value of that parameter, and the market penetration rate. This procedure avoids the need to calculate the exact number of traffic/transit management centers. The actual number and location of transit/traffic management centers in a metropolitan area are likely to be influenced by land use and zoning patterns, political boundaries, and the number of transit operators within the area, as well as other considerations that are difficult to predict. Economies of scale, and industry-experience curve and empirical price trends, of the infrastructure-related equipment packages are used to make projections of the future costs of the components, as previously discussed.

The annual number of components required takes into account the replacement of old equipment, after its useful life has ended, with the new equipment. The annual mix (old versus new) of components is updated each year as the quantity of replaced equipment is added to the necessary quantity of new equipment. In several cases (as shown earlier on Table 4.3), where some equipment packages are common among several market packages, a cost allocation of the common equipment packages is made. The rule of thumb used is that the cost of an equipment package is allocated to the market package that needs to be implemented first before the other market packages. The costs of regional market packages can be aggregated to estimate the national infrastructure market package cost, based on estimates of the numbers of the different types of regions nationwide (as done in Section 8).

7. COST ESTIMATES FOR URBAN AND INTERURBAN DEPLOYMENTS

7.1 REGIONAL DEPLOYMENT COSTS

As mentioned previously five ATIS-related IVIS market packages are considered for this study. Table 7.1 shows the projected costs of the *in-vehicle* equipment packages for these five market packages. This table lists costs on a *per-vehicle* basis. Table 7.2 lists the projected *total market* value of in-vehicle packages sold. Table 7.3 lists the projected costs of the *infrastructure-related* equipment packages. Tables 7.4 and 7.5 list the projected costs of the five IVIS-related *market packages* for the urban and interurban regions, respectively, for a ten-year deployment period. The data in these tables are combined in Appendix B which gives a detailed cost breakdown by various equipment packages for five IVIS market packages. For in-vehicle equipment packages (Tables 7.1 and 7.2), market values are calculated in terms of present value and annualized cost, instead of life cycle cost and levelized cost. Note that the estimates in all of these tables reflect different market penetration rates for different market packages. These cost estimates probably represent the high end since they are based on the assumption that none of the ITS technology currently deployed can be retrofitted or used. Also the estimates reflect some double-counting of costs for components used in more than one equipment package.

Life cycle costs of in-vehicle equipment packages are estimated to be the greatest (i.e., \$10,000/vehicle) for the ISP-based route guidance market package compared to the lowest cost of \$600/vehicle for the broadcast traveler information market package. The corresponding annual levelized costs of these in-vehicle equipment packages are estimated to be \$1,200/vehicle and \$68/vehicle, respectively. The higher cost of in-vehicle equipment packages for the ISP-based route guidance market package is contributed to some extent by the annual service fee (assumed to be \$325) necessary for the interactive vehicle reception equipment package. Projected annual market values of in-vehicle equipment packages are in the ranges of \$7-\$40M and \$2-\$8M for urban and interurban regions, respectively, as shown in Table 7.2. The costs of in-vehicle equipment packages are assumed not to decrease drastically within the next 10 years. The projected market values should represent the future IVIS market fairly well because if future costs are less than those assumed in this study, then it would mean higher penetration rates.

Life cycle costs of infrastructure for various market packages for an urban region range from \$87M to \$120M as shown in Table 7.4. The corresponding costs of infrastructure for the

Table 7.1. Projected Costs of the *In-Vehicle Equipment Packages* for Five IVIS-Related Market Packages for a Ten-Year Deployment Period

Equipment packages	Market packages used in	Ten-year cost (\$ 1996)	
		Life cycle	Annual leveled
Basic Vehicle Reception	B,D	598	68
Interactive Vehicle Reception	I,S	5,294	605
Vehicle Route Guidance	D,S	5,106	584
Vehicle Intersection Control	C	4,854	555

Note: B: Broadcast Traveler Information C: Intersection Collision Avoidance
D: Dynamic Route Guidance I: Interactive Traveler Information
S: ISP-Based Route Guidance

Table 7.2. Projected Regional Market Values of the *In-Vehicle Equipment Packages* for Five IVIS-Related Market Packages for a Ten-Year Deployment Period

Equipment packages	Ten-year market value (\$M 1996)			
	Urban		Interurban	
	Present value	Annualized	Present value	Annualized
Basic Vehicle Reception	52	7	16	2
Interactive Vehicle Reception	221	31	47	7
Vehicle Route Guidance	280	40	58	8
Vehicle Intersection Control	59	8	27	8

Table 7.3. Projected Costs of the *Infrastructure-Related Equipment Packages* for Five IVIS-Related Market Packages for a Ten-Year Deployment Period

Equipment packages	Market packages used in	Ten-year deployment cost (\$M 1996)			
		Urban		Interurban	
		Life cycle	Annual levelized	Life cycle	Annual levelized
Basic Information Broadcast	B,D	2.9	0.4	1.4	0.2
Collect Traffic Surveillance	B,I,D,S	3.2	0.5	0.8	0.1
Infrastructure Provided Route Selection	S	0.6	0.08	0.3	0.04
Interactive Infrastructure Information	I,S	31	4.4	8.6	1.2
Roadway Basic Surveillance	B,I,D,S	74	11	20	2.8
Roadway Intersection Collision	C	0.03	0.004	0.01	0.001
Roadway Signal Controls	C	70	10	14.3	2.0
Roadway Signal Priority	C	10.6	1.5	2.9	0.4
TMC Multi-Modal Coordination	C	15.8	2.2	3.2	0.5
Transit Center Demand Responsive Operations	I,S	1.0	0.1	0.4	0.06
Transit Center Fare & Load Mgmt.	B,I,D	2.0	3	0.8	0.1
Transit Center Fixed Route Operations	B,I,D,S	1.2	0.2	0.4	0.06
Transit Center Tracking & Dispatch	B,I,D,S	3.3	0.5	1.3	0.2

Note: B: Broadcast Traveler Information
D: Dynamic Route Guidance
S: ISP-Based Route Guidance

C: Intersection Collision Avoidance
I: Interactive Traveler Information

Table 7.4. Projected Costs of Five IVIS-Related Market Packages for the *Urban Region* for a Ten-Year Deployment Period

Market packages	Ten-year deployment cost			
	In-vehicle		Infrastructure	
	Life cycle (\$)	Levelized (\$/yr)	Life cycle (\$M)	Levelized (\$M/yr)
Broadcast Traveler Information	598	68	86.6	12.9
Interactive Traveler Information	5,294	605	115.7	17.0
Dynamic Route Guidance	5,704	652	87.6	13.0
ISP-based Route Guidance	10,400	1,189	116.3	17.1
Intersection Collision Avoidance	4,854	555	96.4	13.7

Table 7.5. Projected Costs of Five IVIS-Related Market Packages for the *Interurban Region* for a Ten-Year Deployment Period

Market packages	Ten-year deployment cost			
	In-vehicle		Infrastructure	
	Life cycle (\$)	Levelized (\$/yr)	Life cycle (\$M)	Levelized (\$M/yr)
Broadcast Traveler Information	598	68	24.7	3.5
Interactive Traveler Information	5,294	605	32.3	4.5
Dynamic Route Guidance	5,704	652	25.1	3.5
ISP-based Route Guidance	10,400	1,189	32.6	4.6
Intersection Collision Avoidance	4,854	555	20.4	2.9

interurban region are in the range of 3 to 6 times lower than the urban region, as shown in Table 7.5. Except for the intersection collision avoidance market package, the necessary infrastructure has many equipment packages in common among the remaining four market packages. Thus, for the given projected infrastructure cost, several other IVIS market packages could also be implemented at the same time without any additional cost. The major infrastructure cost among the common equipment packages are for the roadway basic surveillance and roadway signal controls, which are estimated to have a life cycle cost of \$74M and \$70M, respectively, for the urban region as shown in Table 7.3. Life cycle costs of the interactive infrastructure information are estimated to be considerably higher (i.e., \$31M) than one might expect. Recall that the cost of this equipment package was based on peak service volume, (i.e., number of simultaneous users ISP can handle), which was calculated based on a market penetration rate of 6.5% of total household vehicles and a peak service demand at any given time of 10% of the total IVIS vehicles. Life cycle costs of transit-related are considerably lower, in the range of \$1-\$3.3M for the urban region. Note that these costs do not include the cost of equipment installed inside transit vehicles. The levelized (i.e., annualized) cost of infrastructure for these equipment packages closely follow the pattern of the life cycle costs.

7.2 PARTIES LIKELY TO PAY ESTIMATED COSTS

Implementation of the IVIS-related market packages depends on various sectors of the national economy to produce, operate, maintain, and ultimately use their services. Successful deployment requires participation by individuals and organizations that are motivated to provide, purchase, and use each of the necessary system elements. The argument can be made that all costs of ITS services are to be paid eventually by the users or the general public; and ITS is envisioned to have a variety of private sector participants, from automobile manufacturers (OEMs), to telecommunications companies, to product entrepreneurs, to major trucking companies. However, the focus here is on the point at which the cost is likely to be incurred and paid by the responsible party.

Table 7.6 shows the parties that are likely to purchase the equipment packages of IVIS-related market packages. Four parties are identified: federal, state or local, private firms, and consumers. The state or local category includes both state agencies as well as regional and local

Table 7.6. Parties Likely to Pay Estimated Costs of Various Equipment Packages

Equipment packages	Parties likely to pay			
	Federal	State or local	Private sector	Consumer
IN-VEHICLE				
Basic Vehicle Reception				All
Interactive Vehicle Reception				All
Vehicle Route Guidance				All
Vehicle Intersection Control				All
INFRASTRUCTURE				
Basic Information Broadcast			All	
Collect Traffic Surveillance	80% Cap.	20% Cap. + O&M		
Infrastructure Provided Route Selection			All	
Interactive Infrastructure Information			All	
Roadway Basic Surveillance	80% Cap.	20% Cap. + O&M		
Roadway Intersection Collision	80% Cap.	20% Cap. + O&M		
Roadway Signal Controls	80% Cap.	20% Cap. + O&M		
Roadway Signal Priority	80% Cap.	20% Cap. + O&M		
TMC Multi-Modal Coordination	80% Cap.	20% Cap. + O&M		
Transit Center Demand Responsive Operations	80% Cap.	20% Cap. + O&M		
Transit Center Fare & Load Mgmt.	80% Cap.	20% Cap. + O&M		
Transit Center Fixed Route Operations	80% Cap.	20% Cap. + O&M		
Transit Center Tracking & Dispatch	80% Cap.	20% Cap. + O&M		

authorities. The “private” category refers to ITS service providers (not ITS equipment manufacturers or system integrators). Since this study concentrates on IVIS-related market packages for personal vehicles, “consumers” include only private personal vehicle owners. Firms’ costs are generally passed on to consumers. But the extent to which this is reflected in the data is imprecise.

Although state, regional, and local agencies are responsible for the installation of traffic-, transit-, and roadway-related equipment packages, it is anticipated that the role of federal agencies is likely to remain very significant over the next ten years and that they will provide much of the necessary initial funding during this period. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has authorized a variety of programs, such as the National Highway System and IVHS Act, which have made possible the importance of federal leadership in selected areas. Hence, for traffic-, transit-, and roadway-related equipment packages, a large portion of the initial costs (i.e., capital or non-recurring) is assumed to be paid by federal agencies, whereas annual operations and maintenance costs are assumed to be paid by state or local agencies. Cases where replacement and refurbishing of capital equipment can have as much as 80 percent federal share have not been considered here. Specifically, the calculations reflect an upper bound of 80% on federal funds for capital expenditures. This percentage is based on guidelines for the Intelligent Transportation Infrastructure Model Deployment projects.

The equipment packages of IVIS-related market packages span those that have inherent public sector characteristics to those that have private sector characteristics. A strong role is envisioned by the national ITS architecture study for the private sector in the ISP-related equipment packages (DOT 1996a). ISPs are considered to be the information bundler for the various ITS information sources, by making the information collected by public agencies available to final end-users (i.e., inside the vehicles). The estimated costs of three ISP-related equipment packages considered in this study are therefore assumed to be paid completely (both capital as well as operations and maintenance) by the private sector as shown in Table 7.6. Costs incurred by ISPs will be recovered through user fees for the service provided. All costs associated with in-vehicle equipment packages will be paid by consumers (i.e., private vehicle owners), similar to the way in-vehicle systems such as radio and stereo systems are maintained today, including repairs and any recurring costs.

Tables 7.7 and 7.8 tabulate the total costs projected to be paid by each of the four categories of purchasers of these equipment packages. Table 7.7 is for the urban case, and Table 7.8 for the interurban case. Since costs of in-vehicle equipment packages are the same as in Table 7.2 and they are paid by one single category (i.e., "consumers") these costs have not been included in Tables 7.7 and 7.8. The federal government share of total life cycle costs is projected to be the greatest for roadway basic surveillance and roadway signal controls equipment packages (i.e., \$46M and \$45M, respectively for the urban region). Similarly, for these two equipment packages, state or local government might pay \$28M and \$25M, respectively. Based on the recent announcements of ITS model deployment initiatives in four U.S. cities, it is anticipated that some of these costs will be borne by the private sector. For the interactive infrastructure information equipment package, the private sector is likely to pay the most of the costs, estimated to be \$31M and \$8.6M for the urban and interurban regions, respectively. Since life cycle costs in interurban regions are generally considerably lower than in urban regions, the public sector share of the total costs is likewise lower.

7.3 COMPARISON WITH OTHER ESTIMATES

The IVIS systems identified here are consistent with the national ITS architecture study (DOT 1996b). Note that comparisons of cost estimates of this study with other estimates should only be made at the individual equipment package or market package level due to double-counting of infrastructure costs common to several of these market packages. No cost estimates are currently available on equipment packages, except the one recently completed by the national ITS architecture team.² Table 7.9 gives the cost estimates (in terms of capital and O&M) of the ITS architecture study for Urbansville for the equipment packages that are applicable to the IVIS market packages under consideration here. Cost estimates are provided in 5-year increments assuming different market penetration rates as shown in this table. An approximate cost estimate of an IVIS market package can be determined by adding the costs of all of the necessary equipment packages. For example, the capital and average annual O&M costs for infrastructure related to the dynamic route guidance market package are \$68M and \$0.4M, respectively compared to our estimates of life cycle costs and levelized costs of \$88M and \$13M,

² Results from the recent ITS America Study were not available when this study was completed (ITSA 1997).

