Technical Memorandum No. 3.2

Technology Review:

ITS Corridor Master Plans for Florida’s Principal FIHS Limited-Access Corridors

Prepared for:

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List of Acronyms

AAA .... American Automobile Association
ADA .... Americans with Disabilities Act
ADAS .... Atlanta Driver Advisory Service
ANSI .... American National Standards Institute
APTS .... Advanced Public Transportation System
ARG .... Autonomous Route Guidance
ATIS .... Advanced Traveler Information System
ATMS .... Advanced Traffic Management System
AVC .... Automatic Vehicle Classification
AVI .... Automatic Vehicle Identification
AVL .... Automatic Vehicle Location
AVSS .... Advanced Vehicle Safety System
CAD .... Computer Aided Dispatch
CAT .... Carrier Automated Transmission
CCTV .... Closed Circuit Television
CVIEW .... Commercial Vehicle Information Exchange Window
CVO .... Commercial Vehicle Operations
DIRECT ...... Driver Information Radio Experimenting with Communication Technology
DMS .... Dynamic Message Signs
DRG .... Dynamic Route Guidance
DSP .... Digital Signal Processing
DSRC .... Dedicated Short-Range Communications
EDI .... Electronic Data Interchange
EMC .... Emergency Management Center
EML .... Extensible Mark-up Language
EPS .... Electronic Payment Systems
ETC .... Electronic Toll Collection
FCC .... Federal Communications Commission
FDOT .... Florida Department of Transportation
FHWA .... Federal Highway Administration
FIHS .... Florida Intrastate Highway System
GIS .... Geographic Information System
GPS .... Global Positioning System
GSM .... Global System for Mobil (communications)
HAR .... Highway Advisory Radio
HAZMAT .... Hazardous Materials
HOT .... High Occupancy Toll
HOV .... High Occupancy Vehicles
HPMS .... Highway Performance Monitoring System
HRI .... Highway-Rail Intersections
IDAS .... ITS Deployment Analysis Toll
IDU .... Incident Detection Unit
IFTA .... International Fuel Tax Agreement

IMS .... Incident Management System
IRP .... International Registration Plan
ISP .... Information Service Provider
ITS .... Intelligent Transportation Systems
IVR .... Interactive Voice Response
JPO .... Joint Program Office
KHz .... Kilohertz
LED .... Light-Emitting Diode
LOS .... Level of Service
LPR .... License Plate Recognition
MCO .... Maintenance and Construction Operations
MIST .... Management Information System for Transportation
MPH .... Miles Per Hour
MPO .... Metropolitan Planning Organization
MUTCD .... Manual on Uniform Traffic Control Devices
NITSA .... *National ITS Architecture*
NTCIP .... National Transportation Communications for ITS Protocol
O&M .... Operations and Maintenance
OREIS .... Operation Respond Emergency Information System
PCS .... Personal Communications Systems
PSAP .... Public Safety Answering Point
RTMS .... Remote Traffic Microwave Sensor
RWIS .... Road Weather Information System
SDAS .... Surveillance and Delay Advisory System
SWIFT .... Seattle Wide-Area Information for Travelers
TCRP .... Transit Cooperative Research Program
TMC .... Traffic Management Centers
TRANSMIT .... TRANSCOM's System for Managing Incidents and Traffic
TRB .... Transportation Research Board
TTI .... Texas Transportation Institute
TXS .... Tranzit Xpress Systems
USDOT .... United States Department of Transportation
VMT .... Vehicle-Miles Traveled
WIM .... Weigh-in-Motion

1. Introduction

This document provides greater detail regarding the market packages identified as candidates for the five principal Florida Intrastate Highway System (FIHS) limited-access corridors as discussed in *Technical Memorandum No. 3.4 – ITS Physical Architecture*. Table 1.1 indicates that 53 market packages were identified as candidates for deployment in the project area in the *ITS Physical Architecture*. Further study of the technologies and issues associated with these market packages is the focus of this document.

This document presents an overview of each selected market package and the products and services associated with the market package. In addition, the document presents estimates of the benefits and unit costs associated with the market package. Finally, implementation, operation, and maintenance issues, both technical and institutional, are discussed.

The benefits reported for each market package were obtained mainly from the Intelligent Transportation Systems (ITS) Benefit Database and corresponding reports produced by the Joint Program Office (JPO) of the United States Department of Transportation (USDOT). Other resources were used to obtain estimates of the benefits, as needed. In these cases, these sources are identified in the text.

Planning-level estimates of unit costs were obtained mainly based on the *National ITS Architecture (NITSA), Version 3.0,* documents, the user-identified market packages from the ITS Central Office, and from the ITS Cost Database produced by USDOT's JPO for ITS. As with the benefit estimates, other resources were used in the estimation of costs as needed. In these cases, these sources are identified in the text.

The technology review of this document addresses the market packages that are candidates for early deployments on the corridors. These include the Advanced Traffic Management Systems (ATMS), Advanced Traffic Information Systems (ATIS), Commercial Vehicle Operations (CVO), Emergency Management, and Archived Data Market Packages. The Advanced Public Transportation Systems (APTS) and the Advanced Vehicle Safety Systems (AVSS) Market Packages, which are not candidates for early deployments, are not reviewed in this document.

The last section of this document presents an assessment of the market package. Based on this assessment, this technical memorandum identifies "early winners" among these market packages for near-term deployments. Once identified, "early winners" can be formulated into statements of work or "early projects." These "early projects" will assist the Florida Department of Transportation (FDOT) in the procurement and reservation of ITS funds for the ITS corridor programs.

Table 1.1 – Market Packages Selected for the FIHS Limited-Access Corridors

MP NO.	Market Package Name	Applicable
Advanced Public Transportation Systems (APTS)		
APTS1	Transit Vehicle Tracking	✓
APTS2	Transit Fixed-Route Operations	✓
APTS3	Demand Response Time Operations	N/A
APTS4	Transit Passenger and Fare Management	✓
APTS5	Transit Security	✓
APTS6	Transit Maintenance	N/A
APTS7	Multi-Modal Coordination	✓
APTS8	Transit Traveler Information	✓
Advanced Traveler Information Systems (ATIS)		
ATIS1	Broadcast Traveler Information	✓
ATIS2	Interactive Traveler Information	✓
ATIS3	Autonomous Route Guidance (ARG)	N/A
ATIS4	Dynamic Route Guidance (DRG)	N/A
ATIS5	ISP-Based Route Guidance	N/A
ATIS6	Integrated Transportation Management/Route Guidance	N/A
ATIS7	Yellow Pages and Reservations	✓
ATIS8	Dynamic Ridesharing	✓
ATIS9	In-Vehicle Signing	N/A
Advanced Traffic Management Systems (ATMS)		
ATMS01	Network Surveillance	✓
ATMS02	Probe Surveillance	✓
ATMS03	Surface Street Control	N/A
ATMS04	Freeway Control	✓
ATMS05	HOV Lane Management	✓
ATMS06	Traffic Information Dissemination	✓
ATMS07	Regional Traffic Control	✓
ATMS08	Incident Management System (IMS)	✓
ATMS09	Traffic Forecast and Demand Management	✓
ATMS10	Electronic Fare Collection	✓
ATMS11	Emissions Monitoring and Management	N/A
ATMS12	Virtual TMC and Smart Probe Data	N/A
ATMS13	Standard Railroad Grade Crossing	✓
ATMS14	Advanced Railroad Grade Crossing	✓
ATMS15	Railroad Operations Coordination	✓
ATMS16	Parking Facility Management	✓
ATMS17	Reversible Lane Management	✓
ATMS18	Road Weather Information System (RWIS)	✓
ATMS19	Regional Parking Management	N/A
FL ATMS20 *	Speed Management	✓

Table 1.1 (Continued)