Table 7.7. Projected *Urban Region* Costs of the Infrastructure-Related Equipment Packages for Five IVIS-Related Market Packages for a Ten-Year Deployment Period, by Parties Likely to Pay

Equipment packages	Ten-year deployment cost (\$M 1996)							
	Life cycle				Annual levelized			
	Fed	Stat	Pvt	Tot	Fed	Stat	Pvt	Tot
Basic Information Broadcast			2.9	2.9			0.4	0.4
Collect Traffic Surveillance	0.4	2.8		3.2	0.05	0.45		0.5
Infrastructure Provided Route Selection			0.6	0.6			0.08	0.08
Interactive Infrastructure Information			31	31			4.4	4.4
Roadway Basic Surveillance	46.2	27.8		74	6.6	4.4		11
Roadway Intersection Collision	0.02	0.01		0.03	0.002	0.002		0.004
Roadway Signal Controls	45.0	25		70	6.4	3.6		10
Roadway Signal Priority	6.5	4.1		10.6	0.9	0.6		1.5
TMC Multi-Modal Coordination	12.0	3.8		15.8	1.7	0.5		2.2
Transit Center Demand Responsive Operations	0.1	0.9		1.0	0.02	0.08		0.1
Transit Center Fare & Load Mgmt.	0.9	1.1		2.0	0.1	0.2		0.3
Transit Center Fixed Route Operations	0.3	0.9		1.2	0.05	0.15		0.2
Transit Center Tracking & Dispatch	0.6	2.7		3.3	0.1	0.4		0.5

Note: Fed: Federal
Stat: State or Local
Pvt: Private Sector
Tot: Total

Table 7.8. Projected *Interurban Region* Costs of the Infrastructure-Related Equipment Packages for Five IVIS-Related Market Packages for a Ten-Year Deployment Period, by Parties Likely to Pay

Equipment packages	Ten-year deployment cost (\$M 1996)							
	Life cycle				Annual levelized			
	Fed	Stat	Pvt	Tot	Fed	Stat	Pvt	Tot
Basic Information Broadcast			1.4	1.4			0.2	0.2
Collect Traffic Surveillance	0.1	0.7		0.8	0.02	0.08		0.1
Infrastructure Provided Route Selection			0.3	0.3			0.04	0.04
Interactive Infrastructure Information			8.6	8.6			1.2	1.2
Roadway Basic Surveillance	12.3	7.7		20	1.7	1.1		2.8
Roadway Intersection Collision	0.007	0.003		0.01	0.001	0.0		0.001
Roadway Signal Controls	9.1	5.2		14.3	1.3	0.7		2.0
Roadway Signal Priority	1.8	1.1		2.9	0.3	0.1		0.4
TMC Multi-Modal Coordination	2.4	0.8		3.2	0.3	0.2		0.5
Transit Center Demand Responsive Operations	0.05	0.35		0.4	0.007	0.053		0.06
Transit Center Fare & Load Mgmt.	0.4	0.4		0.8	0.05	0.05		0.1
Transit Center Fixed Route Operations	0.1	0.3		0.4	0.02	0.04		0.06
Transit Center Tracking & Dispatch	0.3	1.0		1.3	0.04	0.16		0.2

Note: Fed: Federal
Stat: State or Local
Pvt: Private Sector
Tot: Total

Table 7.9. The National ITS Architecture Study Cost Estimates (1995 Dollars) for the Urbansville Scenario for the Equipment Packages Necessary for the IVIS Market Packages Under Consideration

Equipment packages	1-5 years			6-10 years		
	Market penetration rate (%)	Capital cost (\$K)	Annual O&M cost (\$K)	Market penetration rate (%)	Capital cost (\$K)	Annual O&M cost (\$K)
IN-VEHICLE						
Basic Vehicle Reception	1	3555	0	5	15844	0
Interactive Vehicle Reception	0.3	533	320	3	5286	3492
Vehicle Route Guidance	0.3	4266	1813	2	26772	13191
Vehicle Intersection Control	0	0	0	0	0	0
INFRASTRUCTURE						
Basic Information Broadcast	100	422	316	100	1337	1262
Collect Traffic Surveillance	100	735	136	100	368	203
Infrastructure Provided Route Selection	0	0	0	25	350	13
Interactive Infrastructure Information	100	359	118	100	1097	471
Roadway Basic Surveillance	100	16750	910	100	45000	3510
Roadway Intersection Collision	0	0	0	0	0	0
Roadway Signal Controls	10	11520	205	30	23040	614
Roadway Signal Priority	10	1536	13	25	3328	32
TMC Multi-Modal Coordination	100	217	280	100	109	419
Transit Center Demand Responsive Operations	33	140	1	66	140	2
Transit Center Fare & Load Mgmt.	33	292	7	66	292	14
Transit Center Fixed Route Operations	33	249	231	66	249	462
Transit Center Tracking & Dispatch	0	0	0	66	1694	535

Source: ITS Architecture: Cost Analysis, FHWA, June 1996.

respectively, as shown in Table B.3. Cost estimates were not made explicitly at the IVIS market package level in the ITS architecture study. Note that our study assumes a uniform penetration rate that, after ten years, reaches the midpoint of the range used in the national architecture study (i.e., higher than the value for the 0-5 years period but lower than the 6-10 year period). Our cost estimates in general appear to be higher because we assume that (i) none of the ITS technology is currently deployed and (ii) no drastic reduction in component costs (except for electronic) during the next ten-year period.

The other major source of cost information is the recently completed intelligent transportation infrastructure deployment database, developed by Oak Ridge National Laboratory for the Federal Highway Administration. This database provides information on intelligent transportation infrastructures (ITI) that are operational in the field, in the 75 largest metropolitan areas in the United States, which are being targeted for full ITI deployment within the next 10 years. Out of a total of nine components within the ITI, only three components (i.e., traffic management, freeway management, and transit management) are applicable for IVIS market packages under consideration in our study. Since no cost estimates were reported for transit management, Appendices C and D show the cost estimates of centralized traffic signal control systems and freeway management centers, respectively, currently in place in the U.S. As these tables indicate, the cost estimates do not show any consistent pattern, confirming the difficulty in developing infrastructure-related cost projections.

Cost data on in-vehicle equipment packages under consideration are limited (particularly for vehicle intersection control and vehicle route guidance equipment packages), because many of them are not yet commercially available. A recent update on commercial Advanced Traveler Information Systems (ATIS) by Volpe indicates a cost range of \$1,000-\$4,500 for autonomous route guidance equipment (Volpe 1996). For comparison, annual user expenditures (in 1995 dollars) for the basic service (which includes only the broadcast traveler information market package and Mayday service) estimated by the national architecture study are \$132, plus \$450 in capital equipment, which results in a levelized cost of \$192 per vehicle, compared to \$68 and \$605 per vehicle for the broadcast traveler information and the interactive traveler information market packages, respectively, that this study calculates.

8. SCALING TO NATIONAL TOTALS

Section 7 is a tabulation of the projected costs of deploying selected IVIS-related systems in urban and interurban regions, given certain assumptions about market penetration and other relevant factors. In Section 8, the costs in each of these two regions are aggregated to estimate the costs for *nationwide* urban and interurban deployment.

8.1 AGGREGATION METHOD

Aggregation was based on the ratios of the magnitude of specific parameters (e.g., population, freeway and arterial miles etc.) in the U.S. to the magnitude of those parameters in the region. As described in Section 6.3, these parameters are used in the regional estimates to determine the number of units needed of each component. FHWA data (i.e., Highway Statistics 1995) for 391 urbanized areas having a population greater than 50,000 were used for these estimates. The national cost estimate for *urban* regions corresponds to the 75 largest metropolitan areas targeted for implementation of Intelligent Transportation Infrastructure (ITI) within 10 years. The remaining, smaller urbanized areas (i.e., 316) were used to estimate the cost of nationwide deployment of the IVIS-related market packages in *interurban* regions. FHWA data were extrapolated to the year 2007 by assuming 1% and 2% average annual growth rates for urban and interurban regions, respectively. Other parameters (i.e., number of intersections and number of household vehicles), that were used for the cost estimates, were calculated by applying the ratio of freeway miles and population, respectively, in the U.S. to the region, to the regional cost estimates. Table 8.1 compares the major regional and national parameters used to calculate these ratios.

8.2 NATIONAL TOTALS

Table 8.2 lists projected costs for nationwide urban and interurban implementation of infrastructure-related equipment packages. As indicated earlier, two equipment packages are estimated to be the most costly: Roadway basic Surveillance and Roadway Signal Priority. Their cycle costs for nationwide urban implementation are estimated to be \$3,262M and \$3,981M, respectively. For the interurban region, costs are considerably lower (the costs of corresponding equipment packages are \$877M and \$333M, respectively). With the relatively

Table 8.1. A List of Major Parameters Used in the Regional and National Cost Estimation for the Year 2007

Parameter	Urban		Interurban	
	Regional	National	Regional	National
No. of Household Vehicles	2,033,833	114,943,189	939,431	3,993,7839
No. of Transit Vehicles	2,024	94,581	655	27,837
Population	3,430,019	160,301,958	1,109,283	47,158,754
Miles of Freeway	225	12,716	275	6,403
Miles of Arterial Surface Streets	1,701	70,825	700	38,627
Intersections	2,560	144,680	1,040	24,215

Table 8.2. Projected National Implementation Costs of the *Infrastructure-Related Equipment Packages* for Five IVIS-Related Market Packages for a Ten-Year Deployment Period

Equipment packages	Market packages used for	Ten-year deployment cost (\$M 1996)			
		Urban		Interurban	
		Life cycle	Annual levelized	Life cycle	Annual levelized
Basic Information Broadcast	B,D	121	17	32	5
Collect Traffic Surveillance	B,I,D,S	135	19	36	4.5
Infrastructure Provided Route Selection	S	24	3.4	6.2	0.9
Interactive Infrastructure Information	I,S	1,619	231	264	38
Roadway Basic Surveillance	B,I,D,S	3,262	464	877	125
Roadway Intersection Collision	C	1.4	0.2	0.2	0.03
Roadway Signal Controls	C	3,981	567	333	47
Roadway Signal Priority	C	601	86	68	10
TMC Multi-Modal Coordination	C	890	127	75	11
Transit Center Demand Responsive Operations	I,S	47	7	11	1.6
Transit Center Fare & Load Mgmt.	B,I,D	95	13	22	3.2
Transit Center Fixed Route Operations	B,I,D,S	54	8	13	2.0
Transit Center Tracking & Dispatch	B,I,D,S	154	22	36	5.0

Note: B: Broadcast Traveler Information
D: Dynamic Route Guidance
S: ISP-Based Route Guidance

C: Intersection Collision Avoidance
I: Interactive Traveler Information

lower costs of regional transit-related equipment packages, nationwide implementation costs of, for example, the transit center fixed route operations equipment package are estimated to be \$54M and \$13M, for urban and interurban regions, respectively.

Nationwide implementation costs at the market package level are shown in Tables 8.3 and 8.4 for urban and interurban regions, respectively. A detailed cost breakdown can be found in Appendix E. Since costs of in-vehicle equipment packages are on a per vehicle basis, no cost difference is projected between the two regions and between the levels of aggregation (i.e., regional vs national). The life cycle infrastructure cost for nationwide implementation of the intersection collision avoidance (ICA) market package is estimated to be the greatest among the market packages considered. Whereas, the ISP-based route guidance market package was the most expensive in the regional cases that were considered. The ICA cost projections are dictated mainly by the number of intersections, whose difference in values between the regional and national totals is significantly greater than that for other parameters, as shown in Table 8.1. For example, for the urban region, the life cycle infrastructure cost of the broadcast traveler information market package is estimated to be \$3,800M compared to \$5,400M for the ICA market package. The corresponding levelized costs are \$540M and \$780M, respectively.

For in-vehicle equipment packages, the present value is the greatest for the vehicle route guidance equipment package, among the equipment packages considered here, as shown in Table 8.5. For urban and interurban regions, market values of this equipment package are estimated to be \$16,000M and \$2,400M, respectively. The current technology for most of these equipment packages is far from being commercialized and it is expected that with the decline in the unit cost of these equipment packages, the increase in market penetration rates of these equipment packages will help to maintain the projected market values. The ranges of annualized market values of these equipment packages are estimated to be \$420-\$2,300M and \$97-\$350M, for urban and interurban regions, respectively.

Tables 8.6 and 8.7 tabulate the total costs projected to be paid by each of the four categories of purchasers of nationwide implementation of infrastructure-related equipment packages. It is estimated that the federal government might pay \$2,500M and \$2,000M for roadway signal controls and roadway basic surveillance equipment packages, respectively, for nationwide urban region implementation. The federal share of the corresponding levelized costs

Table 8.3. Projected *National Implementation Costs* (1996 \$) of Five IVIS-Related Market Packages for the *Urban Region* for a Ten-Year Deployment Period

Equipment packages	In-vehicle		Infrastructure	
	Life cycle (\$ per vehicle)	Levelized (\$/yr per vehicle)	Life cycle (\$M)	Levelized (\$M/yr)
Broadcast Traveler Information	600	68	3,821	543
Interactive Traveler Information	5,300	605	5,352	762
Dynamic Route Guidance	5,706	652	3,868	550
ISP-based Route Guidance	10,406	1,189	5,390	767
Intersection Collision Avoidance	4,854	555	5,473	780

Table 8.4. Projected *National Implementation Costs* (1996 \$) of Five IVIS-Related Market Packages for the *Interurban Region* for a Ten-Year Deployment Period

Equipment packages	In-vehicle		Infrastructure	
	Life cycle (\$ per vehicle)	Levelized (\$/yr per vehicle)	Life cycle (\$M)	Levelized (\$M/yr)
Broadcast Traveler Information	600	68	1,016	145
Interactive Traveler Information	5,300	605	1,255	180
Dynamic Route Guidance	5,706	652	1,027	146
ISP-based Route Guidance	10,406	1,189	1,265	180
Intersection Collision Avoidance	4,854	555	476	68

Table 8.5. Projected *National* Market Values (1996 \$) of the *In-Vehicle Equipment Packages* for the Five IVIS-Related Market Packages for a Ten-Year Deployment Period

Equipment packages	Urban		Interurban	
	Present value (\$M)	Annualized (\$M/yr)	Present value (\$M)	Annualized (\$M/yr)
Basic Vehicle Reception	2,948	420	683	97
Interactive Vehicle Reception	12,476	1,776	2,001	285
Vehicle Route Guidance	15,843	2,256	2,447	348
Vehicle Intersection Control	3,332	474	1,158	165

Table 8.6. Projected *National Urban Region Implementation* Costs of the Equipment Packages for the Five IVIS-Related Market Packages for a Ten-Year Deployment Period, by *Parties Likely to Pay*

Equipment packages	Ten-year deployment cost (\$M 1996)							
	Life cycle				Annual levelized			
	Fed	Stat	Pvt	Tot	Fed	Stat	Pvt	Tot
Basic Information Broadcast			121	121			17	17
Collect Traffic Surveillance	16	119		135	2	17		19
Infrastructure Provided Route Selection			24	24			3.4	3.4
Interactive Infrastructure Information			1,619	1,619			231	231
Roadway Basic Surveillance	2,025	1,237		3,262	288	176		464
Roadway Intersection Collision	0.9	0.5		1.4	0.1	0.1		0.2
Roadway Signal Controls	2,545	1,436		3,981	362	205		567
Roadway Signal Priority	369	232		601	53	33		86
TMC Multi-Modal Coordination	681	209		890	97	30		127
Transit Center Demand Responsive Operations	6	41		47	1	6		7
Transit Center Fare & Load Mgmt.	44	51		95	6	7		13
Transit Center Fixed Route Operations	15	39		54	2	6		8
Transit Center Tracking & Dispatch	31	123		154	4	18		22

Note: Fed: Federal
 Stat: State or Local
 Pvt: Private Sector
 Tot: Total

Table 8.7. Projected *National Interurban Region Implementation* Costs of the Equipment Packages for the Five IVIS-Related Market Packages for a Ten-Year Deployment Period, by *Parties Likely to Pay*

Equipment packages	Ten-year deployment cost (\$M 1996)							
	Life cycle				Annual levelized			
	Fed	Stat	Pvt	Tot	Fed	Stat	Pvt	Tot
Basic Information Broadcast			32	32			5	5
Collect Traffic Surveillance	4	32		36	0.6	3.9		4.5
Infrastructure Provided Route Selection			6.2	6.2			0.9	0.9
Interactive Infrastructure Information			264	264			38	38
Roadway Basic Surveillance	0.1	0.1		0.2	77	48		125
Roadway Intersection Collision	544	333		877	0.02	0.01		0.03
Roadway Signal Controls	213	120		333	30	17		47
Roadway Signal Priority	42	26		68	6	4		10
TMC Multi-Modal Coordination	57	18		75	8	3		11
Transit Center Demand Responsive Operations	1	10		11	0.2	1.4		1.6
Transit Center Fare & Load Mgmt.	10	12		22	2.0	1.2		3.2
Transit Center Fixed Route Operations	3	10		13	0.5	1.5		2.0
Transit Center Tracking & Dispatch	7	15		22	1	4		5

Note: Fed: Federal
Stat: State or Local
Pvt: Private Sector
Tot: Total

of these equipment packages is \$360M and \$290M, respectively. The private sector is likely to pay the most for the interactive infrastructure information equipment package. Its life cycle costs are projected to be \$1,600M and \$260M for urban and interurban regions, respectively. Note that these estimates are likely an upper bound. A significant reduction in the share of the public sector cost is anticipated should there be significant reduction in the costs of these equipment packages, as commercialization of these technologies progresses and as more cost sharing takes place between local/state governments and the private sector.

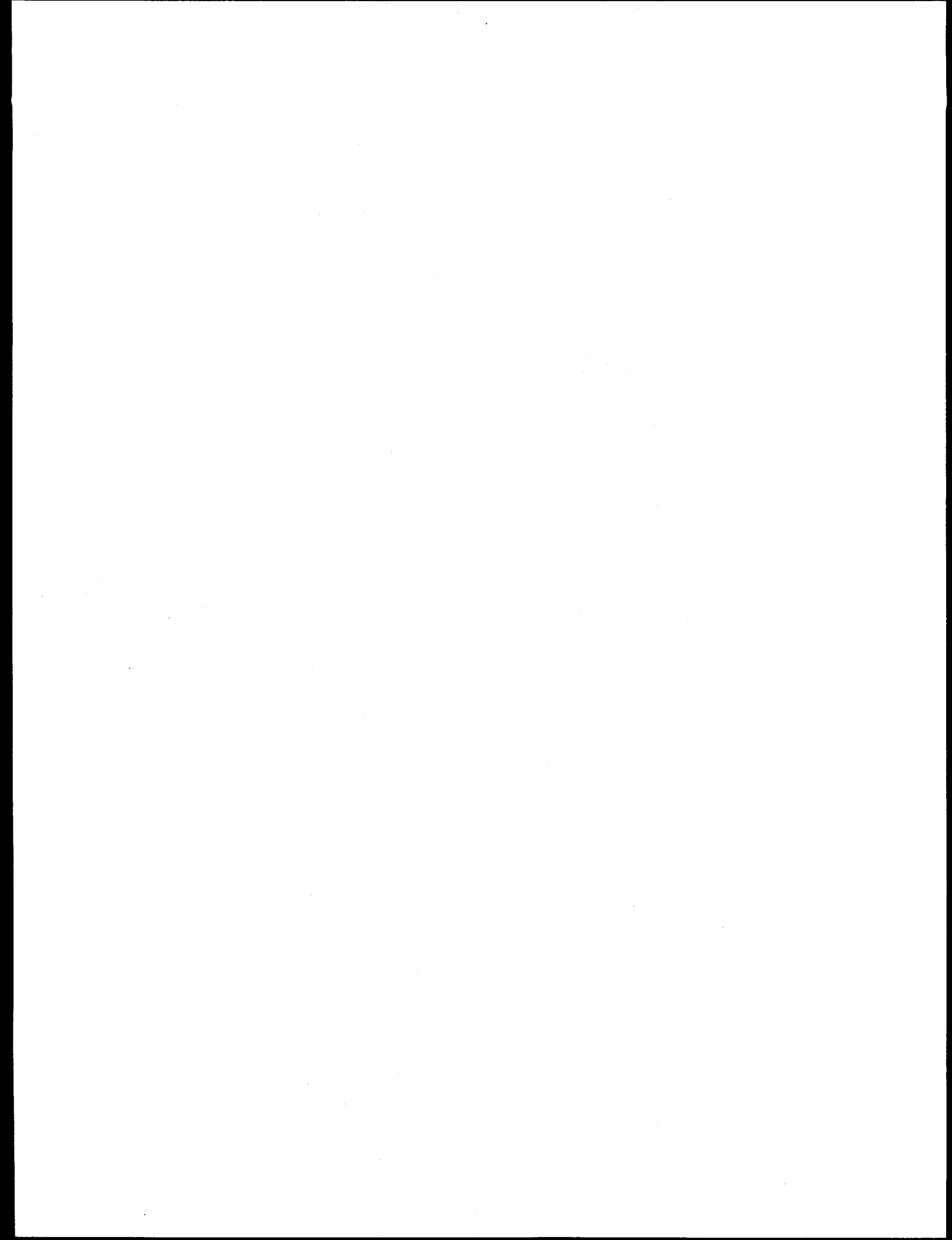
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APPENDIX A

IVIS SOFTWARE DESCRIPTION



ITS COST INFORMATION SYSTEM DESCRIPTION

The Intelligent Transportation Systems Cost Information provides a means of organizing and retrieving information about the components of intelligent vehicle systems, including both in-vehicle and infrastructure-related equipment; and of using this information to calculate deployment costs for the user-defined scenarios. ITS systems are defined based on the national ITS architecture. This information system provides price data, equipment descriptions, and data-source documentation. The data base contains information for all of the components of the five market packages considered in this study. Users of the software can edit this information. Software users can enter baseline or "master" data on different models for the various components of the equipment packages; define scenarios; and catalog cost

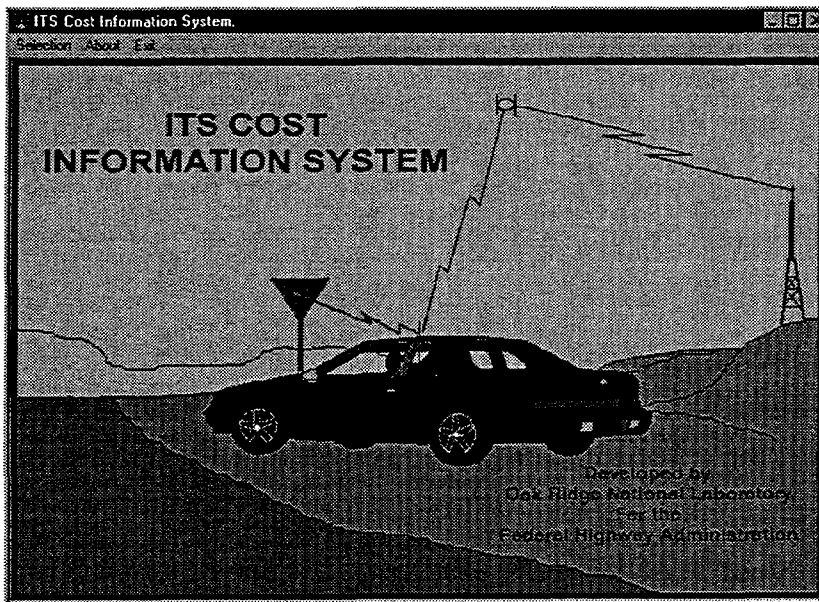


Fig. A.1. Opening screen of the ITS Cost Information System software.
screens.

information. In addition, there are user-interfaces for other modules that allow users to "build" their own deployment scenarios and to calculate their costs. The software allows users either to build a scenario or to update the master database by means of sequential steps, implemented in the software by different

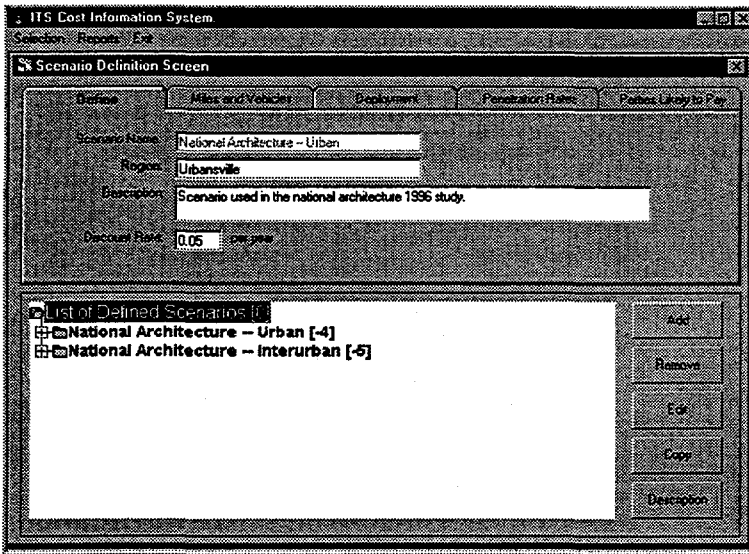


Fig. A.2. Scenario definition screen.

The upper section displays a series of tabs where the user can enter information about the scenario. After a deployment scenario is created, the user can add and/or remove market package(s) associated with the scenario as shown in Figure A.3. The user can also choose and edit “Models” or ITS equipment associated with the scenario. A description of the market packages, equipment packages, or

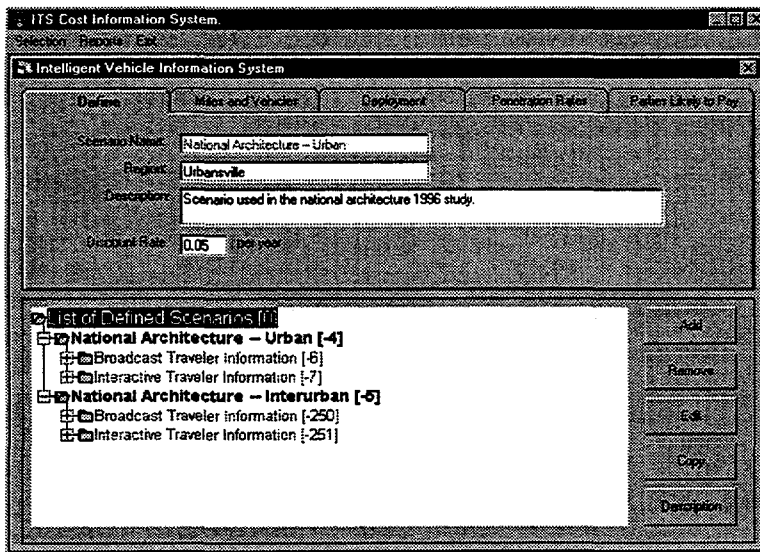


Fig. A.3. Market package in scenario screen.

Figure A.1 shows the opening screen of the software (version 7.2.98) which contains the Main Menu. The “Selection” option allows the user to add a new, or modify an existing, deployment scenario. If the user chooses to define a scenario, a screen is displayed with an upper and lower section, as shown in

Figure A.2. The “Scenario Tree

View” is always displayed in the lower part of the screen. The upper section displays a series of tabs where the user can enter information about the scenario. After a deployment scenario is created, the user can add and/or remove market package(s) associated with the scenario as shown in Figure A.3. The user can also choose and edit “Models” or ITS equipment associated with the scenario. A description of the market packages, equipment packages, or equipment components can be obtained by clicking on the “Description” button, as shown in Figure A.4.

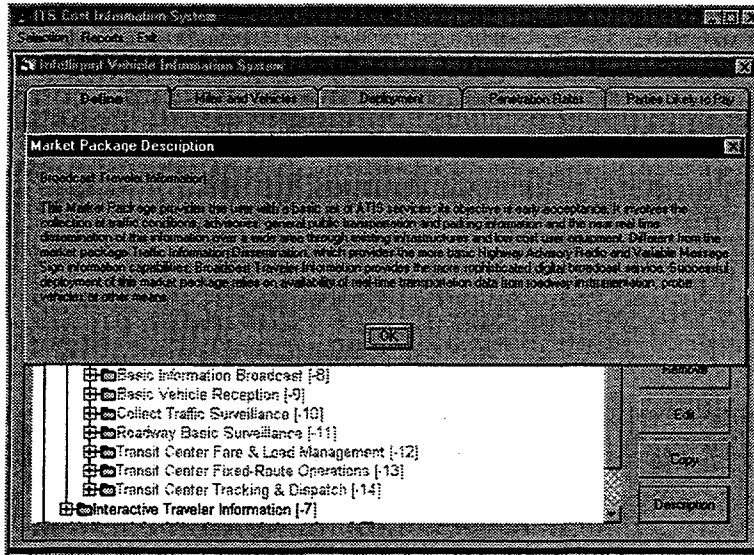


Fig. A.4. Market package description.

Figure A.5 provides a means of editing the name, description, and components associated with an equipment package. The screen displays one equipment package at a time and a list of components that comprise that equipment package. The user can then add or remove components from that equipment package. Components are added by selecting from a list of all components, which is displayed when the “Add to this Equipment Package” function is activated.

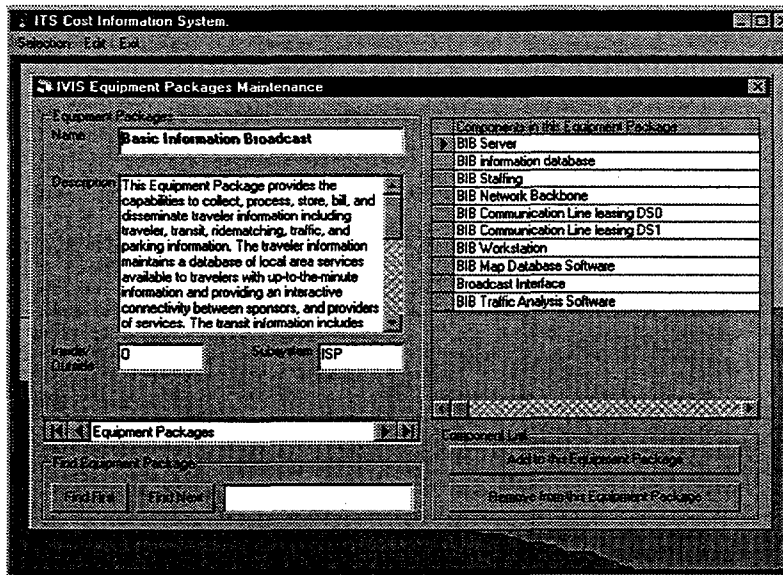


Fig. A.5. Equipment package maintenance screen.

Besides defining deployment scenarios under the “Selection” option, it also allows maintenance of user-defined master market packages, equipment packages, components, and models including editing data within the models. For example, the “Equipment Packages Maintenance” screen as shown in

Similarly, the “Components Maintenance” screen allows editing, creation, and deletion of components. Items that can be edited include the name, description, and the default model. From this screen, the user can go directly to the “Component Models” screen for editing the models

associated with the component. The default model for a component is the model that is automatically assigned to a component when defining a scenario. A component may be deployed through any one of several models, but can have only one default model at a time. Any model that is listed for a component can be used depending on the needs of the particular scenario, selected at the discretion of the user.

The "Component Model" screen is used to create, edit, and remove models. There are three ways to enter this screen.:

- The "Edit Master Models" under the option "Selection" brings up the component model screen. This screen displays one model at a time and allows the user to select other models by using the arrow buttons at the bottom of the screen. A list of all models on the database sorted by model name is displayed when "Lookup" is selected.
- If the user is editing a component in the "Components Maintenance" screen, the models screen can be entered by clicking on the "Edit Model" button. Only the selected default model associated with the particular component being edited will be displayed.
- From the "Scenario Tree View" (i.e., the lower half section of screen) on the "Scenario Definition" screen the user can enter the component models screen by selecting the model and clicking on the "Edit" button. Doing so will display the "Scenario Component Model" screen. This screen will allow the user to edit component model information specific to that scenario without changing the master component model record. To change the component model for a particular component in a scenario, the user can display the list of assigned models for a component by selecting the component and clicking on the "Edit" button. A list of all of the models that may be used for that particular component will be displayed and a different component model can be selected. Only one model can be selected for one component. By default, the default model is assigned to the component. In the models screen several tabs allow for the editing of costs as shown in Figure A.6. These screens are also the heart of the user interfaces for the cost calculations provided by the ITS software.

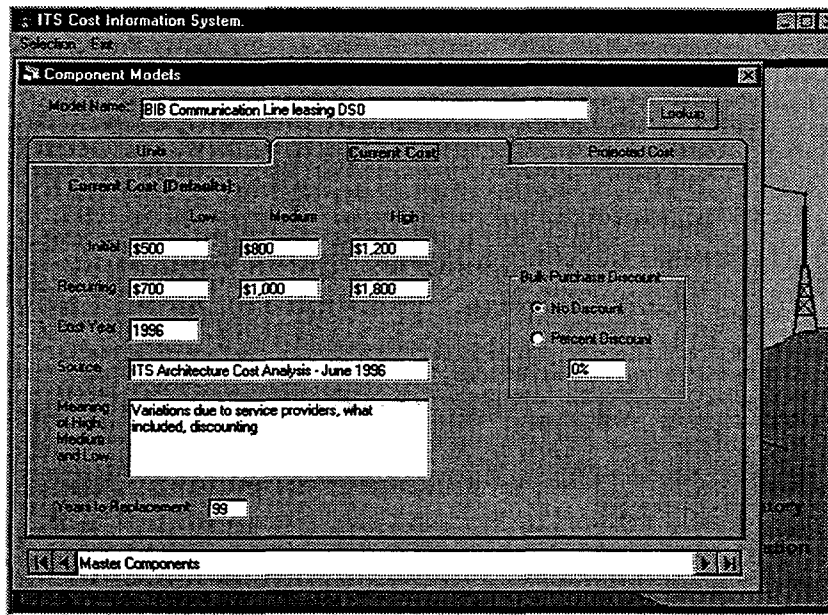


Fig. A.6. Models' cost data editing screen.

The "Tree View" display at the bottom of the "Scenario Definition" screen Figure A.2 shows the hierarchical relations of all of the ITS components. The software comes with a set of basic market packages, equipment packages, components, and

component models. This "Tree View" also shows user-defined scenarios and the market packages that the user has selected for the scenarios. The user can then go down the tree and observe the various levels of detail within a scenario. At the "leaf level" of the tree, the user can then define the component models to be implemented with a particular scenario.