Advanced Vehicle Safety Systems (AVSS)		
AVSS01	Vehicle Safety Monitoring	N/A
AVSS02	Driver Safety Monitoring	N/A
AVSS03	Longitudinal Safety Warning	N/A
AVSS04	Lateral Safety Warning	✓
AVSS05	Intersection Safety Warning	N/A
AVSS06	Pre-Crash Restraint Deployment	N/A
AVSS07	Driver Visibility Improvement	✓
AVSS08	Advanced Vehicle Longitudinal Control	N/A
AVSS09	Advanced Vehicle Lateral Control	✓
AVSS10	Intersection Collision Avoidance	N/A
AVSS11	Automated Highway System (AHS)	✓
Commercial Vehicle Operations (CVO)		
CVO01	Fleet Administration	✓
CVO02	Freight Administration	✓
CVO03	Electronic Clearance	✓
CVO04	CV Administrative Process	✓
CVO05	International Border Electronic Clearance	✓
CVO06	Weigh-in-Motion (WIM)	✓
CVO07	Roadside CVO Safety	✓
CVO08	On-Board CVO Safety	✓
CVO09	CVO Fleet Maintenance	✓
CVO10	HAZMAT Management	✓
Emergency Management		
EM1	Emergency Response	✓
EM2	Emergency Routing	✓
EM3	Mayday Support	✓
FL EM4 *	Evacuation Management	
Archived Data and Management		
AD1	ITS Data Mart	✓
AD2	ITS Data Warehouse	✓
AD3	ITS Virtual Data Warehouse	✓
Maintenance and Construction Operations (MCO)		
FL MCO1 *	Maintenance and Construction Management	✓

* This indicates user-identified market packages for project needs and will be modified to reflect *NITSA, Version 4.0*, in the future.

2. Network Surveillance (ATMS01)

2.1 Overview

This market package includes traffic detectors, closed-circuit television (CCTV) camera assemblies, the supporting field equipment, traffic management center (TMC) equipment, and communications links between the TMC and field devices. The data generated by this market package enables traffic managers to monitor traffic and road conditions, identify and verify incidents, manage and control traffic, detect faults in field device operations, and collect census data for traffic strategy development and long-range planning. The collected data can also be analyzed and made available to users and the Information Service Provider (ISP) Subsystem.

TMC central equipment collects, stores, and provides electronic access to the traffic surveillance data. Traffic detectors measure traffic parameters such as occupancy, volume, vehicle classification, and speed. CCTV assemblies provide video surveillance over a target area.

2.2 Traffic Detector Products/Services

Traffic detection technologies vary in their capabilities and costs. Traditionally, inductive loop detectors have been the predominant form of detectors. Several types of non-intrusive detectors have been used for traffic detection to overcome problems associated with loop detectors. These detectors include passive infrared, active infrared, true presence microwave, Doppler microwave, passive acoustic, pulse ultrasonic, and video image processing.

The data collected using traffic detectors can be used locally, such as when ramp-metering control uses the data to change the traffic signal timing. The data can also be used remotely, such as when the data is sent back to the TMC for central traffic monitoring and control. Below is a discussion of the available detection technologies and their advantages and disadvantages.

2.2.1 Inductive Loop Detectors

Inductive loop detectors operate on the principle of inductance. An alternating current through the wire generates an electromagnetic field around the loop. A conductor, such as the engine of a vehicle, that passes through the field will absorb electromagnetic energy and decrease the inductance and resonant frequency of the loop. Hence, changes in inductance, or frequency-trip preset thresholds, indicate vehicle detection. Loop detectors have several advantages compared to other types of detectors including their mature technology and accuracy in measuring traffic flow. In addition, loop detector performance is not affected by weather and lighting conditions. The main disadvantage of loop detectors, however, is the difficulty of installation and maintenance without disrupting traffic flow. In addition, loop detectors can require frequent maintenance and repairs, primarily due to poor installation, resulting in an increase in their life-cycle costs.

2.2.2 Doppler Microwave Radar

Doppler microwave radar measures the speed of vehicles within its field of view using the Doppler principle. According to this principle, the difference in frequency between the transmitted and received signals is proportional to the vehicle speed. Thus, the detection of a frequency shift denotes the passage of a vehicle. This type of detector cannot detect stopped vehicles and is, therefore, not suitable for applications that require vehicle presence.

These detectors are not affected by inclement weather conditions, measure speed directly, and are non-intrusive technologies. They can measure both volume and speed. However, they cannot measure vehicle occupancy and cannot detect vehicles moving at speeds less than five miles per hour (MPH). Examples of these products are PODD by PEEK, TDN-30 by Whelen, and TDW-10 by Whelen.

2.2.3 True Presence Microwave Radar

These detectors transmit a sawtooth waveform, also called a frequency-modulated continuous wave that varies the transmitted frequency continuously with time. It permits stationary vehicles to be detected by measuring the range from the detector to the vehicle and also calculates vehicle speed by measuring the time it takes for the vehicle to travel between two internal markers.

These detectors are not affected by inclement weather and lighting conditions; they can provide volume, speed, and occupancy; and they can operate from side-fire location, with good accuracy. They are also non-intrusive, low cost, and provide multi-lane detection. However, their speed measurement from side-fire location is less accurate than other technologies like video image detectors and Doppler microwave radars. The remote traffic microwave sensor by Electronic Integrated Systems is an example of this type of technology.

2.2.4 Passive Infrared Detectors

The passive infrared detectors use an energy sensitive photon detector to measure the infrared energy emitted from an object in its field of view. Passive infrared detectors do not transmit energy of their own.

Examples of the advantages of this technology are that it is non-intrusive and it is not affected by lighting conditions. However, a single detector mounted in a side-fire location cannot provide vehicle speeds. ASIM Technologies and Eltec Instruments manufacture examples of these detectors.

2.2.5 Active Infrared Detectors

Active infrared detectors transmit low energy in the near infrared spectrum. A portion of this energy is reflected back into the receiver of the detector from a vehicle in its field of view. These sensors can measure vehicle volume, presence, occupancy, classification, and speed. The speed is measured by noting the time it takes a vehicle to cross two infrared beams that are scanned across the road surface at a known distance. Some laser radar models have the ability to classify vehicles by measuring and identifying their profiles.

The advantages of this technology are that it is a non-intrusive technology and can measure volume, presence, and speed. However, near-infrared laser sensors are limited to the same range as can be seen by the human eye in inclement weather and lighting conditions. Examples of these detectors are those manufactured by MBB sensTech and Schwartz Electro-Optics, Inc.

2.2.6 Ultrasonic Detectors

To detect traffic, ultrasonic detectors transmit sound at 25 to 50 kHz, depending on the manufacturer. These frequencies lie above the audible region. A portion of the transmitted energy is reflected from the road or vehicle surface into the receiver portion of the instrument and is processed to give vehicle passage and presence.

The advantages of this technology include its measurement of speed directly and it is easy to install and non-intrusive. The disadvantages include that it requires over-head mounting and might be less accurate during congested conditions. Examples of these detectors are TC-30 by Microwave Sensors and Lane King by Novax Industries.

2.2.7 Passive Acoustic Detectors

These detectors use acoustic microphones to pickup vehicular sounds from a focused area within a lane on a roadway. This technology can detect volume, speed, and occupancy. Passive acoustic technology advantages include a non-intrusive technology and the potential classification of vehicles. However, disadvantages can include the inability to detect small/fast-passing vehicles and loud vehicles on adjacent lanes can give false readings. The technology is also affected by environmental conditions. Smartsonic by IRD is an example of this type of detector.

2.2.8 Video Image Detectors

Video image detectors measure traffic parameters by analyzing the images supplied by video cameras. The images are digitized and then passed through algorithms that identify changes in the image background to gather information such as vehicle passage, presence, speed, vehicle length, and incident occurrence.