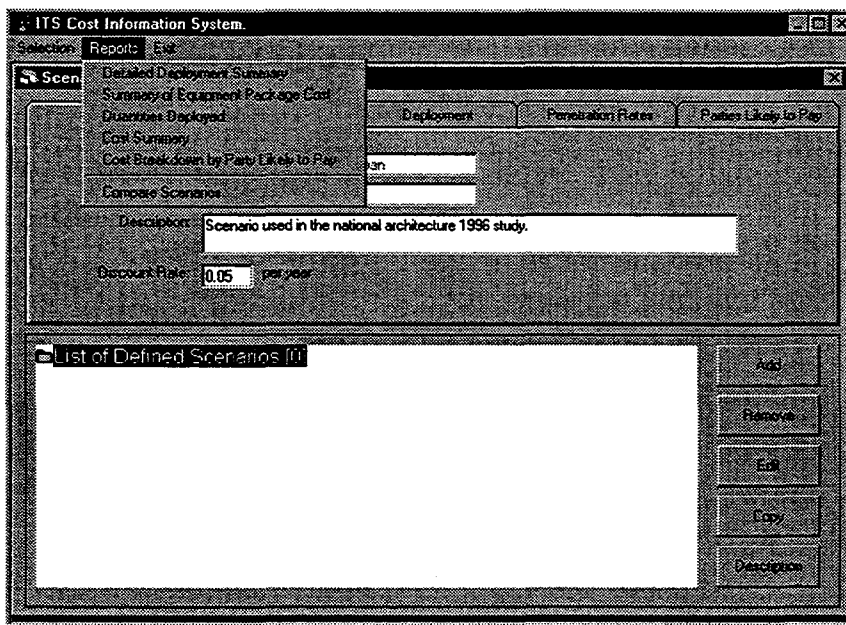
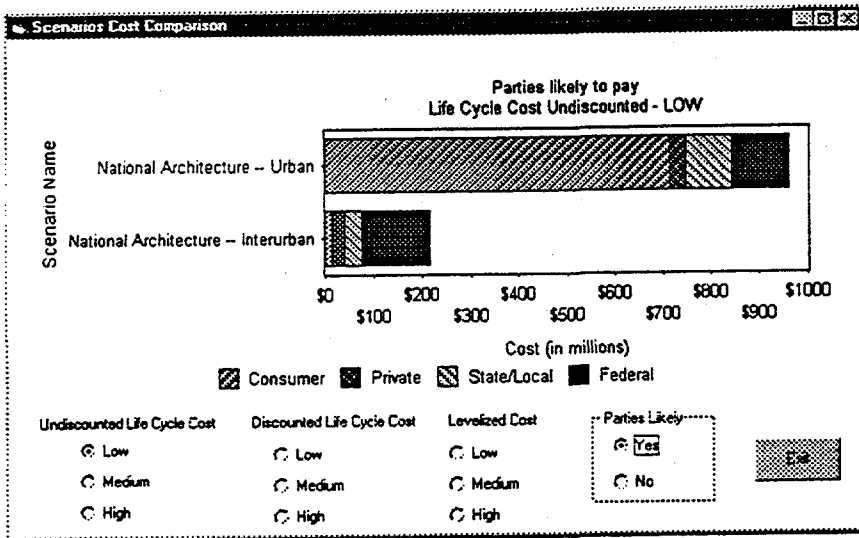


Fig. A.7. Reports sub-menu.

The menu on the top of the "Scenario Definition Screen" gives the user access to the reports. Figure A.7 displays the reports sub-menu and all the available reports. A sample "Detail Deployment Summary" report is included at the back of this appendix.

The system also lets users compare the cost of up to five scenarios. There are four different ways the calculated costs can be compared: (i) undiscounted life cycle cost, (ii) discounted life cycle cost, (iii) levelized cost, and (iv) parties likely to pay. Figure A.8 displays the result of comparing the parties likely to pay cost for two scenarios.



Operating system requirements for the software are Windows 95 or MS NT 4.0, and 10 - 15 MB of available disk space. The software was developed in Visual Basic 5.0. MS Access software is used for the database.

Fig. A.8. Scenario cost comparison.

Table A.1. A Sample Detailed Deployment Summary Cost Report

Detailed Deployment Cost

Scenario Name: National Architecture -- Interurban
 Region: Thruville
 Description: Scenario used in the national architecture 1996 study.
 Discount Rate: 5%
 Deployment Years: 10

Projected at End of Deployment

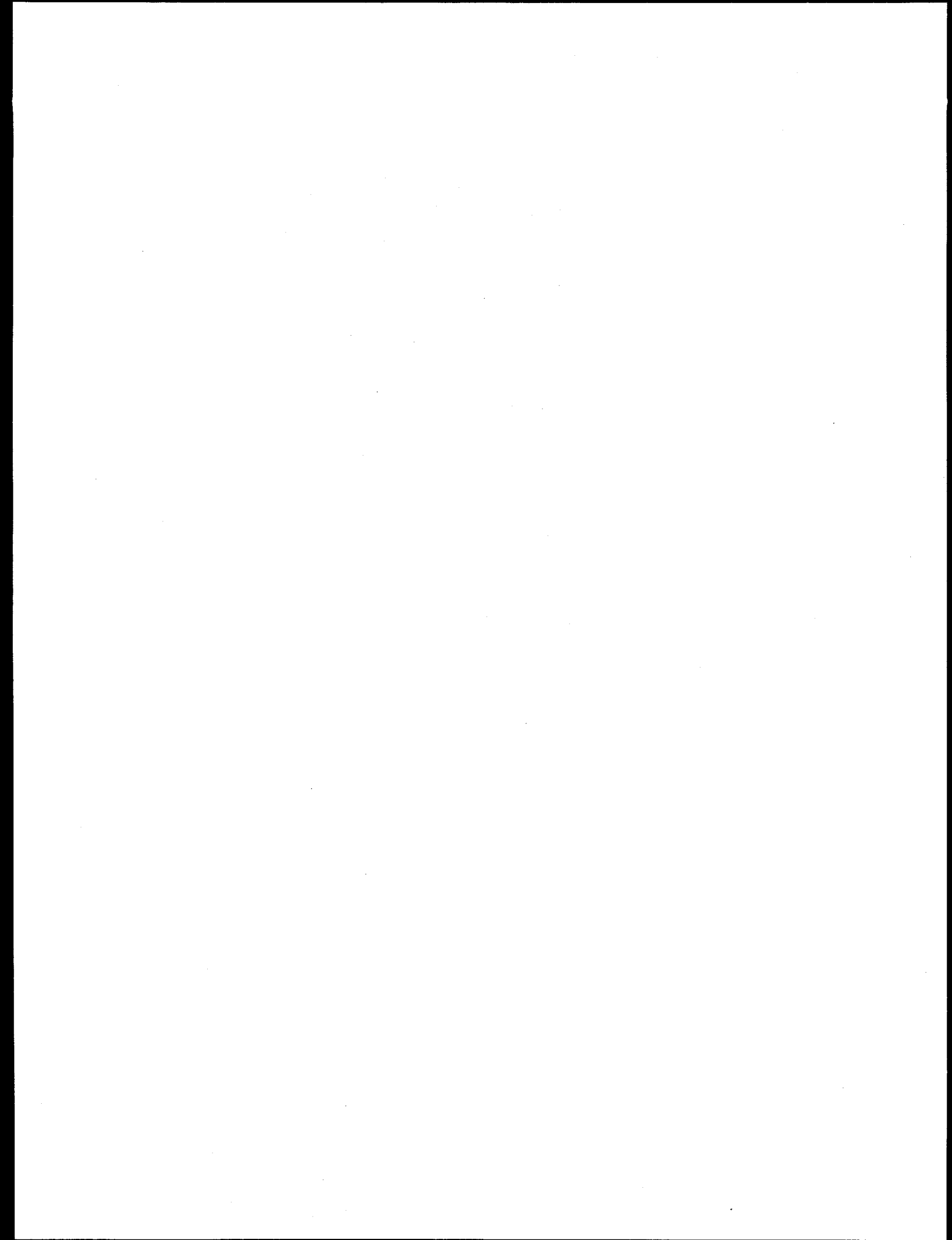
Freeway Miles: 275
 Arterial Miles: 490
 Intersections: 1,040
 Population: 939,431
 Number of Transit Vehicles: 655
 Number of Household Vehicles: 939,431
 Peak Service Volume: 0.10

Deployment Year: 1997 Percent of Total Deployed This Year: 10%

Market Package: Broadcast Traveler Information

Equipment Package: Basic Information Broadcast

Model Name	QUANTITY				Undiscounted Cost ('98\$)		
	New This Year	Replaced Old	Total New + Replaced	Left to be Cumulative Deployed	Low	Medium	High
BIB Server	1	0	1	1	\$38,111	\$57,167	\$142,919
BIB Staffing	1	0	1	1	\$105,104	\$131,381	\$157,657
BIB Traffic Analysis Software	1	0	1	1	\$142,919	\$285,838	\$714,596
Broadcast Interface	1	0	1	1	\$103,680	\$248,833	\$311,041
BIB Map Database Software	1	0	1	1	\$9,527	\$19,055	\$71,459
BIB Workstation	1	0	1	1	\$2,858	\$4,763	\$11,433
BIB Communication Line leasing DS1	1	0	1	1	\$5,702	\$19,699	\$46,656
BIB Communication Line leasing DS0	1	0	1	1	\$1,244	\$1,866	\$3,110
BIB Network Backbone	1	0	1	1	\$62,208	\$103,680	\$155,520
BIB information database	1	0	1	1	\$42,875	\$57,167	\$95,279
Total for Equipment Package Basic Information Broadcast					\$514,233	\$929,454	\$1,709,674



APPENDIX B

PROJECTED *REGIONAL* COSTS OF FIVE IVIS MARKET PACKAGES

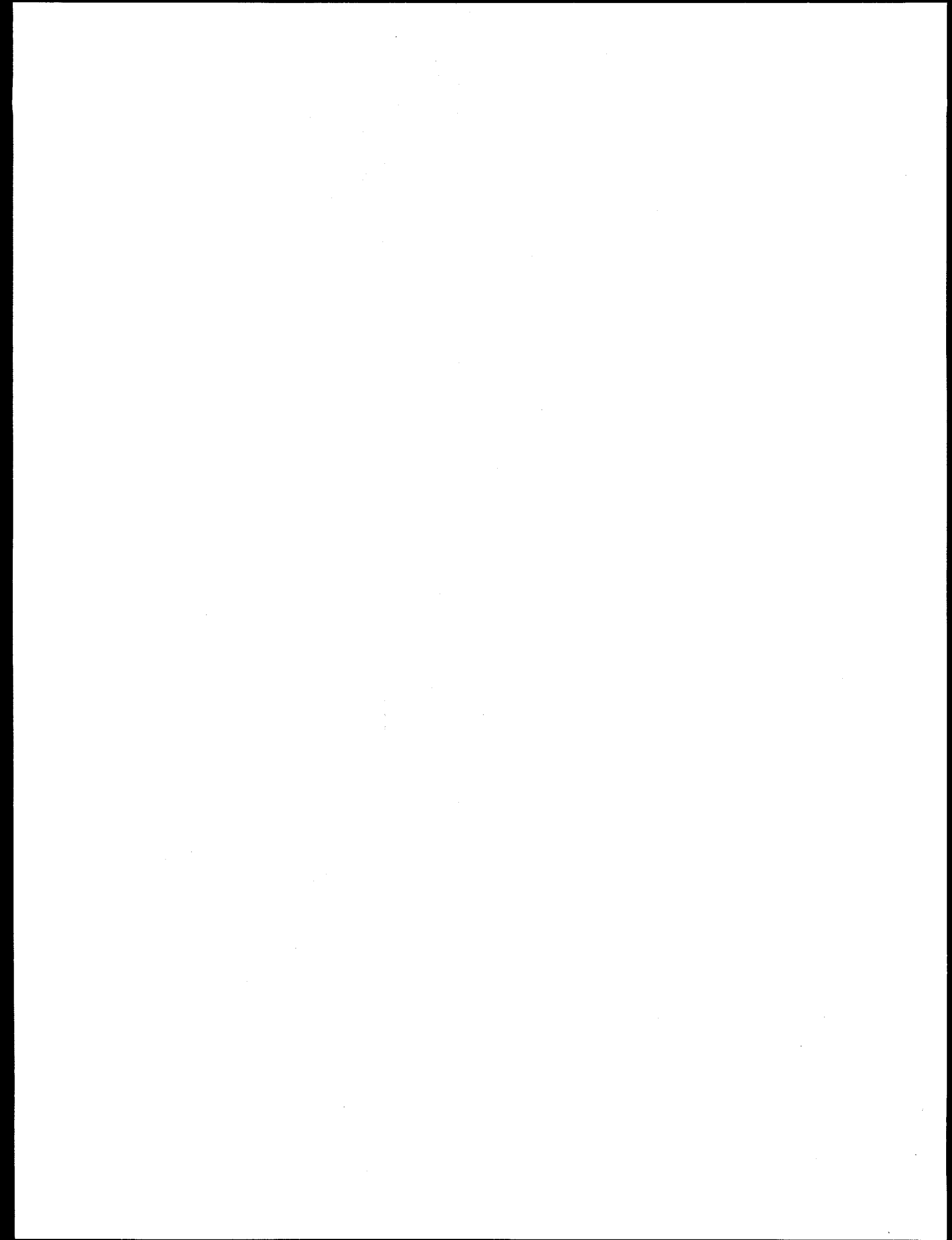


Table B.1. Projected Costs (1996 dollars) of the *Broadcast Traveler Information Market* Package for *Urban and Interurban* Regions for a Ten-Year Deployment Period

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Basic Vehicle Reception	598×10^{-6} /vehicle	598×10^{-6} /vehicle	68×10^{-6} /vehicle	68×10^{-6} /vehicle
INFRASTRUCTURE	Basic Information Broadcast	2.9	1.4	0.4	0.2
	Collect Traffic Surveillance	3.2	0.8	0.5	0.1
	Roadway Basic Surveillance	74	20	11	2.8
	Transit Center Fare & Load Management	2.0	0.8	0.3	0.1
	Transit Center Fixed-Route Operations	1.2	0.4	0.2	0.06
	Transit Center Tracking & Dispatch	3.3	1.3	0.5	0.2
	TOTAL		86.6	24.7	12.9

Table B.2. Projected Costs (1996 dollars) of the *Interactive Traveler Information Market* Package for *Urban and Interurban* Regions for a Ten-Year Deployment Period

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Interactive Vehicle Reception	$5,294 \times 10^{-6}$ /vehicle	$5,294 \times 10^{-6}$ /vehicle	605×10^{-6} /vehicle	605×10^{-6} /vehicle
INFRASTRUCTURE	Interactive Infrastructure Information	31	8.6	4.4	1.2
	Collect Traffic Surveillance	3.2	0.8	0.5	0.1
	Roadway Basic Surveillance	74	20	11	2.8
	Transit Center Fare & Load Management	2.0	0.8	0.3	0.1
	Transit Center Fixed-Route Operations	1.2	0.4	0.2	0.06
	Transit Center Tracking & Dispatch	3.3	1.3	0.5	0.2
	Transit Center Demand Responsive Operations	1.0	0.4	0.1	0.06
	TOTAL	115.7	32.3	17.0	4.5

Table B.3. Projected Costs (1996 dollars) of the *Dynamic Route Guidance* Market Package for *Urban and Interurban* Regions for a Ten-Year Deployment Period

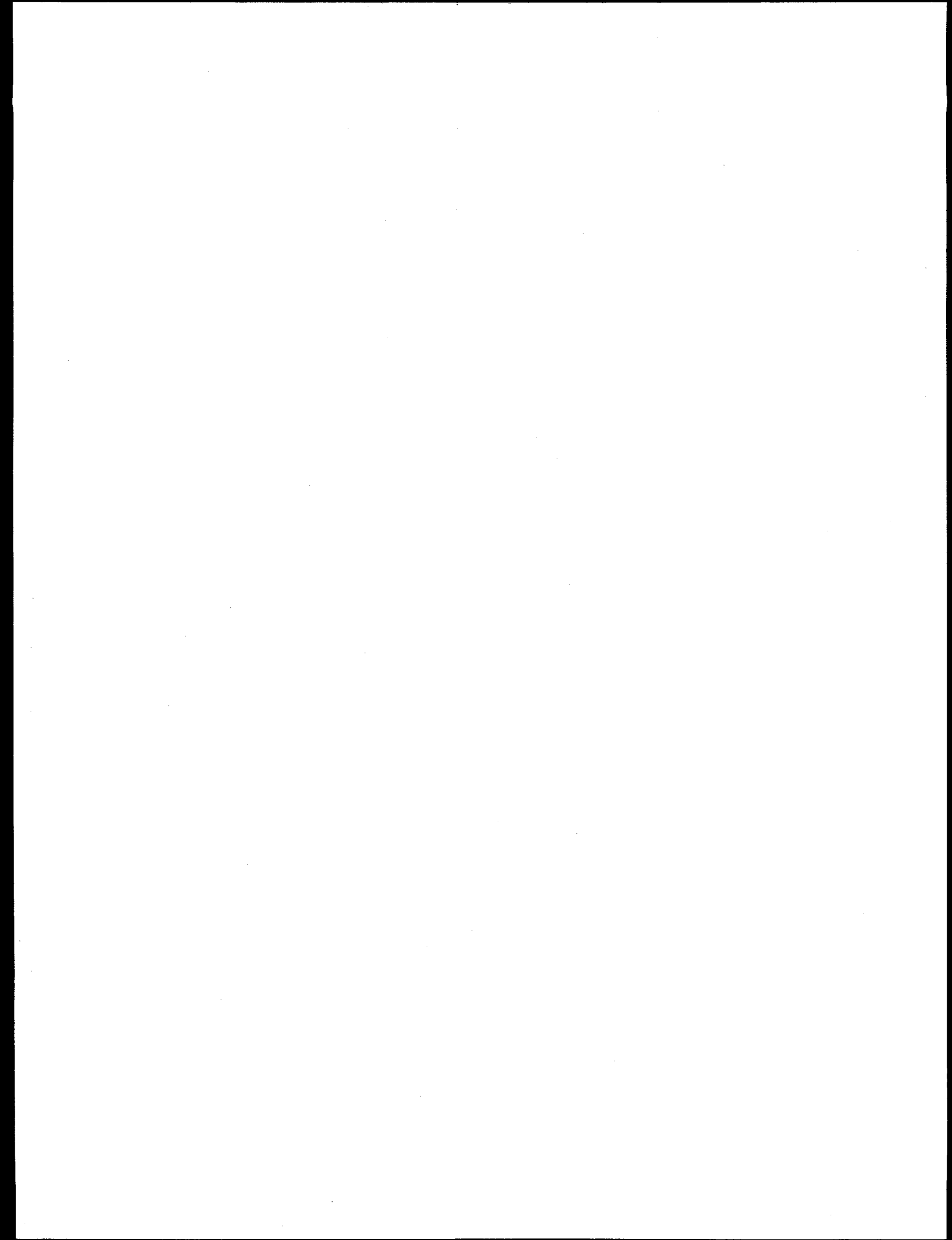
Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Basic Vehicle Reception	598 x 10 ⁻⁶ /vehicle	598 x 10 ⁻⁶ /vehicle	68x 10 ⁻⁶ /vehicle	68x 10 ⁻⁶ /vehicle
	Vehicle Route Guidance	5,106 x 10 ⁻⁶ /vehicle	5,106 x 10 ⁻⁶ /vehicle	584x 10 ⁻⁶ /vehicle	584 x 10 ⁻⁶ /vehicle
INFRASTRUCTURE	Basic Information Broadcast	2.9	1.4	0.4	0.2
	Collect Traffic Surveillance	3.2	0.8	0.5	0.1
	Roadway Basic Surveillance	74	20	11	2.8
	Transit Center Fare & Load Management	2.0	0.8	0.3	0.1
	Transit Center Fixed-Route Operations	1.2	0.4	0.2	0.06
	Transit Center Tracking & Dispatch	3.3	1.3	0.5	0.2
	Transit Center Demand Responsive Operations	1.0	0.4	0.1	0.06
	TOTAL	87.6	25.1	13.0	3.5

Table B.4. Projected Costs (1996 dollars) of the *ISP-Based Route Guidance* Market Package for *Urban and Interurban* Regions for a Ten-Year Deployment Period

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Interactive Vehicle Reception	5,294 x 10 ⁻⁶ /vehicle	5,294 x 10 ⁻⁶ /vehicle	605x 10 ⁻⁶ /vehicle	605x 10 ⁻⁶ /vehicle
	Vehicle Route Guidance	5,106 x 10 ⁻⁶ /vehicle	5,106 x 10 ⁻⁶ /vehicle	584x 10 ⁻⁶ /vehicle	584 x 10 ⁻⁶ /vehicle
INFRASTRUCTURE	Interactive Infrastructure Information	31	8.6	4.4	1.2
	Infrastructure Provided Route Selection	0.6	0.3	0.08	0.04
	Collect Traffic Surveillance	3.2	0.8	0.5	0.1
	Roadway Basic Surveillance	74	20	11	2.8
	Transit Center Fare & Load Management	2.0	0.8	0.3	0.1
	Transit Center Fixed-Route Operations	1.2	0.4	0.2	0.06
	Transit Center Tracking & Dispatch	3.3	1.3	0.5	0.2
	Transit Center Demand Responsive Operations	1.0	0.4	0.1	0.06
	TOTAL	116.3	32.6	17.1	4.6

Table B.5. Projected Costs (1996 dollars) of the *Intersection Collision Avoidance* Market Package for *Urban and Interurban* Regions for a Ten-Year Deployment Period

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Vehicle Intersection Control	$4,854 \times 10^{-6}$ /vehicle	$4,854 \times 10^{-6}$ /vehicle	555×10^{-6} /vehicle	555×10^{-6} /vehicle
INFRASTRUCTURE	Roadway Intersection Collision	0.03	0.01	0.004	0.001
	Roadside Signal Priority	10.6	2.9	1.5	0.4
	Roadway Signal Controls	70	14.3	10	2.0
	TMC Multi-Modal Coordination	15.8	3.2	2.2	0.5
	TOTAL	96.4	20.4	13.7	2.9



APPENDIX C

SUMMARY OF COST ESTIMATES OF CENTRALIZED
TRAFFIC CONTROL SYSTEMS CURRENTLY IN THE U.S

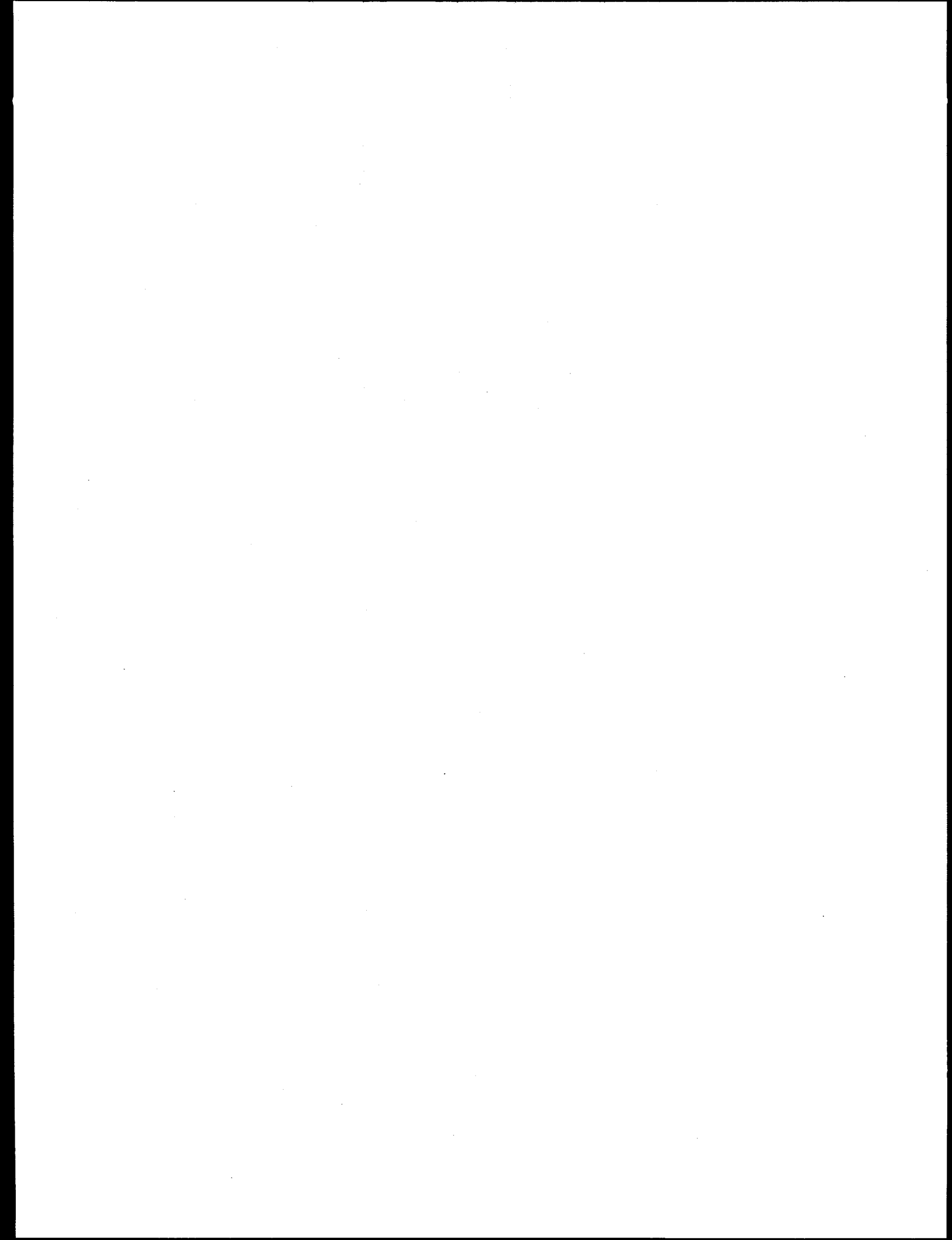


Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S.

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
Atlanta, GA	Transportation Management Center	I-75 and I-85 inside of the I-285 perimeter	50	137000	3000	34	The initial capital construction cost of \$137,000,000 covers the entire ATMS (FMS, 6 TCCs, and Marta's operation center).
Baltimore, MD	SHA Traffic Operations Center (TOC) Golden Ring Mall	Current coverage with current deployment: 400 miles. Baltimore Beltway (I-695), I-95 north & south of I-695, I-83, I-795, MD-295, and various arterials around the Baltimore metropolitan area. Current deployment is loose (i.e. equipment is very far apart) Future coverage with future deployment: 400 miles (same routes as current coverage), with much closer deployment of equipment (1/2 - 1 mile detection spacings and 1 - 2 mile CCTV spacings on some routes and interstates.	200	NA	433	4	The primary function of this Traffic Operations Center is incident management. The annual operating budget is \$1.3 million for the SHA Traffic Operations Center Golden Ring Mall, SHA Traffic Operations Center College Park, and the State Operations Center
Baltimore, MD	Statewide Operations Center (SOC)	1000 miles Current coverage: This center provides coverage for the areas of the state that are not currently covered by the other TOC's; as well as control for the other TOC's areas when they are not in operation. This center is built to accommodate any future growth in the state's ATMS program. Future coverage: Same as above plus I-68, I-97, I-70, US-50, and other major arterials and interstates throughout the state of Maryland.	500	NA	433	18	The annual operating budget is \$1.3 million for the SHA Traffic Operations Center Golden Ring Mall, SHA Traffic Operations Center College Park, and the State Operations Center
Boston, Lawrence, Salem, MA	Regional Traffic Operations Center	Southeast Expressway (I-93), I-95/SR-128 corridor, and I-93 north	52	7000	NA	NA	A Temporary Traffic Operations Center (TOC) has been in operation since 11/15/95 on the 8 miles of the Southeast Expressway. This facility was installed in conjunction with a moveable barrier counter follow HOV lane. The operations of the Temporary TOC will be transferred to the Region TOC once it has been constructed

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
							A Regional TOC is currently under design to be colocated with the State Police Facility in Framingham. This center will be operational in approximately 2 years and will monitor 52 miles of freeways. Field equipment which includes inductive loops, overhead radar detectors, CMS, and CCTV are also under design with an incident management focus.
Buffalo, Niagara Falls, NY	NITTEC Traffic Operations Center	The Traffic Operations Center is currently in design. It is estimated that 50 miles of freeways will have electronic surveillance.	50	2000	NA	1	
Charlotte, Gastonia, Rock Hill, NC	Congestion Avoidance and Reduction for Autos and Trucks (CARAT)	Detection and surveillance equipment along a 15.2 mile segment of I-77 from the South Carolina state line to Sunset Road.	15	13200	500	12	
Chicago, Gary, Lake County, IL	INDOT Traffic Management Center	Westbound Borman Expressway (I-80, I-94) from Burr St. to Kennedy Ave.	3	1400	250	11	
Chicago, Gary, Lake County, IL	IDOT Traffic Systems Center	136 centerline miles covering portions of the following expressways: Edens I-94 John F. Kennedy Expressway I-90 & I-94 Dan Ryan Expressway I-90 & I-94 Dwight D. Eisenhower Expressway I-290 Adlai E. Stevenson Expressway I-55 Calumet Expressway I-94 I-57 Kingary Expressway I-80 & I-94 Lake Shore Drive US 41 Elgin-O'Hare Expressway None of the tollways are covered	136	12000	2000	9 permanent, 3-8 temporary	In 1997 electronic surveillance will be expanded to include a total of 153 miles. A real time traffic condition map can be found on the internet at http://www.atccs.uec.edu/GCM/GCM.html
Cincinnati, Hamilton, OH	Cincinnati ARTMIS	I-71, I-75, I-77, I-275, SR-562, and Cross County Highway	88	20000	1500	8 - 16	
Dallas, Fort. Worth, TX	Transportation Management Satellite - Dallas	I-635 from I-35E east to I-75 I-75 from Woodall Rodgers Freeway north to I-635 I-35E from SR12 north to I-635	NA	110000	500	4	The Dallas Area Transportation Management Satellite is currently under construction.