The advantages of this technology include the ability to measure all required traffic parameters (volume, speed, presence, occupancy, density, queue length, dwell time, headway, classifications), it is flexible in detection, and it allows multi-lane detection. In addition, video images might be transmitted to the center, if so desired and if the communications technology used supports this transmission. The disadvantages include the possibility of performance degradation due to adverse weather and lighting conditions, the possibility of large vehicles obscuring small vehicles, and the relatively higher installation costs. Proper set up and calibration is critical to achieving acceptable performance. Examples of these detectors include Autoscope by Image Sensing Systems, CCATS by Traficon, VideoTrack-900 by Peek, and Vantage by Iteris.

2.2.9 Magnetometers

Magnetometers detect perturbations in the Earth's magnetic field caused by the metallic components of vehicles. These detectors can detect volume, classification, headway, presence, and speed. Speed can either be measured based on a single device or by using a speed trap (two devices).

Magnetometers attached to the surface are subject to damage. Magnetometers that can be mounted under the pavements are available but they require boring. An example of a magnetometer product is the Canoga Non-Invasive Microloop Vehicle Detection System manufactured by 3M. These detectors are placed in conduits under the roadway.

2.2.10 Detector Technology Comparison

Reported performance for the most widely used detector technologies were summarized in a report entitled "Evaluation of Some Existing Technologies for Vehicle Detection" from the Texas Transportation Institute (TTI) in September 1999. Table 2.1 presents a comparison of the technologies. It should be recognized that many of these technologies are constantly being improved. Future studies that evaluate these technologies should be continuously monitored. In particular, the Minnesota Department of Transportation is currently conducting a project that compares these technologies in real-world conditions. The results from this project should be very useful in determining the performance of these detectors under various field conditions.

Table 2.1 – Qualitative Evaluation of Detector Types for Freeway Applications

Detector Technology	Life-Cycle Costs	Detection Accuracy		Failure Rate	Speed Accuracy	Incident Detection	Classification Accuracy	Mounting		Maintenance Requirements	Directional Detection	Effect of Weather
		Low Volume	High Volume					Overhead	Sidefire			
Inductive Loop	C	A	A	C	B	B	B	D	D	C	B	A
Active Infrared	C	A	A	U	B	B	A	A	D	A	D	B
Passive Infrared	A	A	B	U	D	D	D	A	A	A	D	A
Radar	A	A	A	U	A/B*	B	B	A	A	A	D	A
Doppler Microwave	A	A	B	U	A	A	D	A	C	B	B	A
Passive Acoustic	B	B	B	U	C	C	C	A	B	A	D	C
Pulse Ultrasonic	A	A	A	U	D	D	D	A	B	U	D	U
Video Tripwire	B	A	A	B	C	C	C	B	B	B	B	C
Video – Tracking	B	A	A	B	B	B	C	B	B	B	B	C

Code: A = Excellent; B = Fair; C = Poor; D = Nonexistent; U = Unknown.
* A: Overhead Mounting; B: Sidefire Mounting

Source: *"Evaluation of Some Existing Technologies for Vehicle Detection"* from TTI, September 1999.

2.3 CCTV Products/Services

CCTV refers to a system of monitoring devices and supporting architecture that provides video surveillance over a target area. When this system is deployed as part of an ATMS, the CCTV system performs the following tasks:

- Verifies the occurrence and exact location of incidents;
- Collects information about incident situations, such as cause and nature of incidents and the congestion levels;
- Allows agencies to respond with correct actions;
- Allows agencies to monitor the quality of the on-scene response; and
- Allows observation of adverse weather and other hazardous conditions.

The CCTV system consists of central hardware/software, roadway equipment, and a communications system. CCTV roadway equipment includes a camera, lens, an environmental enclosure, a pan-tilt positioning system, a camera controller/receiver, and a mounting pole.

Several vendors offer CCTV camera products for ITS applications. Some of these vendors include Cohu, Philips, Vicons, Diamond Electronics, Javlin, and Pelco. The CCTV camera technology is continuously changing, with new technologies or advancements occurring in relatively short periods. CCTV technologies/products that were state-of-the-art a few years ago are now out-of-date. Thus, it is important to review the CCTV technologies/products that are available in the market at the time of a CCTV system deployment. This section presents a review of the CCTV camera technologies/products currently available.

Below is a discussion of the CCTV camera components.

2.3.1 Cameras

All camera vendors currently produce digital signal processing (DSP) cameras. DSP cameras offer several advantages over their analog counter parts including:

- DSP cameras eliminate discrete components, thus potentially improving reliability;
- Component reduction allows a smaller and lighter weight camera that consumes less power;
- DSP cameras include electronic (digital) zoom in addition to the optical zoom provided by the lens; and
- DSP cameras potentially improve image quality by reducing analog components that are subject to drift.

All cameras used for traffic applications use solid-state charged couple devices as the imaging sensors. The charged couple device sensor is a self-scanning, semi-conductor array that is responsible for converting the optical input to an electromagnetic signal. A technique called “interline transfer” is used to move photo-generated charges from the image sensor to a read-out register. Interline transfer is the technique specified for traffic surveillance operations because it allows viewing of scenes with bright headlights at night with minimal streaks, smears, or blooming.

The size of the charged couple device sensor is an important camera characteristic and is measured by the diagonal of the sensor in inches. In recent years, the CCTV camera sensor sizes have decreased significantly. State-of-the-art cameras have $^1/_4$- and $^1/_3$-inch sensor sizes. The use of a smaller sensor size reduces costs and improves image quality. This is true because smaller sensor sizes reduce the required zoom lens sizes, resulting in an increase in camera sensitivity and a decrease in the camera’s environmental housing dimensions and pan/tilt unit requirements. The camera stability also increases since the wind loading is lower on smaller enclosures and pan/tilt units. In addition, the costs of smaller lenses are lower.

One of the most important characteristics of a CCTV camera is its night operation. During daylight hours, plenty of light is available for the cameras to provide adequate view. However, a camera with high sensitivity is required at night. Sensitivity measures the amount of light that the camera can use to provide adequate views. Sensitivity is measured in either LUX or Foot Candles. A foot-candle is about 0.1 LUX.

In general, black and white cameras are more sensitive and provide higher resolution than color cameras. Color cameras require more light to produce a usable picture compared to black and white cameras. However, color video allows better object recognition compared to black and white video. This is because human eyes can interpret more features from color video.

Camera resolution is the amount of the resolvable detail in a picture. Horizontal resolution is expressed as the amount of resolvable detail in the horizontal direction of the picture. It is expressed as the number of distinct vertical lines, alternatively black and white, which can be seen in a distance equal to picture height. Cameras used for traffic surveillance applications produce horizontal resolutions of 460 to 470 horizontal television lines. These resolutions are sufficient for traffic surveillance applications.

2.3.2 Camera Lens

A lens is an optical component consisting of one or more pieces of optical glass to focus a scene onto a camera sensor. For traffic surveillance applications, remotely controlled motorized zoom lenses are used to enlarge or reduce the size of the image. A zoom lens physically alters its field of view from wide angle to narrow band by changing its focal length (focal length is defined as the distance from the focal point to the principle point of the lens).

All reviewed cameras provide auto iris with manual override capability. The provided iris controls the light passing through the lens unit to the sensor based on the scene lighting conditions. The ability to select between an automatic and manual iris is important because during nighttime or heavily overcast days, an automatic iris lens closes down the iris due to headlights shining directly into the camera. This reduces the amount of light and affects the camera's ability to produce a usable picture. By manually opening the iris, the operator can view the scene. Preset positioning can also be specified for camera lens products so that an operator can quickly zoom and focus on critical areas in the field of view.