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
		SR 12 from SR183 north to I-35E SR183 from SR97 east to I-35E					
Dallas, Fort. Worth, TX	TXDOT Satellite Operations Center (SOC) - Fort Worth	I-35W from Alta Mesa Blvd. to I-30: 5 miles I-20 from I-35W to I-20/I-820 split: 8 miles	13	18000	675	13	The Satellite Operation Center (SOC) is an interim control center. The TRANSVISION traffic management center is scheduled to open in 1998, at which time there will be approximately 80 freeway miles under surveillance
Denver, Boulder, CO	Colorado TOC	The Colorado Traffic Operations Center monitors highway conditions throughout the state. In Denver 7 miles of I-25, from Mile High Stadium to US 36, are equipped with electronic surveillance.	7	4500	500	12	
Detroit, Ann Arbor, MI	Michigan Intelligent Transportation Systems Center	I-75, I-94 and M-10 32.5 miles Future: 250 miles	33	16000	800	15	
El Paso, TX	El Paso Freeway Management Center	I-10: 27 miles US 54: 8 miles I-375: 30 miles	65	14000	250	8	
Fresno, CA	Central Valley Transportation Management Center	I-5 From Lebec, CA TO SR 152 182 miles SR 99 From I-5 TO SR 152 165 miles	347	50	500	15	
Greensboro, Winston-Salem, High Point, NC	Winston-Salem Freeway Management Center	US 52 - From I-40 to University Parkway (9 miles) I-40 - From NC 801 to Union Cross Road (22 miles) Business 40/US 421	41	4000	350	11	The freeway management center will use the loop detectors to evaluate the effectiveness of the changeable message signs. Other government agencies will have software which will allow them to access traffic data via a modem
Greensboro, Winston-Salem, High Point, NC	Greensboro Freeway Management Center	I-40 at High Point Road: 0.75 miles I-40/I-85 corridor: 20 miles I-87 corridor: 3 miles I-40 corridor: 13 miles	27	1500	300	7	Currently there are two video surveillance cameras near I-40 at High Point Road, primarily to view interchange. The Greensboro city DOT has four additional cameras on the city coliseum facility used to monitor special event traffic. These may also be utilized in emergency conditions, traffic would be detoured along this route. This route also has in place lane control signs and small changeable message boards to operate a reversible lane system

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
							There are in place sixteen overhead variable message signs along I-40/85 from NC 62 in Alamance County to I-85 south at Groometown Road and I-40 to NC 66 in Forsyth County. These are used in conjunction with the incident management program to provide information to the traveling public and to aid in the implementation of detour routes. Future plans of 1996 construction are to install nine video cameras along I-40 from NC 68 to Elm/Eugene Street. These will be used for Incident Management activities in order to monitor traffic conditions, and verification of accident occurrence and location.
Hartford, New Britain, Middletown, CT	Newington Operations Center	Electronic surveillance of 19 miles of freeway in the Hartford metropolitan area.	18	30000	3000	48	The Newington Operations Center monitors 18 miles of freeways and 300 signalized intersections in the Hartford area, and monitors another 100 signalized intersections throughout the state. The 48 personnel, \$3,000,000 budget, and \$30,000,000 capital construction cost includes the Newington Operations Center and the Bridgeport Operations Center.
Honolulu, HI	Transportation Management System	Interstates H-1, H-2, and H-3	44	90000	NA	NA	The Hawaii Department of Transportation (HDOT) intends to coordinate the Traffic Management Center development with the City of Honolulu's system. HDOT is planning to phase 44 miles of surveillance equipment along the interstate over the next 4 years.
Houston, Galveston, Brazoria, TX	Houston TranStar (Awaiting Survey Response)		NA	NA	750	16	
Las Vegas, NV	McCarran Freeway Management System	Airport tunnel connector and I-215	5	2000	2000	43	
Los Angeles, Anaheim, Riverside, CA	Orange County Transportation Management Center - Caltrans District 12	The TMC covers the following freeways: I-5, I-405, SR 55, SR 73, SR 22, SR 57, SR 91	258	4400	7000	23	
Los Angeles, Anaheim, Riverside, CA	Los Angeles Transportation Management Center	All freeways in Los Angeles and Ventura Counties	750	NA	6300	75	

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
Miami, Fort Lauderdale, FL	I-595 Changeable Message Sign System (CMSS)	I-595 in Fort Lauderdale; approximately 20 miles	20	5000	500	6	The I-595 Changeable Message Sign System (CMSS) is being installed in phases; the information provided is for Phase I and Phase II. A management center is planned for the I-595 CMSS, and it is anticipated that the Florida DOT will operate the facility.
Miami, Fort Lauderdale, FL	Pompano Traffic Operations Center	To be determined	NA	1000	NA	12	The Pompano Traffic Operations Center will provide: Area surveillance of all mainline toll plazas Toll lane surveillance of select SunPass electronic toll collection system lanes General purpose lane surveillance of high-volume metropolitan areas of the Turnpike.
Miami, Fort Lauderdale, FL	Golden Glades Interchange Control Center	I-95, Sr 826, Florida Turnpike, and SR 441	32	4000	250	6	The current center is established to control the integrated ATIS & ATMS for the region around the Golden Glades Interchange (GGI). The ATIS & ATMS system is still under construction. After completion of construction, it will provide assistance to all the incoming traffic, on freeway and arterials within approximately 4 mile radius of the GGI. The highways covered include I-95, SR 286, Florida's Turnpike, and SR 441, including all the freeways or freeway connecting ramps, entrance ramps and exit ramps. The control center is expected to expand in two to three years to provide assistance to an additional 16 miles of I-95. This expanded control center will also provide additional user services for other modes of travel. After about six years, this center will merge with the SEFI Intelligent corridor systems and other southern Florida centers.
Milwaukee, Racine, WI	Monitor Traffic Operations Center	Current/Stage 1 - 33 miles • I-43 between STH 100 (S 107th St) & North Ave in Milwaukee Co. • I-94 between Airport Spur in Milwaukee Co. & Moorland Rd in Waukesha Co. • I-794 within Milwaukee Co. • US-45 between I-94 & North Ave in Milwaukee Co.	33	35000	650	20	Future MONITOR Stages: There is anticipated to be at least two more additional stages to the MONITOR system. Additionally, a fiber optic communication network may be implemented at some point in the future. A permanent highway advisory radio system will also be implemented, anticipated to be in MONITOR Stage 4. Ultimately, the MONITOR system will operate from a state

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
		<ul style="list-style-type: none"> • US-41 between National Ave and Wisconsin Ave in Milwaukee Co. Stages 2 and 3: Scheduled to expand in FY 96 to 75 miles. Extend: • North on I-43 to Mequon Rd in Ozaukee Co. • Northwest along US-41 to Lannon Rd in Washington Co. • West on I-94 to US-164 • Southwest on I-43 to Racine Ave in Waukesha Co. • South on I-94 to Milwaukee Co. line • Entire I-94/I-43/I-894 freeway loop 					owned Traffic Management Center (TMC), with incident management capabilities originating from this building Other possible features to the MONITOR system would include integration of signal systems of various corridors throughout the Milwaukee area and an intertie to the Gary-Chicago-Milwaukee ITS priority corridor.
Minneapolis, St. Paul, MN	MN/DOT Traffic Management Center	I-94, I-394, I-494, I-694, I-35W, I-35E, US 212, US 169, SR 5, SR 36, SR 62, SR 77, and SR 100	160	40000	2100	43	
New Haven, Meriden, CT	Bridgeport Operations Center	The Bridgeport Operations Center has electronic surveillance along 56 miles of I-95 from the New York state line to New Haven, and monitors 200 signalized intersections in southwest Connecticut.	56	30000	3000	48	Bridgeport Operations Center operates 44 Changeable Message Signs, 36 are along I-95 and 8 are along arterial streets. The 48 personnel, \$3,000,000 budget, and \$30,000,000 capital construction cost includes the Newington Operations Center and the Bridgeport Operations Center.
New York, Northern New Jersey, Long Island, NY	Metropolitan Area Guidance Information Center (MAGIC)	I-80 from George Washington Bridge to mile post 40.8: 28.5 miles SR 17 from mile post 6.7 to mile post 12.3: 5.6 miles SR 4 from mile post 2.2 to mile post 10.9: 8.7 miles US 46 from mile post 47.5 to mile post 72.0: 24.5 miles I-287 from mile post 37.1 to mile post 44.5: 7.4 miles I-280 from mile post 0 to mile post 2.5: 2.5 miles I-95 from mile post 117.1 to mile post 122.5: 5.4 miles US 1, US 9, US 46 from mile post	92	34000	3200	18	

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
		62.8 to mile post 64.8: 2.0 miles SR 23 from mile post 4.7 to US 202: 7.7 miles					
Norfolk, Virginia Beach, Newport News, VA	Traffic Management System of Hampton Roads	I-64 between I-564 & I-264/VA-44	19	NA	3000	26	
Orlando, FL	I-4 Surveillance and Motorist Information System (I-4 SMIS)	I-4 from Lake Mary south to the Southern Connector Extension	39	8600	191.5	3	This center is electronically linked to the Orlando Traffic Management Center (TMC) in downtown Orlando which coordinates Orlando's UTCS. The linkage provides for information sharing and coordination between city streets and I-4.
Portland, Vancouver, OR	Portland Traffic Management Operations Center	Route Miles I-5 25 mi I-205 35 mi I-84 13 mi I-405 4 mi US 26 9 mi SR 217 7 mi SR 99E 6 mi SR 224 4 mi	103	NA	3500	NA	The Incident Response Program in Portland, which is planned to be operational by July 1, 1996, will be coordinated with the Portland Traffic Management Operations Center.
Providence, Pawtucket, Fall River, RI	Traffic Operations Center	I-95 from south of Route 10 north to Providence/Pawtucket line I-195 from I-95 east to Route 114 Route 10 from I-95 east to Dean Street	NA	5000	NA	NA	The construction of the Traffic Operations Center will be conducted in 2 phases. Phase I includes installation of 6 Portable Variable Message Signs, 2 Permanent Variable Message Signs, and 7 CCTV locations. Phase I will be completed by late 1996 - early 1997. Phase II includes installation of 11 Permanent Variable Message Signs and 10 CCTV locations, and will be completed by late 1997.
Sacramento, CA	CHP/Caltrans Transportation Management Center	SR 99: 12 miles I-80: 2 miles I-80 Business: 9 miles SR 50: 18 miles	41	8100	NA	8	
San Antonio, TX	TransGuide	Current coverage (26 miles): I-10 from SR 345 south to Southcross Blvd I-35 from I-10 east to North Braunfels Ave. US 281 from Hildebrand Ave south to Southcross Blvd. Future coverage (additional 31 miles):	57	36000	2500	18	Currently there are 26 miles of freeways under electronic surveillance, by August 1996 there will be a total of 57 miles.

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
		I-10 from SR 345 north to Camp Bullis Rd. I-410 from SR 16 east to I-35 US 281 from Hildebrand Ave. north to I-410					
San Francisco, Oakland, San Jose, CA	Coastal Region Transportation Management Center	The Coastal Region Transportation Management Center serves the coastal areas from Santa Barbara north to Oregon. Many of the freeways in the San Francisco, Oakland, San Jose area are equipped with surveillance equipment	NA	100000	2000	25	The Coastal Region Transportation Management Center will be assuming the duties of traffic management from the Vallejo Interim Traffic Management Center in June 1996. The Vallejo Interim Traffic Management Center will then serve as a backup center in case of a natural disaster.
Seattle, Tacoma, WA	Olympic Region Traffic Systems Management Center	The current Freeway Management Center in Lakewood does not have electronic surveillance, but it has an extensive plan for 7 VMS, 5 changeable signs, data stations every 1/2 mile, 22 ramp meters, and 15 CCTV.	NA	10000	NA	6 existing, 13 planned	
Seattle, Tacoma, WA	Traffic Systems Management Center (TSMC)	Current Electronic Surveillance: I-5 S 170th St. to 128th St. SW ... 33.5 miles I-90 I-5 to Front Street ... 17.0 miles I-405 I-5 @ Southcenter to SR-522 ... 11.5 miles SR-520 I-5 to Lk Sammamish Pkwy ... 23.5 miles SR-167 84th Ave S to I-405 ... 5.0 miles Total ... 90.5 miles Future Electronic Surveillance (planning, design, and construction): I-5 Pierce CA. to S 170th St ... 13.5 miles I-5 128th St SW to Marysville ... 12.25 miles I-405SR-522 to Swamp Creek I/C ... 6.8 miles SR-2 I-5 to SR-9 ... 5.0 miles SR-18 I-5 to I-90 ... 28.0 miles	91	30000	1600	29	

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
		SR-167 SR-18 to 84th Ave S ... 7.0 miles SR-509 Des Moines Way to 1st Ave Bridge ... 5.3 miles SR-518 SR-509 to I-5 ... 3.8 miles SR-520 Lk Sammamish Pkwy to SR-202 ... 1.3 miles SR-522 I-405 to SR-9 ... 2.5 miles SR-525 I-5 to SR-99 ... 2.8 miles SR-526 Mukilteo to I-5 ... 4.5 miles SR-599 I-5 to SR-99 ... 1.75 miles Total ... 94.5 miles					
St. Louis, MO	MHTD Traffic Center (St. Louis)	I-64/US 40 St. Charles County to I-70 ... 28 miles I-270 I-55 TO State Line ... 36 miles I-70 Muege Rd. to I-64 ... 25 miles I-44 SR 141 to I-55 ... 17 miles I-55 Exit 193 to I-64 ... 17 miles I-170 I-270 to I-64 ... 11 miles TOTAL ...134 miles	134	8650	1550	6	The MHTD Traffic Center is in design and has been funded; it is expected to be completed in 1997. The approximate annual operating budget will increase from \$1,200,000 in 1996 to \$1,550,000 in 1997. The 208 mile fiber optic backbone is being installed under a resource sharing agreement with a telephone company. The agreement calls for exchanging communications for right-of-way access with no cost to MHTD.
Tampa, St. Petersburg, Clearwater, FL	Sunshine Skyway Bridge (I-275)	Sunshine Skyway Bridge on I-275 over Tampa Bay, connecting Pinellas County to Manatee County.	9	NA	280	4	
Washington, DC	I-66/I-95/I-395 Traffic Management System	I-66, I-95, I-395 TMS being extended 20 miles on I-66 and 20 miles on I-95	32	NA	700	22	

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table C.1. A Summary of Cost Estimates of Various Centralized Traffic Signal Control Systems Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Freeway Miles	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
Washington, DC	SHA Traffic Operations Center (TOC-3) College Park	Current coverage with current deployments: 400 miles Capital Beltway (I-495 & I-95), I-270, US-50, US-29, MD-295 and various arterials around the Washington, D.C. metropolitan area. Current deployment is loose (i.e. equipment is far apart) Future coverage with future deployments: 400 miles same routes as current coverage with much closer deployment of equipment (1/2 - 1 mile detection spacing and 1 - 2 mile CCTV spacing on some routes and interstates.	200	NA	433	4	The annual operating budget is \$1.3 million for the SHA Traffic Operations Center Golden Ring Mall, SHA Traffic Operations Center College Park, and the State Operations Center

APPENDIX D

SUMMARY OF COST ESTIMATES OF FREEWAY
MANAGEMENT CENTERS CURRENTLY IN THE U.S

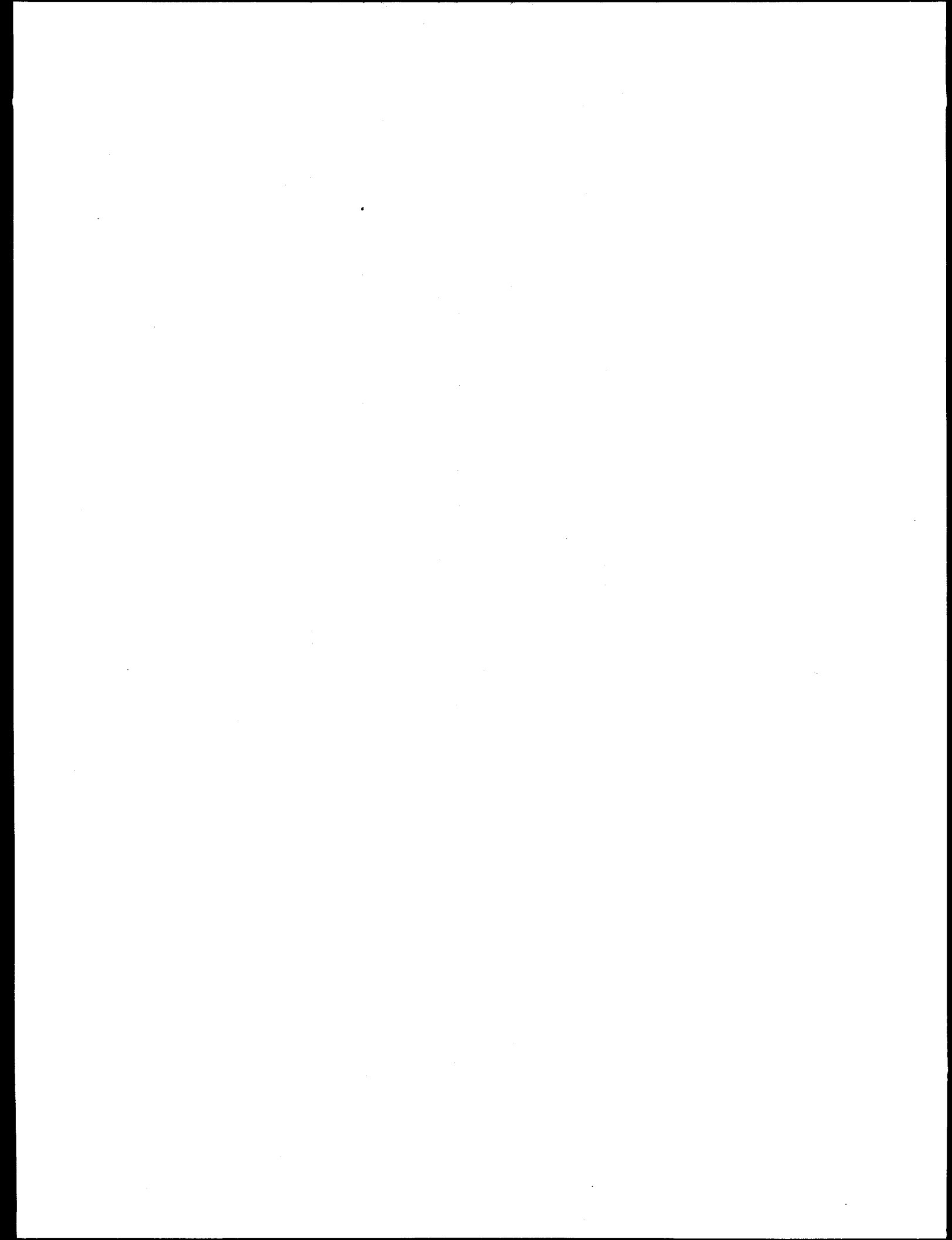


Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S.

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
Charleston, SC	City of Charleston	8 square miles in downtown plus another 50 miles.	180	2600	55	11	
Charlotte, Gastonia, Rock Hill, NC	Charlotte Traffic Signal Control Center	Charlotte City Limits	410	1500	1000	15	The City of Charlotte operates a centralized signal control system in the central business district, and 24 distributed systems on other arterials. The centralized system control signals at 130 intersections using a DEC MicroVAX II with UTCS software, and twisted pair cable. The city currently operates 24 distributed systems and is designing 2 more. These systems control a total of 280 intersections. All the staff members can access the distributed systems from their desktop PC's. The distributed systems utilized telephone dial-up communication.
Cincinnati, Hamilton, OH	Traffic Control Center	City of Cincinnati corporate limits	80	NA	60	8	
Dallas, Fort. Worth, TX	City of Plano	City of Plano	96	1600	605	NA	
Dallas, Fort. Worth, TX	City of Garland	57 square miles in the City of Garland	104	1300	400	8	
Dallas, Fort. Worth, TX	City of Fort Worth - Traffic Control Management Center	City of Fort Worth	240	4000	740	21	Existing system installed in 1987 coordinates/monitors 240 signalized intersections, 140 CBD, 40 on coordinated arterials and 60 on isolated intersections. Upgrade and expansion of system is currently underway.
Dallas, Fort. Worth, TX	City of Richardson Signal System	City of Richardson	96	1500	35	10	For additional information on the Richardson Signal System see the internet web site http://vette.cor.net .
Dayton, Springfield, OH	City of Kettering	City of Kettering	72	470	1000	4	
Dayton, Springfield, OH	City of Dayton Signal System	City of Dayton	340	1000	2000	25	The City of Dayton operates signals at a total of 340 intersections. Of these, 220 operate under a distributed closed loop system. The remainder are fixed time signals.
Denver, Boulder, CO	City of Lakewood	City of Lakewood	200	650	825	8	
Denver, Boulder, CO	City of Aurora	Aurora City Limits	105	2000	300	2	
Detroit, Ann Arbor, MI	Oakland County Traffic Operations Center	Oakland County	506	22000	3000	40	

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
El Paso, TX	Traffic Management Center	Citywide	263	2500	1100	34	The initial capital construction cost of the current system was \$2,500,000, the system which is currently in design will cost \$3,000,000
Fresno, CA	Fresno	Caltrans District 6 includes signalized intersections in Madera, Fresno, Kings, Tulare, and kern Counties. Currently, Caltrans is monitoring systems in Madera, Fresno, and Tulare Counties. These systems include: Madera 5 signals Aug/1992 Fresno 21 signals Nov/1994 Tulare 24 signals Dec/1993	50	5	NA	2	
Grand Rapids, MI	Grand Rapids Signal System	Grand Rapids and portions of Walker, Wyoming, Kentwood, and surrounding townships	230	3700	140	2	
Greensboro, Winston-Salem, High Point, NC	Highpoint Signal System	City of High Point	135	600	160	5	The City of High Point currently operates signals at 135 intersections. Of these, 50 are centrally controlled, 50 are controlled by 3 closed-loop arterial systems, and 35 are time base controlled. A new UTCS based central signal control system is in design. This system will replace the existing systems and will control signals at 165 intersections.
Greensboro, Winston-Salem, High Point, NC	Greensboro Traffic Management Center	City limits of Greensboro	300	3230	1000	13	
Greensboro, Winston-Salem, High Point, NC	Winston-Salem Traffic Control Center	Area in and near the city limits of Winston-Salem.	300	5400	370	11	
Greenville, Spartanburg, SC	City of Spartanburg Traffic Signal Control Center	City of Spartanburg	60	NA	400	4	Currently in Spartanburg 60 of the 99 signals are centrally controlled. 35 signals are in design designed to be centrally controlled.

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Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
Hartford, New Britain, Middletown, CT	Newington Operations Center	300 intersection in the Hartford metropolitan area, and another 100 intersections state wide	400	30000	3000	48	The Newington Operations Center monitors 18 miles of freeways and 300 signalized intersections in the Hartford area, and monitors another 100 signalized intersections throughout the state. The 48 personnel, \$3,000,000 budget, and \$30,000,000 capital construction cost includes the Newington Operations Center and the Bridgeport Operations Center. The UTCS based system operated at the Newington Operations Center is scheduled to be phased out in favor of Closed Loop systems.
Hartford, New Britain, Middletown, CT	City of Hartford Traffic Signal System	There are 230 signalized intersection maintained by the City of Hartford, of which 200 are centrally controlled.	200	9000	80	10	The operating budget of \$80,000 does not include personnel costs.
Honolulu, HI	Honolulu Traffic Management Center	Central business area of Honolulu	300	7000	350	6	
Jacksonville, FL	Jacksonville Urban Traffic Control Center	Central Business District	140	NA	180	3	
Kansas City, MO	City of Lenexa, KS	City of Lenexa	25	400	NA	4	The City of Lenexa presently has 25 signals on fiber optic communications lines (out of a total of 45 signals). They operate by zone master/slave Time of Day plans (6-8 plans). Timing changes, reports and online monitoring is available via TRANSLINK software, and dialup modems. Additional fiber to be added in 1996 will bring 3 more signals online. The initial capital cost of install the fiber optic communications was \$400,000.
Kansas City, MO	Overland Park Traffic Control System	City of Overland Park, Kansas	94	1300	100	1 Full Time; 2 Part Time	
Las Vegas, NV	Las Vegas Area Computer Traffic System (LVACTS)	City of Las Vegas, City of North Las Vegas, and Clark County	472	6000	750	8	
Little Rock, North Little Rock, AK	Traffic Control Center	Little Rock Central Business District	123	NA	662	18	
Los Angeles, Anaheim, Riverside,	Los Angeles Automated Traffic	500 sq. miles Arterial and network street	1855	5600	1300	20	

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
CA	Surveillance and Control (ATSAC)	systems includes freeway off-ramp signals					
Los Angeles, Anaheim, Riverside, CA	Anaheim Traffic Management Center	Entire City of Anaheim	212	8000	1500	15	The Anaheim Traffic Management Center has a two-way communications link with the Caltrans District 7 Traffic Operations Center in Los Angeles and the District 12 Office in Orange County.
Los Angeles, Anaheim, Riverside, CA	Long Beach Traffic Management Center	City of Long Beach and Signal Hill	281	300	2500	18	The Long Beach Traffic Management Center controls 281 of the city's 505 signalized intersections.
Los Angeles, Anaheim, Riverside, CA	City of Santa Ana - Traffic Management Center	City of Santa Ana	250	8000	1800	3	
Los Angeles, Anaheim, Riverside, CA	Pasadena Traffic Management Center (TMC)	City of Pasadena	280	6000	250	10	
Los Angeles, Anaheim, Riverside, CA	ITRAC	City of Irvine	220	3000	1500	9	
Louisville, KY	City Wide Traffic Signal System (C.W.S.S.)	Area within city limits	580	7000	500	29	The C.W.S.S. project status (as of March 1996): 1) Design 85% complete 2) Construction 15% complete
Miami, Fort Lauderdale, FL	Broward County Traffic Control Center	All traffic signals within the borders of Broward County. These include all signals on the State system as well as signals within the incorporated limits of cities within the County (by virtue of Traffic Engineering Agreements), and County signals. This comprises a total of approximately 1,250 devices being maintained.	896	2100	636	15	Approximate initial capital construction cost of \$2,100,000 refers to SR 7 - 39 intersections, 1979)
Miami, Fort Lauderdale, FL	Dade County Traffic Control Center	All of Dade County (1800+ sq miles) Including 400+ sq miles of urbanized area	2090	65000	2000	17	
Minneapolis, St. Paul, MN	City of St. Paul	City limits of St. Paul	340	3000	850	12.5	
Minneapolis, St. Paul,	Minneapolis Traffic	All traffic signals within the	790	6000	1700	22	Of the 790 signalized intersections, 735 are

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
MN	Engineering	City of Minneapolis.					under centralized control.
Nashville, TN	Metro Nashville Traffic Control Center	Present: Central Business District and major arterials Future: Entire metro area	376	6800	900	17	The original system, developed by Frederick R. Harris, was installed in 1987. The system installed in 1996 (MIST) is upgrading and replacing the system installed in 1994 (KVE Systems). The 188 NEMA controllers under construction and the 375 in design include controllers that were in the original system, and are being replaced or upgraded. The current 486 PC central computer is being replaced by a Pentium computer. The 65 inductive loops are installed, but are not operational at this time. They include only system sampling detectors, and do not include intersection approach detectors.
New Haven, Meriden, CT	Bridgeport Operations Center	The Bridgeport Operations Center has electronic surveillance along 56 miles of I-95 from the New York state line to New Haven, and monitors 200 signalized intersections in southwest Connecticut.	200	30000	3000	48	Bridgeport Operations Center operates 44 Changeable Message Signs, 36 are along I-95 and 8 are along arterial streets. The 48 personnel, \$3,000,000 budget, and \$30,000,000 capital construction cost includes the Newington Operations Center and the Bridgeport Operations Center.
New Orleans, LA	City of New Orleans	Orleans Parish	38	850	1500	20	
New York, Northern New Jersey, Long Island, NY	NYC DOT Traffic Management Center	5 Boroughs in New York City, the Bronx, Brooklyn, Manhattan, Queens, and Staten Island.	6000	100000	27000	100	
New York, Northern New Jersey, Long Island, NY	Traffic Operations Center - North, Newark NJ	Arterials in Northern New Jersey	40	50000	NA	N/A	New Jersey DOT is installing closed loop systems along various arterials in Northern New Jersey. Arterials with traffic signal system presently installed or under construction are: RT 24/202 (Morris County) RT 9 (Middlesex and Monmouth Counties) RT 1, RT 9 (Essex, Union, and Middlesex Counties) New Jersey DOT is also presently completing installation of an Intelligent Transportation System Traffic Control System on RT 18 in New Brunswick and East Brunswick. This system uses OPAC to run traffic adaptive control on RT 18. All

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Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
							Systems will be operated from TOC-North. The Traffic Operations Center-North will utilize a Video Imaging Detector, Changable Message Signs and Highway Advisory Radio in conjunction with the MAGIC freeway management system
New York, Northern New Jersey, Long Island, NY	Nassau County Central Traffic Signal Computer	Nassau County	560	5200	500	5	Nassau County is located on Long Island, approximately 25 miles east of New York City. In Nassau County there are 1,948 traffic signals. 1,471 of these signals are owned and maintained by Nassau County. Currently, 560 of these signals are under computer control with current plans to bring another 101 on line within the next year. Nassau County is made up of many east/west arterials with high westbound volumes in AM peaks and high eastbound volumes in PM peaks
New York, Northern New Jersey, Long Island, NY	Westchester County	Westchester Avenue in the City of White Plains	15	1500	100	4	
New York, Northern New Jersey, Long Island, NY	White Plains Traffic Control Center	City of White Plains	96	5000	1150	13	
Norfolk, Virginia Beach, Newport News, VA	Norfolk Traffic Signal System	City of Norfolk	100	NA	500	12	
Oklahoma City, OK	Oklahoma City Traffic Control Center	Downtown/CBD	132	1000	3500	75	
Omaha, NE	City of Omaha	City of Omaha In general the signals are as follows: North Border: I-680 West Border: 168th Street South Border: Harrison Street East Border: Missouri River	500	5500	880	16	
Orlando, FL	Seminole County Action Center (SEMTAC)	Major arterials in Seminole County	89	408	4000	12	
Orlando, FL	Metro Orlando Computerized Signal	Primarily within Orlando City limits, plus selected state	400	1500	400	7	

Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
	System (MOCSS)	roads outside of city limits					
Phoenix, AZ	City of Mesa	City limits of Mesa	255	700	1578	14	
Phoenix, AZ	City of Phoenix	Central Phoenix is covered by the existing system, distributed control for entire city is currently under design	480	900	2000	26	
Phoenix, AZ	City of Tempe Traffic Operations	64 sq. miles	155	800	412	5	
Portland, Vancouver, OR	Portland Traffic Operations Center	City of Portland	930	NA	100	12	There are a total of 930 traffic signals within the Portland City limits, 400 of which communicate with the central computer
Raleigh-Durham, NC	Raleigh Traffic Control Center	Municipal corporate limits of Raleigh	400	6200	850	15	
Richmond, St. Petersburg, VA	Richmond Signal System	From as far west as 25th Street, westward to I-195, north to I-95, and south to the James River.	260	NA	842	13	
Rochester, NY	Rochester/Monroe County Traffic Control Center	There are 341 traffic signals within the City of Rochester, 30 traffic signals in two adjacent suburbs that are on the UTCS system, and 10 suburban signals on a closed loop system.	381	14000	350	17	
Sacramento, CA	Traffic Operations Center	Central Area/Downtown bounded by Richards Blvd on the north Broadway on the south 2nd St. on the west Alhambra St. (31st) on the east	250	1500	400	3.5	
Salt Lake City, Ogden, UT	Salt Lake City Transportation Division	Salt Lake City	220	2300	NA	6	
San Antonio, TX	Central Business District Control Center	San Antonio metropolitan area	600	5000	250	40	
San Diego, CA	La Mesa Traffic Management Center	City of La Mesa	24	1204	235	2	In the City of La Mesa there are 66 signalized intersections, 53 owned by the city and 13 by Caltrans. Currently there 24 signalized intersections under centralized control, 17 in the process of being connected, and 25 in the design phase