2.3.3 Environmental Enclosure

Environmental enclosures are specified to increase the camera reliability and reduce maintenance costs. For extra protection, pressurized and sealed enclosures can be specified. The CCTV camera and its lens are assembled and tested in the manufacturer's factory, then fitted into an enclosure that is sealed and pressurized with dry nitrogen to keep out moisture, pollution, chemicals, salt, and grime. This type of housing also prevents condensation on the lens and the housing faceplate. Environmental enclosures cost more than other housings, but the savings from service calls offset the additional cost. Another benefit of the factory sealed and pressurized housing is the assurance of a properly installed lens on the camera.

2.3.4 Pan-Tilt Positioning Systems

Pan-tilt positioning systems are mechanical devices upon which the camera housing is attached to allow the camera to change its field of view. Panning allows the camera to move in the horizontal plane, while tilting controls movement in the vertical plane. An option is available that allows the pan/tilt mechanism to move to predetermined positions. Preset positions save time and help precise viewing of problem areas.

2.3.5 Camera Controllers/Receivers

The camera controllers/receivers are located at the site of the camera and typically housed in a cabinet that is either roadside or pole-mounted. The camera controllers/receiver is normally connected to the camera unit via a composite cable, which carries the video signal, pan-tilt control signals, the lens zoom control, and the power cables for the camera and pan-tilt units. The camera controller/receiver provides local and remote control of camera functions. Local video output is also available in order to facilitate local maintenance.

2.3.6 Central Control System Components

The central hardware/software that collects traffic surveillance as part of the TMC can be either stand-alone or combined with other equipment packages, such as TMC freeway control and TMC incident management.

2.3.7 Mounting Poles

CCTV assemblies can be mounted on buildings or pole mounts specified for CCTV applications. In either case, care must be taken in order to prevent excessive vibration of the camera. Such vibration leads to distortion of image quality, rendering the device ineffective. Vibration can be generated due to wind-loading effects or the passage of large trucks.

2.4 Benefits

Network surveillance using CCTV cameras and traffic flow detectors is a prerequisite for many other market packages. It is required to provide optimal freeway control, incident management, traveler information, central data warehousing, traffic forecasting and demand management, and electronic toll collection (ETC). This market package must be combined with other ATMS and ATIS market packages to realize its full benefits. Most evaluation studies in the literature have evaluated network surveillance in combination with other market packages.

In Richardson, Texas, the information provided by CCTV cameras is used by tow truck dispatchers to position appropriate vehicles near the collision site prior to the request for service from the police department. This advance notice reduces the incident response time for clearance by five to seven minutes on average. In northern Virginia, it is estimated that CCTV system implementation reduces the average incident duration by four to seven minutes.

2.5 Cost

The cost of roadside detection varies depending on the selected technology. Below are the estimated costs for four types of detectors and CCTV cameras. The CCTV camera costs are based on an estimate from a recent study. The other costs are from the ITS Unit Cost Database.

Table 2.2 – Estimated Costs for ATMS01
(Network Surveillance Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Inductive Loop	Four loops with controller, power, etc.		3 – 8	0.5 – 0.8
Video Image	One sensor both directions		22 – 29	0.2 – 0.4
Passive Acoustic	Two sensors both directions		4.4 – 10	0.2 – 0.4
True Presence Microwave	Two sensors both directions		6	0.2 – 0.4
CCTV Video Camera		10	45	0.2 – 1.3
CCTV Structure		20	8	
Communications	DS1 line	20	0.5 – 1	4.8 – 8.4
TMC Hardware/Software	Processor and Software	20	135 – 165	6.75 – 8.25
Integration	Integration with other systems	20	225 – 275	11.25 – 13.75

2.6 Implementation, Operation, and Maintenance Issues

This market package implements infrastructure equipment, which is used by many ATMS market packages. It also provides the information necessary for other ITS packages such as Traveler Information and Emergency Management. Thus, understanding the data requirements of these other market packages is an important consideration in the design and implementation of network detection.

There is a wide range of detection technologies in the market. These technologies are continuously advancing. It is important to evaluate the performance of the state-of-the-art technologies, taking into consideration the detection system requirements. Important factors that should be considered include functionality, reliability, accuracy, data timeliness, proven effectiveness, ease of maintenance, ease of calibration, ease of installation, ease of operation, effect of installation on traffic operation, expected life, the required communications medium, and life-cycle costs.

The selection of detector spacing and placement is another important issue. This selection should consider such factors as system requirements, the selected detection technology/product requirements, costs, maintenance requirements, clear zone requirements, rights-of-way, and power source locations.

In general, the funding for ATMS detection systems comes from public agencies. However, ATIS public/private partnerships have provided opportunities for private sector participation in providing funds for surveillance system deployments.

There is a potential user acceptance problem with the implementation of CCTV systems due to concerns about the loss of privacy. This is because of the ability of system operators to view and record images of the corridor and the surrounding areas. CCTV products exist that prevent operators from viewing specified sectors in the camera's field of view. ITS America is developing a set of privacy principles to address this concern.

Most likely, video and data will be shared with other agencies including transportation, enforcement, emergency, media, and ISPs. Agreements between these agencies are needed to set responsibilities for sharing and controlling the information.

The CCTV assembly is normally mounted on poles or building structures along the corridor. The mounting height and location for each camera must be selected to provide the required desired coverage of the corridor. If the cameras are to be mounted on building structures and/or outside the corridor rights-of-way, appropriate agreements, permits, and easements must be obtained to ensure successful deployment, operation, and maintenance of the system.

The CCTV assembly must be located and mounted taking into consideration the physical features that affect the camera's vision. Disruption to traffic during equipment installation and maintenance should be minimized. This is particularly a concern when using in-pavement detectors.

3. Probe Surveillance (ATMS02)

3.1 Overview

This market package provides an alternative approach to the network surveillance traffic detectors discussed above. Two general implementation paths are supported by this market package: 1) wide-area wireless communications between the vehicle and the center are used to communicate current vehicle location and status, and 2) dedicated short-range communication (DSRC) between the vehicle and roadside is used to provide equivalent information back to the center. The market package enables traffic managers to monitor road conditions, identify incidents, analyze and reduce the collected data, and make it available to TMC staff and private ISPs.

3.2 Products/Services

This market package includes the following equipment:

- ISP and TMC central software and hardware that support the collection of vehicle probe data by the center. It provides the capability to accept and process probe vehicle information.

- Roadside beacons and communications links are required for the short-range communications option. Roadside probe beacons monitor traffic and road conditions by collecting information from passing vehicles.

- In-vehicle equipment includes capabilities for the probe vehicle to identify its location. It can also include advanced features such as measuring traffic conditions (as in link travel time and speed) and transmitting these data to either the ISP or TMC.

Probe vehicle surveillance operates by measuring vehicle positions and recording the time of the measurement. This can be accomplished using automatic vehicle location (AVL) systems such as global positioning systems (GPS), toll tag readers, measurement of cellular telephone coordinates, license plate readers, and vehicle signature measurements using traffic detectors.

Most of the current probe surveillance applications have utilized ETC tags for automatic identification of vehicles. However, the Federal Communications Commission's (FCC) requirements that cellular telephone carriers must accurately provide the location of emergency 911 calls promise to provide a cost-effective method for probe surveillance based on cellular telephone call locations. Further discussion of FCC requirements is presented below in the discussion of the Emergency Management Market Packages.

Probe surveillance has been implemented in a number of locations including San Antonio, Houston, and New York. Below is a description of these systems.

3.2.1 TransGuide System, San Antonio

The TransGuide probe surveillance system became operational in 1997 as part of San Antonio's ITS Model Deployment Initiative. The system augmented the 26-mile Texas Department of Transportation's loop detector system in the downtown San Antonio area that formed the core of the legacy Traffic Management System. The roadside devices are located at 54 locations covering 98 centerline miles. The probe surveillance system is intended solely for traffic data gathering, as no toll roads exist in the region. A website uses probe data and provides a system-wide speed map and capabilities to determine the trip time between two interchanges on the network. Travel times are now being automatically displayed on variable message signs throughout the region as well. TransGuide software is available to public agencies under a free license from the Texas Department of Transportation. TransGuide software has been developed by Southwest Research Institute and operates on Sun computers in a Unix operating environment. Amtech deployed and maintains the field equipment in the system.

Applying for tags is free and voluntary. As the vehicles pass by the tag reader field sites, the roadside antennas recognize the tags and report the tag reads to the data processing system, located at the TransGuide Operations Center. The tag reads are reported using conventional modems over analog dial-up telephone lines. When a tag read arrives at the Operations Center, the automatic vehicle identification (AVI) data processing system records the tag data in the hash table associated with the site. Tag data is composed of a unique identifier and a time stamp of the read. Later, the tag passes by a second site resulting in its data being recorded in a second hash table. Every time the system reads new tag data, it scans adjacent sites for matching tag data. Tag reads need not arrive in time-order. When a match is found, the travel time and speed over the link is calculated. The tag identification number is scrambled and the system is not used to give speeding tickets or track vehicles or drivers. By spring 2000, over 500,000 tags had been distributed.

3.2.2 TranStar System, Houston

Operational since 1993, the Houston area was the first to deploy a probe surveillance system for travel time calculations. The system encompasses approximately 130 sites throughout Houston. A map display that uses the system outputs is currently posted on the TranStar website and several governmental offices in the city. The website experiences over 400,000 hits per month. The system was not designed for and is not very suited for portability. Their main objective is to operate, maintain, and enhance the system to take into account new technology as well as adding additional features for incident management. TTI developed and maintains the processing software. Amtech deployed and maintains the field equipment in Houston.

The original pilot distributed several thousand Amtech AVI tags to volunteers. These tags were placed behind the rear view mirror of vehicles. Since then, most of these tags have been replaced by those for toll roads in the region. The transponder tag is read by antennas/readers mounted on overhead roadway structures. As a car passes under antennas/readers, time and location are recorded so that travel times and average speeds can be calculated.

Field controllers transmit location, time, and tag identification information to a central processor. Software matches tag identification numbers to determine which roadway segment the vehicle traveled. By knowing the link traveled and the beginning and end time volume, travel times can be determined. Special software was developed that would eliminate bad data. This software analyzes the data and removes anomalies such as extremely long or short travel times or travel between two non-adjacent points.

The current system processes approximately one million tags per day. Many more reads occur but they are not processed. Dial-up phone lines are used to communicate data from the field to the central controller. Each of the field computers can hold information for fifty tags. The system encompasses approximately 130 sites throughout Houston.

3.2.3 TRANSMIT, New York City Area

Operational since 1995, TRANSMIT (TRANSCOM's System for Managing Incidents and Traffic) is a system that began as an operational test to evaluate the use of AVI technology as an incident detection tool. The current system uses 22 reader locations and covers 19 miles of the New York Throughway and Garden State Parkway. TRANSMIT is currently under expansion as part of the TRIPS123 (formerly “iTravel”) ITS Model Deployment Initiative. The expansion is both in coverage, including 200 miles of the New York metropolitan area, and functionality, including travel time determination. The expanded TRANSMIT was originally planned to be operational in 1997. It is now expected to become operational by the end of 2000. The Management Information System for Transportation (MIST) freeway management software is needed to utilize TRANSMIT.

The system uses vehicles equipped with transponders as traffic probes. Mark IV Interagency Group tags and readers are used. Tag-equipped probe vehicles are assigned a random identification number as they enter a system populated with AVI readers spaced one kilometer apart. Software analysis is used to help identify:

- Incidents;
- Travel times; and
- Speeds.

When a vehicle does not arrive within a specified time (three standard deviations of the average travel time), the system records it and increases the confidence level on an incident thermometer. The more vehicles that are late, or the longer the time the vehicles do not arrive, the higher the confidence level. When this level gets to a user-defined threshold, the system triggers an alarm alerting the operator that there may be an incident. The operator would then analyze the data and determine whether to call the Thruway or Parkway personnel to verify the incident at that location.

3.3 Benefits

Probe surveillance provides information required for other market packages including the Incident Management, Traveler Information, and Data Warehousing Market Packages. To realize its full benefits, probe surveillance must be combined with these market packages.

In New York City, the TRANSMIT probe surveillance system was completed in January of 1995 and included the installation of antennas and ETC tag readers at intervals of 0.5 to 2.1 miles. This spacing between readers was selected to maximize the probability of incident detection by minimizing the false alarm rate (maximum of two percent) and the mean time to detect an incident (maximum of five minutes).

3.4 Cost

Below are the costs of probe surveillance. The reader equipment and installation costs are based on our analysis of a recent ITS deployment plan. The other costs are from the ITS Unit Cost Database. Please note that the database estimated that the software cost for the ISP is $250,000-$500,000 and $150,00-$200,000 for the TMC. Our analysis of the costs in the plan mentioned above indicates that the cost of the central data server including data collection, processing, fusion, web-based map, and connections between the TMC and ISP is about $400,000.

Table 3.1 – Estimated Costs for ATMS02
(Probe Surveillance Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
ISP Software Upgrade		20	250 – 500	12.5 – 25
TMC Hardware	One workstation	5	5 – 10	0.5 – 1.0
TMC Software and Integration		5	150 – 200	15 – 20
TMC Labor	One Operator			50
Communications to Reader	DS0	20	0.5 – 1.0	0.6 – 1.2
On-Board Device		20	8	
Reader Cost Per Site	Reader equipment and installation	10	30	3

3.5 Implementation, Operation, and Maintenance Issues

This market package implements infrastructure equipment, which is used by many other ATMS packages. It also provides the information necessary for many ITS packages. Thus, understanding the data requirement of these packages is essential for the design and implementation of these market packages.

In general, the technologies that determine travel times using probe surveillance are mature, reliable, and cost effective. One of the technical problems facing the system is the large amount of collected data that needs to be transmitted to the center, and the communications system must take this into consideration.

There is a potential user acceptance problem with this market package due to concerns about the loss of privacy as a result of the ability to track individual vehicles. Measures were implemented to mask the identity of the vehicle owner from the transportation agency. Agencies have implemented outreach programs to explain the measures taken against privacy violations.

An adequate number of probe vehicles is required on each network link to obtain reliable estimates of travel information. Probe vehicles can report significant travel time variations on arterial links due to intersection stop times. Thus, larger sample sizes are required for arterial links.

This market package relies on mature technologies with rapid innovation. The maturity varies depending on the technology selected. As stated above, most of the existing probe surveillance systems utilize AVI technologies/products that are associated with toll collection. New technologies have been introduced for the purpose of probe surveillance in recent years including tracking of vehicles based on cellular phone calls, tracking of vehicles using license plate readers, and tracking based on vehicle signatures measured by inductive loops. These technologies are still in the experimental stages but are producing promising results.

Cell phone tracking is a probe surveillance alternative that promises to be a low cost and effective alternative. However, this technology is unproven and a high degree of risk is associated with its use as a sole-source for deployment.

The use of a GPS AVL system often requires communications from individual vehicles to the center, which can be costly.

Due to the large volume of data collected by probes, data reduction techniques are required to identify and filter out-of-bounds or extreme data reports. Data management software is needed for the reduction and fusion of probe data and other sources of network operation data. One issue with implementing this market package is whether to license one of the existing central system softwares discussed above or to write new software for this purpose.