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

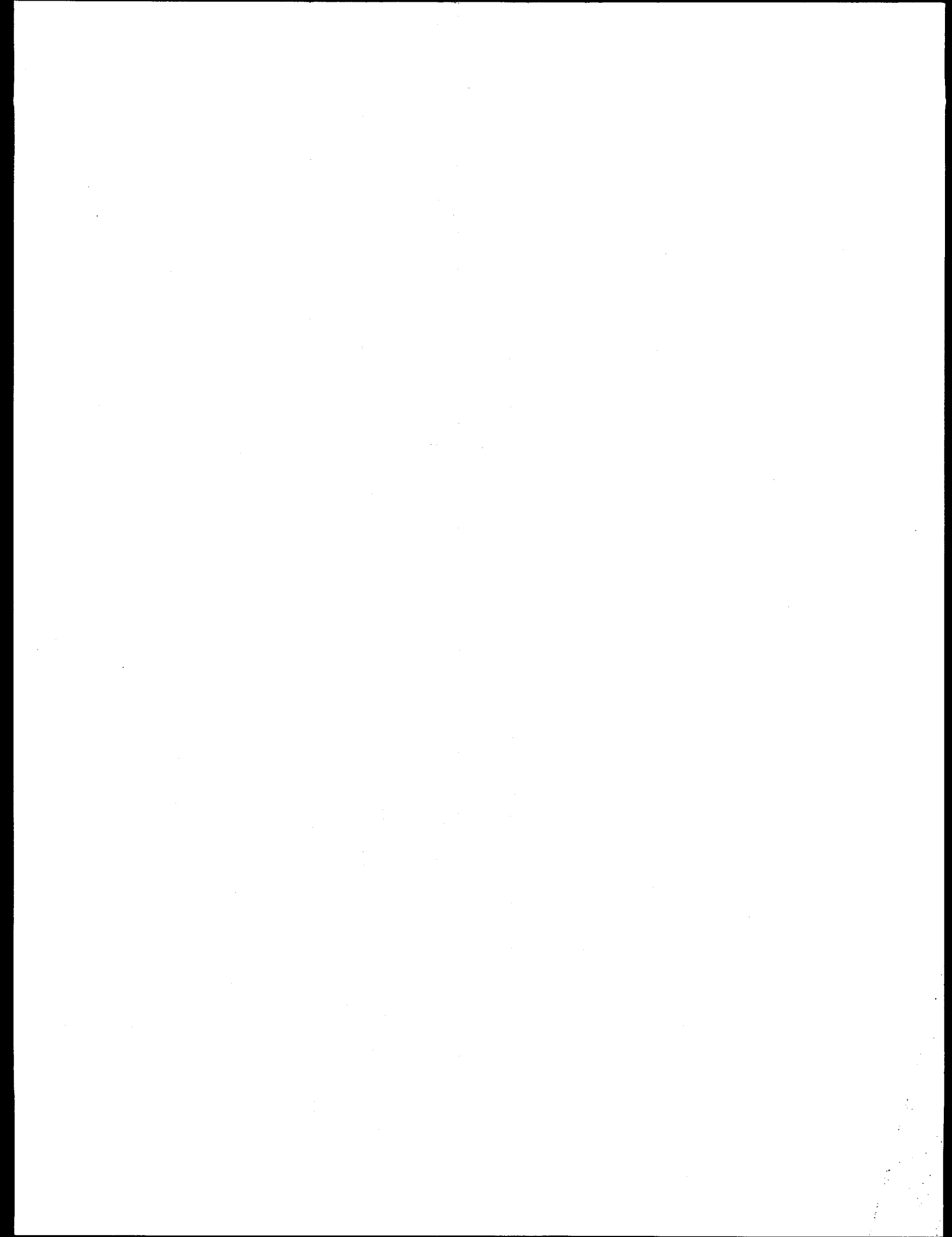
Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
San Francisco, Oakland, San Jose, CA	Santa Clara County	Santa Clara County	155	NA	2500	18	There are plans to connect the La Mesa TMC with the Caltrans and City of San Diego TMCs, but no hard design or funding schedules have been established. Connections to the traffic signal systems in the cities of Lemon Grove and El Cajon are also planned.
San Francisco, Oakland, San Jose, CA	San Jose Signal Central	Intersections are being brought on-line throughout the city, and the downtown area is also equipped with CMS and CCTV camera coverage.	540	30000	740	10	
Seattle, Tacoma, WA	City of Bellevue Traffic Control Center	City Limits	137	1600	750	8	
Seattle, Tacoma, WA	City of Lynnwood	The centralized traffic signal control system in South Snohomish County serves the cities of Lynnwood, Edmonds, and Mount Lake Terrace. This system has WS DOT signals controlling the ramps for I-5 at 220th Street SW and 196th Street SW.	64	3250	500	7	
Tampa, St. Petersburg, Clearwater, FL	Pinellas County	All of Pinellas County which is not in St. Petersburg or Clearwater	280	5000	2500	24	
Tampa, St. Petersburg, Clearwater, FL	City of Tampa	City of Tampa	500	7000	950	16	
Tampa, St. Petersburg, Clearwater, FL	City of St. Petersburg	City of St. Petersburg	285	3000	500	10	
Tampa, St. Petersburg, Clearwater, FL	City of Clearwater	City of Clearwater	130	1500	500	11	
Toledo, OH	City of Toledo Signal System	City limits; 84 square miles	540	NA	1100	20	
Tucson, AZ	Transportation	Tucson Metropolitan Area	320	500	465	4	A television display of roadway congestion

Source: Intelligent Transportation Infrastructure Deployment Database (1996)

Table D.1. A Summary of Cost Estimates of Various Freeway Management Centers Currently in Place in the U.S. (Cont'd)

City, State	Infrastructure Name	Coverage Area	Signals Controlled	Capital Cost (\$k)	Annual Operating Budget (\$k)	Personnel (No.)	Comments
	Management Section	extends beyond city limits in some areas to bring State and County controlled signals into the system.					levels is deployable, but is still being fine tuned. Transit status information is expected to be deployed in 18-20 months
Washington, DC	Washington DC Traffic Signal System	Washington DC	1350	44000	NA	10	
West Palm Beach, Boca Raton, Delray, FL	Palm Beach County Traffic Control Signal Center	Within the geographic boundaries of Palm Beach County.	383	4500	250	9	



APPENDIX E

PROJECTED *NATIONAL* IMPLEMENTATION COSTS
OF FIVE IVIS MARKET PACKAGES

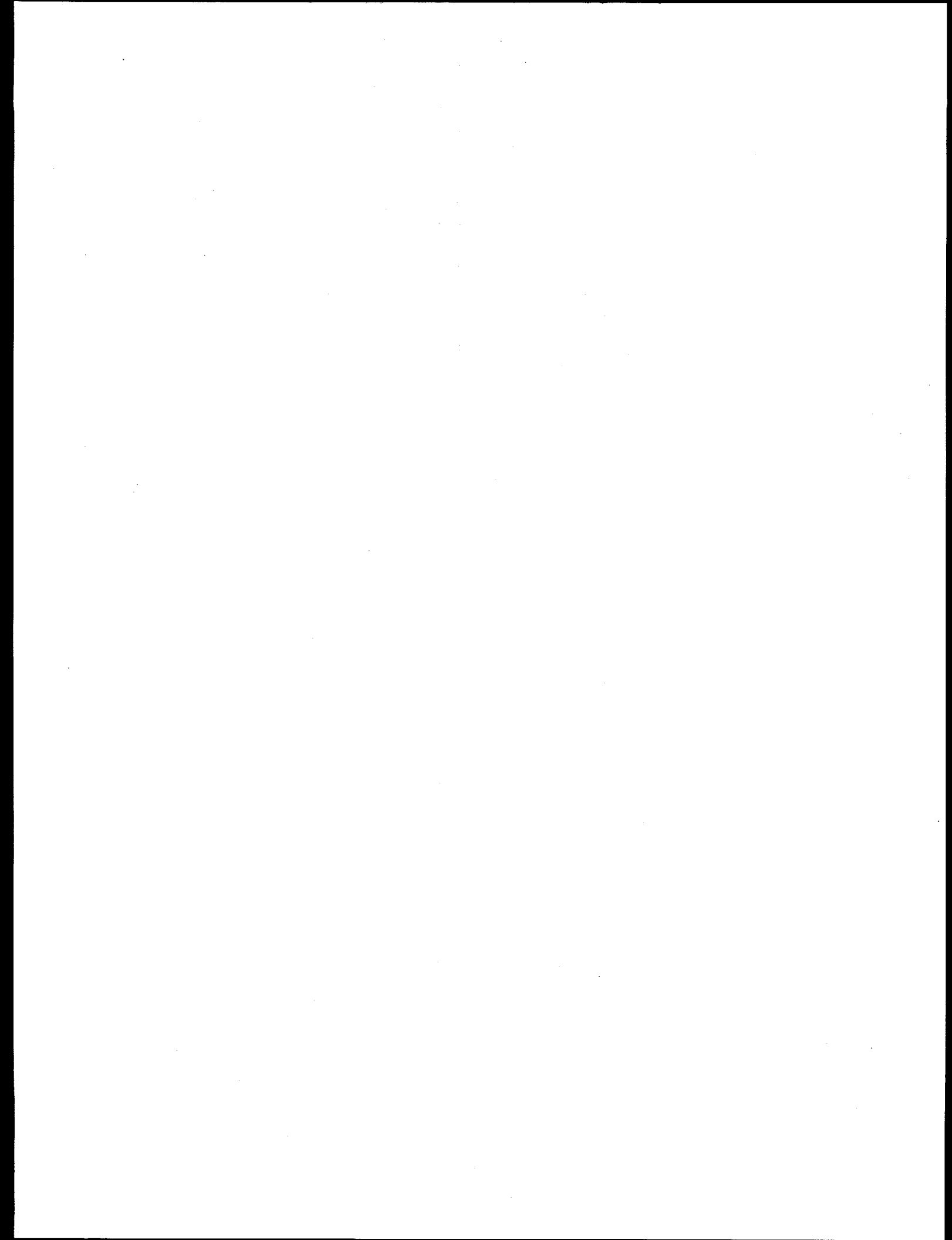


Table E.1. Projected *National Implementation Costs* (1996 dollars) of the *Broadcast Traveler Information Market Package* for *Urban and Interurban Regions* for a *Ten-Year Deployment Period*

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Basic Vehicle Reception	598 x 10 ⁻⁶ /vehicle	598 x 10 ⁻⁶ /vehicle	68 x 10 ⁻⁶ /vehicle	68 x 10 ⁻⁶ /vehicle
INFRASTRUCTURE	Basic Information Broadcast	121	32	17	5
	Collect Traffic Surveillance	135	36	19	4.5
	Roadway Basic Surveillance	3,262	877	464	125
	Transit Center Fare & Load Management	95	22	13	3.2
	Transit Center Fixed-Route Operations	54	13	8	2.0
	Transit Center Tracking & Dispatch	154	36	22	5.0
	TOTAL	3,821	1,016	543	144.7

Table E.2. Projected *National Implementation Costs* (1996 dollars) of the *Interactive Traveler Information Market Package* for *Urban and Interurban* Regions for a Ten-Year Deployment Period

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Interactive Vehicle Reception	$5,294 \times 10^{-6}$ /vehicle	$5,294 \times 10^{-6}$ /vehicle	605×10^{-6} /vehicle	605×10^{-6} /vehicle
INFRASTRUCTURE	Interactive Infrastructure Information	1,619	264	231	38
	Collect Traffic Surveillance	121	32	17	5
	Roadway Basic Surveillance	3,262	877	464	125
	Transit Center Fare & Load Management	95	22	13	3.2
	Transit Center Fixed-Route Operations	54	13	8	2.0
	Transit Center Tracking & Dispatch	154	36	22	5.0
	Transit Center Demand Responsive Operations	47	11	7	1.6
	TOTAL	5,352	1,255	762	180

Table E.3. Projected *National Implementation Costs* (1996 dollars) of the *Dynamic Route Guidance Market Package* for *Urban and Interurban Regions* for a *Ten-Year Deployment Period*

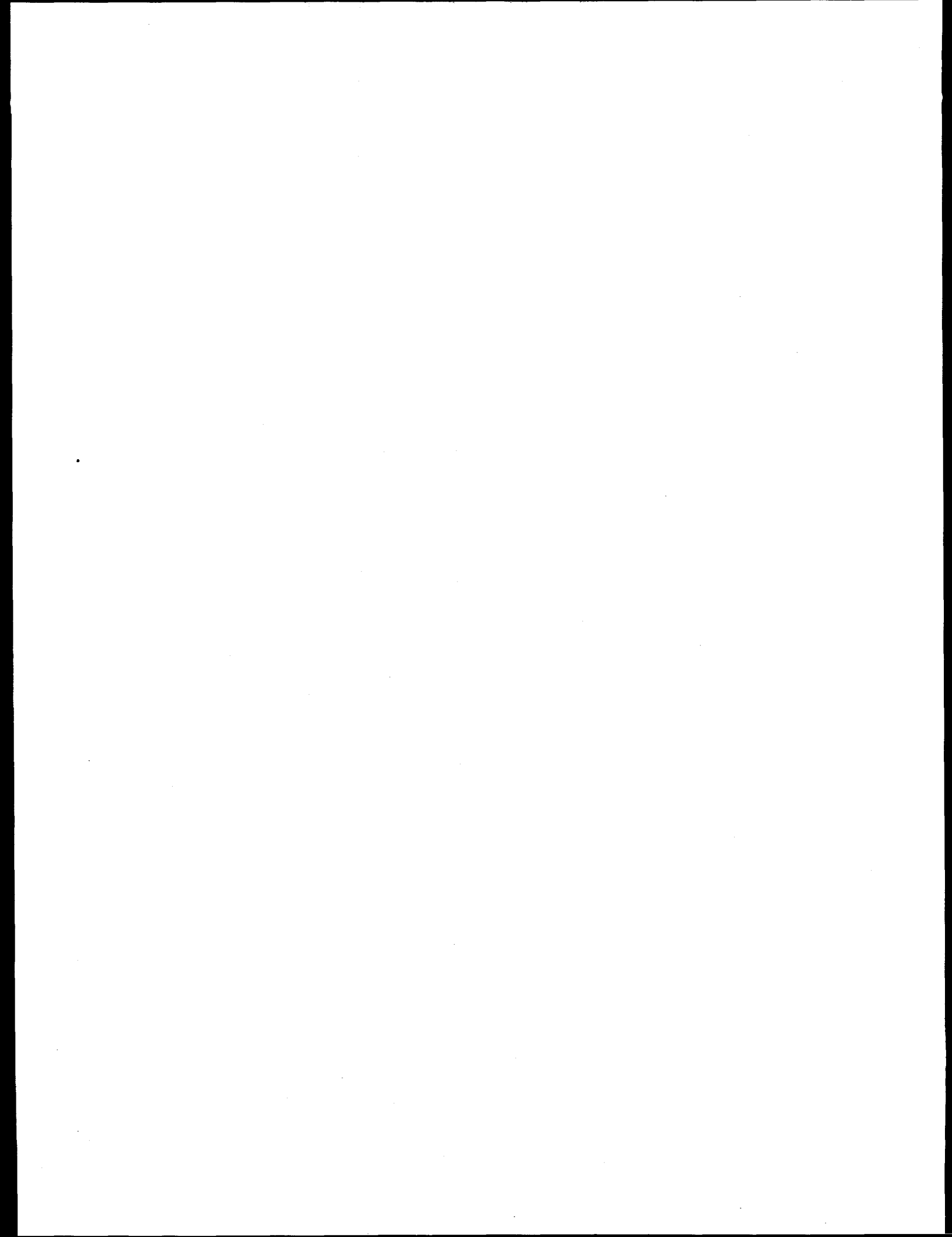
Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Basic Vehicle Reception	598 x 10 ⁻⁶ /vehicle	598 x 10 ⁻⁶ /vehicle	68x 10 ⁻⁶ /vehicle	68x 10 ⁻⁶ /vehicle
	Vehicle Route Guidance	5,106 x 10 ⁻⁶ /vehicle	5,106 x 10 ⁻⁶ /vehicle	584x 10 ⁻⁶ /vehicle	584 x 10 ⁻⁶ /vehicle
INFRASTRUCTURE	Basic Information Broadcast	121	32	17	5
	Collect Traffic Surveillance	135	36	19	4.5
	Roadway Basic Surveillance	3,262	877	464	125
	Transit Center Fare & Load Management	95	22	13	3.2
	Transit Center Fixed-Route Operations	54	13	8	2.0
	Transit Center Tracking & Dispatch	154	36	22	5.0
	Transit Center Demand Responsive Operations	47	11	7	1.6
	TOTAL	3,868	1,027	550	146

Table E.4. Projected *National Implementation Costs* (1996 dollars) of the *ISP-Based Route Guidance Market Package* for *Urban and Interurban Regions* for a *Ten-Year Deployment Period*

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Interactive Vehicle Reception	5,294 x 10 ⁻⁶ /vehicle	5,294 x 10 ⁻⁶ /vehicle	605x 10 ⁻⁶ /vehicle	605x 10 ⁻⁶ /vehicle
	Vehicle Route Guidance	5,106 x 10 ⁻⁶ /vehicle	5,106 x 10 ⁻⁶ /vehicle	584x 10 ⁻⁶ /vehicle	584 x 10 ⁻⁶ /vehicle
INFRASTRUCTURE	Interactive Infrastructure Information	1,619	264	231	38
	Infrastructure Provided Route Selection	24	6.2	3.4	0.9
	Collect Traffic Surveillance	135	36	19	4.5
	Roadway Basic Surveillance	3,262	877	464	125
	Transit Center Fare & Load Management	95	22	13	3.2
	Transit Center Fixed-Route Operations	54	13	8	2.0
	Transit Center Tracking & Dispatch	154	36	22	5.0
	Transit Center Demand Responsive Operations	47	11	7	1.6
	TOTAL	5,390	1,265	767	180

Table E.5. Projected *National Implementation Costs* (1996 dollars) of the *Intersection Collision Avoidance Market Package* for *Urban and Interurban* Regions for a *Ten-Year Deployment Period*

Equipment packages		Life cycle cost (\$M)		Levelized cost (\$M/year)	
		Urban	Inter	Urban	Inter
IN-VEHICLE	Vehicle Intersection Control	$4,854 \times 10^{-6}$ /vehicle	$4,854 \times 10^{-6}$ /vehicle	555×10^{-6} /vehicle	555×10^{-6} /vehicle
INFRASTRUCTURE	Roadway Intersection Collision	1.4	0.2	0.02	0.03
	Roadside Signal Priority	601	68	86	10
	Roadway Signal Controls	3,981	333	567	47
	TMC Multi-Modal Coordination	890	75	127	11
	TOTAL	5,473	476	780	68



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