4. Freeway Control (ATMS04) and Speed Management (FL ATMS20)

4.1 Overview

The control of freeway operations includes ramp control, lane control, and dynamic speed control based on observed freeway conditions. Freeway control needs the Network Surveillance Market Package to support freeway traffic monitoring and traffic responsive control strategies. Enforcement might be included to improve safety and operation of freeway control.

4.2 Products/Services

Several off-the-shelf freeway control systems are available. In addition, transportation agencies are implementing freeway control systems with central and field equipment software customized for their applications. Below is a discussion of available products/services.

4.2.1 Dynamic Lane-Use Control

Dynamic lane-use control can be used in the case of temporary lane closures due to incidents or maintenance activities. It can be also used for the restriction of lanes to specific types of vehicles, such as the case with high occupancy vehicle (HOV) and truck lanes. A third application, reversible lane management, is discussed under a separate market package (ATMS18).

Dynamic mainline control includes all or some of the following technologies: lane-use control signs, hydraulically or electrically controlled lifting gates, pop-up delineators, movable lane barriers, surveillance, and fixed communications. Below is a discussion of these lane-use control technologies:

- **Lane-Use Control Signals –** These are overhead signals that indicate current lane control status. The signal displays normally used include a downward green arrow, an amber X, a flashing amber X, and a red X. The displays are used to indicate whether a travel lane is available for use, using the green arrow or red X. The signals alert motorists to the impending shift in use by displaying an amber "X" in a lane that is about to close or change direction and a red "X once a shift is complete. The technologies used for these signals are fiber optic, light-emitting diode (LED), neon, and bulb matrix. The signals can be controlled and monitored from a central location, such as a TMC. In one application of these signs, they were placed an average of 1,000 feet apart.

- **Gates –** Hydraulically or electrically controlled lifting gates (barriers) present a physical barrier in the road that could be used to close the lanes to traffic. One example is the Semaphore barrier gates, which are similar to the ones used for rail-grade crossings. The gate control and monitoring can be done from the TMC. The software at the TMC prevents operation of the devices in an improper sequence, such as the lowering of a gate without the corresponding pop-up delineators in place (if such delineators are used).

- **Pop-up delineators –** These delineators can be raised or lowered remotely as needed. A pop-up delineator has a flexible pylon that withstands collisions and does not cause any damage to the vehicle since it bends under pressure and returns to its original position after the pressure is released.

- **Movable Lane Barriers –** These are physical barriers installed temporarily by transfer vehicles to separate lanes of opposing traffic. Such barriers are often used in the morning and/or afternoon peak periods. An example of this type of barrier consists of three-foot concrete segments, joined by pins and commonly called moveable Jersey barriers.

- Surveillance – Dynamic mainline control might include sensors that detect wrong-way vehicles and CCTV cameras that allow traffic monitoring and lane-use control signal displays.

4.2.2 Ramp Control

Freeway ramp control involves the use of control devices, such as traffic signals, signs, and gates, to balance demand and capacity in order to maintain optimum freeway operations and prevent operation breakdowns. The primary applications of ramp control include entrance ramp metering, entrance ramp closure, and exit ramp closure.

Entrance ramp metering includes allowing vehicles to enter the freeway at a given rate, typically four to fifteen vehicles per minute for single lane metering. The rates may be fixed, based on the time of day, or may be variable minute-by-minute (traffic responsive) based on measured parameters on and off the freeway mainline. One or more signals are used to control the ramp traffic. Ramp metering can be implemented on a local level (for individual ramps) or on a system-wide basis. In system-wide control, individual metering rates are determined based on the overall system conditions, not just the conditions in the immediate vicinity of the ramp. System-wide control requires communications between field controllers and the TMC.

Entrance ramp and exit ramp closures involve closing ramps with automatic gates or manually placed barriers. Manually placed barriers include cross bucks, barrels, or cones. Automatic barriers are similar to the ones used at railway crossings. Manual placement of barriers is labor intensive. Thus, the use of automatic barriers that enable a ramp to be opened or closed automatically from a control center increases the efficiency and flexibility of the operation.

Ramp control system operation can be enhanced with the use of other ITS elements, such as network surveillance to modify the control strategy, and information dissemination technologies to notify travelers of changes in ramp operation. Advance ramp control signs with flashing beacons can be used to warn motorists of changes in ramp operations.

4.2.3 Dynamic Speed Limit Systems

Three types of dynamic speed limit systems can be used:

- Dynamic speed limit based on measured traffic volume, occupancy, and/or speed. Traffic detectors such as inductive loop, microwave, and video image detectors measure these parameters. Algorithms are included to lower speed limits as congestion increases. Speed limits are then displayed using dynamic message signs (DMS). Enforcement cameras can be used to enforce the speed limit.

- Ramp Rollover Warning Systems: These systems consist of weigh-in-motion (WIM) scales, height detection, and a processor to calculate the threshold speed for trucks on the ramp. The threshold speed is calculated based on the maximum curvature of the ramp. The system can alert drivers to slow down by activating a DMS or other device when the maximum safe speed is approached.

- Down Grade Warning Systems: These systems are similar to the ramp rollover warning systems discussed above. However, they are used to advise truck drivers of safe descent speed prior to a mountain or ramp grade.

4.3 Benefits

Ramp meters can be used to improve freeway operations. In addition, ramp meters have been shown to improve safety by reducing crashes in merge areas.

A recent evaluation of the Twin Cities ramp meter project in Minnesota indicated a 22 percent savings in freeway travel time, 26 percent reduction in crashes, and 14 percent increase in freeway throughput. The study found that the benefit to cost ratio of ramp metering is 15:1. During peak periods, the average metered on-ramp delay was 2.3 minute/vehicle.

A study in the Seattle, Washington, area over a six-year period shows that crash rates decreased by 38 percent. During this period, significant growth in the traffic volume was observed while speeds have remained steady or increased by up to 20 percent. The average delay caused by ramp meters has remained at or below three minutes.

An evaluation of a ramp metering system on I-494 in the Minneapolis-St. Paul region showed a 30 percent increase in throughput and an increase in freeway speed from 30 to 50 MPH. Peak period demands increased between 2.9 and 7.2 percent. A reduction in ramp delays was also observed.

A national survey of ramp metering systems reported speed increases between 16 and 62 percent and increases in throughput between 8 and 22 percent, while demand increased 17 to 25 percent. Crash rates were also reduced after implementing ramp-metering strategies.

In England, an evaluation of a dynamic speed limit system showed that crashes decreased by 28 percent. Motorists were more inclined to remain in their lane when there was no longer a faster lane. This resulted in a smoother traffic flow that improved traffic operations. In France, a five percent increase in effective capacity was observed during peak hours after implementing a dynamic speed limit system.

An evaluation of a Ramp Rollover Warning System at three sites in Maryland and Virginia indicated that before implementing the system, there were ten reported rollover truck crashes between 1985 and 1990. After system implementation, between 1993 and 1997, there were no rollover crashes at any of the sites and average truck speed was reduced by about 7 MPH. An evaluation of a Down Grade Warning System in Colorado showed an overall 13 percent drop in crashes resulting from excessive truck speeds.

4.4 Cost

Below are the estimated unit costs for ramp metering control.

Table 4.1 – Estimated Costs for ATMS03 and ATMS20
(Freeway Control and Dynamic Speed Control Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Ramp Meter (controller, power, etc.)	Per location	5	30 – 50	1.5 – 3.5
Loop Detector (double set)		5	7	0.7
Central Hardware	Three workstations	5	15 – 30	
Software and Integration		5	180 – 220	
Labor				180 – 220
DS1 Communications		20	0.5 – 1	4.8 – 8.4

4.5 Implementation, Operation, and Maintenance Issues

Several ramp metering algorithms are available and others are being developed to determine the metering rates for both time-of-day operations and traffic responsive control functions. These algorithms should be reviewed and compared to determine the best algorithm(s) for implementation.

Ramp metering faces political challenges. User acceptance of these systems is one of the major considerations. This is due to the perception that downstream on-ramp traffic levels of service (LOS) are being scarified to allow better LOS for upstream through traffic.

Another concern is the effect on the surface street network. This is due to the possibility of queue spillback from the ramps and traffic diversion to adjacent streets. Adequate storage capacity and the effect on adjacent streets should be carefully studied. There should be inter-jurisdictional cooperation and coordination between the freeway and surface street management agencies to minimize the impacts. Integrated ramp metering/surface street signal timing optimization could be beneficial. HOV by-pass lanes can be considered as part of an overall demand management strategy.

One of the major recommendations of the recent Twin Cities' ramp metering study in Minnesota is to "balance the efficiency of moving as much traffic during the rush hours as possible, consistent with safety concerns and public consensus regarding queue lengths at meters". In light of this recommendation, steps were taken including reducing the operating time frame of ramp meters, allowing meters to change more quickly from red to green, and keeping several meters at flashing yellow.

The Freeway Control Market Package provides equipment and information that can be used to support regional traffic control, IMS, HOV/reversible lane management, traffic information dissemination, and multi-modal coordination. Thus, the deployment of these market packages should be coordinated.

Dynamic lane and speed control signs are not currently standardized in the Manual on Uniform Traffic Control Devices (MUTCD). Dynamic speed control lacks enforceability in most state legal codes, which has reduced its application in the United States. In addition, there could be some liability issues associated with these systems.

The installed ITS infrastructure should be carefully documented at the time of installation. This documentation saves time and money at later stages of project life.

5. High Occupancy Vehicle (HOV) Lane Management (ATMS05)

5.1 Overview

This market package provides management of HOV lanes using ITS technologies. Some of the strategies that can be used include automatic enforcement of HOV lanes, high occupancy toll (HOT) lanes, and preferential treatment of HOVs on metered ramps.

5.2 Products/Services

5.2.1 Monitoring/Enforcement

These devices include vehicle passenger occupancy detectors that may be installed in conjunction with license plate readers to verify HOV compliance. A Texas A&M study identified three technologies that have potential use for this purpose: video image detector, AVI, and infrared machine vision. [See "Video Enforcement of HOV Lanes: Field Test Results for the I-30 HOV Lane in Dallas," presented at the 78th Annual Meeting of the Transportation Research Board (TRB), January 1999]. Initially, the Texas A&M study found no products available for testing. Later, a vendor demonstrated a promising video product. An HOV enforcement system called HOVER was developed in the Texas A&M study based on this video product. The system is a semi-automated video enforcement system that performs four basic tasks:

- Collects and transmits video snapshot images to remote computer workstations;
- Performs automatic license plate character recognition on the license plate images;
- Synchronizes the captured images of vehicle occupants with license plate characters; and
- Searches a license plate database containing vehicle occupancy histories and, based on the failure to meet set criteria, displays the vehicle license plate characters and vehicle compartment images on a computer monitor for review and enforcement.

5.2.2 High Occupancy Toll (HOT) Lane System

Critics of HOV lanes have pointed out the excess capacity of HOV lanes as a reason for opening the lanes to all users. The HOT systems have been proposed to allow solo drivers to use the HOV lanes by paying a toll. Various strategies could be developed to determine the required toll rates. The toll rates are made variable by time of day and distance traveled. These rates are adjusted to maintain an acceptable LOS to ensure that HOV and transit users would not be negatively impacted. Fully electronic toll systems are normally used on these lanes. (ETC is discussed in the ATMS10 Market Package section below.) HOV vehicles' use of the lanes will continue to be free. Only HOVs and motorists equipped with ETC devices would be permitted in the HOT lanes.

5.2.3 Bypass Ramp Metering Lanes

Ramp metering provides an opportunity to give priority treatment to HOVs and encourages the use of HOV lanes. This priority can be in the form of a bypass of the meter or a preferential metering rate as compared with that of the general-purpose ramp metered lane. The treatment can be used in conjunction with HOV lanes or where no HOV lanes are provided.

5.3 Benefits

HOT lanes can increase potential revenues significantly while at the same time addressing the problem of perceived or real under-use of these lanes. Single occupancy vehicles being priced out of the lanes could achieve an adequate LOS.

By-pass lanes are expected to increase vehicle passenger occupancy, thus reducing traffic demands. Automated enforcement is expected to increase compliance with HOV lane restrictions and reduce the costs associated with deploying a large number of enforcement vehicles to ensure compliance.

5.4 Cost

The HOVER system cost was estimated in the Texas A&M study mentioned above to be about $150,000. Table 5.1 shows the costs for this market package as estimated by *NITSA*.

Table 5.1 – Estimated Costs for ATMS05
(HOV Lane Management Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Loop Detectors	One double set	5	5 – 8	0.5 – 0.8
Fixed Lane Signal		20	6 – 8	0.6
Fixed Message Boards		20	50 – 75	2.5 – 4.0
Video Monitoring/Enforcement		20	30 – 50	0.6 – 1.0
Software Billing/Enforcement		20	30 – 50	3 – 5
Central Software Development/Integration		10	180 – 220	12 – 14
Hardware		5	3.0	
Monitor		5	3	
Controller Software Upgrade		3	45 – 55	
DS1 Communications Line		20	0.5 – 1.0	4.8 – 8.4
Operator				90 – 110

5.5 Implementation, Operation, and Maintenance Issues

In general, the technologies that are required for this market package are mature, except for HOV lane monitoring/enforcement equipment. As stated above, sensors that are required to determine vehicle passenger occupancy are still in the early stages of development. In addition, several challenges are still facing license plate reader technologies. Privacy concerns are also associated with systems that are able to identify passenger occupancy.

Legislative issues are associated with HOT lanes. For instance, legislation might allow the implementation of HOT lanes for new facilities. However, retrofitting of existing lanes may require some modifications to existing legislation.

User acceptance of the value-pricing concept of HOT lanes and the by-pass ramp metering of HOV lanes needs to be addressed. Education of the public on the benefits of these concepts must be a major initiative to gain acceptance of these concepts.

6. Traffic Information Dissemination (ATMS06)

6.1 Overview

This market package allows traffic information to be disseminated to drivers and vehicles using roadway equipment such as DMS, trailblazer signs, and/or highway advisory radio (HAR). This package provides tools that can be used to notify drivers of incidents and detour information. Careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information. This package also covers the data delivery and interface equipment that provides traffic information from a TMC to the media, transit management center, emergency management centers (EMCs), and ISPs.

6.2 Dynamic Message Signs (DMS) Products/Services

DMS are used in traffic management applications to provide real-time information to motorists. The messages can be changed on a real-time basis to affect motorists' route choices. The signs are strategically located along main travel corridors prior to access points connecting to diversion routes. When an incident occurs, a real-time message is displayed informing the motorists of the occurrence and location of the incident. Some agencies display the expected delay caused by the incident and even the suggested diversion routes. In addition to being used for freeway and arterial street management applications, DMS have been used for other purposes, such as parking and toll plaza information dissemination.

In general, DMS can be classified into three categories:

- **Mechanical or Light Reflecting –** These signs do not generate light and depend on external light sources such as external sign lights, vehicle headlights, or sunlight. Examples of these types of signs are rotating drums and reflective disk signs.

- **Light-Emitting** – These signs generate their own light on or behind the viewing surface of the signs. Light-emitting signs include bulb matrix, fiber-optic, and LED signs.

- **Hybrid Signs** – These signs combine a light-reflecting technology (normally reflective disk) with a light-emitting technology (normally LED or fiber-optic).

The following is a list of the DMS technologies that have been used in transportation applications:

- Rotating drum (prism) signs display messages by rotating one to four drums. Triangular and square drums are the most common. Typically, rotating drum signs are capable of displaying up to twelve different messages. These types of signs are still used by several agencies, particularly in the northern part of the United States.

- Flip (reflective) disk signs consist of a series of disks (circular, rectangular, or square). The messages are displayed by electro-mechanically rotating appropriate disks to show a reflectorized side. The reflectorized side is usually yellow and the other side is black. Circular flip disk signs are the most widely-used light-reflecting signs in the United States.

- Bulb matrix (incandescent) signs use an array of light bulbs affixed to a dark background surface. This is one of the oldest light-emitting DMS technologies and is still popular in California.

- Fiber-optic matrices with shutter signs use a bundle of fiber-optic cables to direct light radiating from an internal light source (halogen lamp) to lenses at the sign's viewing phase. These lenses create dots, which are then used to form characters. Rotating mechanical shutters either permit light from the lamps to pass through the fibers or block the light to form a character. Using a different color light source or placing a colored filter at the ends of various fiber strands can display multiple color characters.

- LED signs use solid-state devices that glow when a voltage is applied to form characters and symbols. Most LEDs are rated for 100,000 hours of service. The early LED DMS applications did not perform as well as the fiber optic with shutter technology, particularly in hot and humid weather. The main reason is that this technology used a combination of red and green LEDs to display the amber color required for DMS applications. Due to the large number of LEDs required to produce a readable message, these DMS signs produced internal heat that resulted in a high LED failure rate. In addition, these signs consumed a high amount of power due to the large number of LEDs that they used and the large ventilation fans required to control the generated heat. Another problem with the old LED DMS was that the light output of the green LEDs degraded over time resulting in the degradation of message visibility. In recent years, second-generation single color amber LED technologies have been used. These technologies have enhanced the suitability of LED signs for highway applications significantly.

- Hybrid signs combine two DMS technologies (the flip disk technology with a light-emitting technology) to produce signs that exhibit the qualities of both technologies. Typically, a hybrid sign consists of flip disks with a small hole in the center of each disk. Behind each hole is a fiber-optic bundle or a cluster of LEDs. The integration of the light emitting technologies with the flip disk technology improves the visibility of the flip disk signs significantly.

Recent DMS purchases for highway applications have primarily been fiber optic with shutter, LED, and hybrid technology sign types. In a survey of transportation agencies performed a few years ago, only half of the responding agencies indicated they would consider light-reflecting technologies for future purchase. In addition, only twelve percent of the agencies would consider bulb matrix technology; however, most of the agencies would consider light-emitting technologies, such as fiber-optic, LED, and hybrid. Examples of the light-emitting DMS vendors are Vultron, DAMBACH, FiberOptic Display Systems, ADDCO, Skyline Products, Daktronics, and MARK IV.

6.3 Trailblazer Signs Products/Services

Trailblazer signs can be used to provide motorists who have been rerouted around incident locations with real-time guidance over alternate routes. The signs guide motorists through the alternate routes and direct them back to their original routes downstream of the incident location. Trailblazer signs could be static, dynamic, or static with flashing beacons.

Trailblazer signs along an alternative route can take on several designs. The design objective for trailblazers is to ensure high target value and ease of recognition. The messages on trailblazer signs should be as simple as possible, providing the following types of information: 1) destination affirmation and 2) route affirmation and direction.

Trailblazer display designs could include the use of colors, shapes, and sometimes logos and symbols. In general, trailblazers should include an arrow. The trailblazer sign can provide the arrow on the same sign face as the other informational items. It can also be on a separate arrow assembly. When a separate arrow assembly is used, the preference is to use the same color combinations for all components of the trailblazer assembly.

For route diversion around incidents, the trailblazers used should be easily understood by diverted drivers without confusing other drivers traveling on the alternate route. Trailblazers should be located at every point where diverted drivers may become confused. Many of these drivers might be driving the alternative route for the first time. Thus, they need information that helps them decide on the appropriate course of action. Generally, a trailblazer is needed in advance of intersections where drivers have to make decisions. It is also recommended that an additional trailblazer be installed between two major intersections when spaced 1.6 kilometers or more apart.

Blankout signs can be used as dynamic trailblazer signs. These signs are capable of displaying messages that are fixed. The messages are displayed only when the signs are illuminated. Blankout signs can be neon-type, fluorescent lamps behind a cutout legend, LED, or fiber optics on a fixed grid.

Normally, dynamic trailblazers have changeable arrows that allow guidance along various alternative routes for different incident types and locations. This could be the only information provided on the trailblazer. However, the sign could also include the word "ALT" and a standard shield for the route that motorists are diverting from. In addition, it could include the direction of the diverted traffic such as "East" or "West."

Dynamic trailblazer signs normally have controllers that receive commands from the traffic operation center and store messages in its memory buffer, confirm the message content, and display stored messages on the sign. Each controller would have a unique address for communications purposes.

6.4 Highway Advisory Radio (HAR) Products/Services

HAR can be used as a motorist information system to warn motorists, via their car radio, of construction and maintenance, adverse weather conditions or advisories, roadway closures/lane blockages, traffic incidents, emergencies, special events, and natural disaster evacuations. HAR can be classified into:

- **Vertical Antenna HAR Systems –** These systems are the most widely used HAR systems. They use individual antennas or a series of antennas electronically connected together to transmit information. Vertical antenna systems are small and easy to install and less costly than the cable systems discussed below. However, they are subject to damage by vandalism or weather. Also, the signal may interfere with other HAR coverage zones on the same or adjacent roadways. Both portable and permanent vertical HAR antennas have been used.

- **Inductive Cable Antenna HAR Systems –** These systems use cable installed either under the pavement or adjacent to the road. Generally, the cable antenna systems operate at low power levels (0.1 watt) and consist of an antenna using buried coaxial cable placed along the roadside, which limits the transmission to a short lateral distance of 30 to 45 meters. The signal system is strong enough to provide full coverage of multi-lane facilities without causing interference to other HAR systems. If installed below ground, these systems are not subject to damage by weather or vandalism. These systems must extend the full length of the coverage area and are more costly to purchase, install, and maintain, and they cannot be transported from one location to another.

The components of a HAR system include a transmitter, recorder, antenna, and grounding system. The transmitter converts an audio signal into an AM radio signal that can be broadcast. The recorder system is used to record the messages that are broadcast by the system. The grounding system propagates radio waves along the earth's surface and reduces the risk of damage by lightning.

The ten-watt HAR transmitter has a broadcast radius of about three to six miles. FCC licensing is required for the ten-watt HAR systems. The licensing procedure includes studies to confirm that the HAR system does not interfere with other AM-licensed broadcast stations.

If a HAR system is utilized, highway advisory signs should be placed to indicate the presence of the HAR stations. These signs could be static signs that include a pair of flashing lights on the top to inform motorists of the presence of HAR messages.

The HAR operations can be controlled locally or remotely. Local control requires site visits to change the HAR messages. Remote control involves calling the HAR station using a communications medium, such as a standard telephone line or a cellular telephone. From the remote location, the operator can turn the system on or off, load new messages, change messages, and decide which messages to play. Examples of HAR vendors include Transportation Intelligence, LPB Communications, and Information Station Specialists.

6.5 Benefits

In the evaluation of the INFORMS operational test, 45 percent of drivers said they diverted to the alternative route in response to DMS messages. In a typical incident, five to ten percent of mainline traffic diverted to several upstream off ramps, based on the passive messages (no recommended alternative route), and ten to twenty percent diverted in response to active messages. The percentages varied widely based on the availability of alternative routes, severity of the incident, and other factors. The diversion percentage increased as the directness and excess capacity of the alternative route increased. The results of another survey taken in Houston to determine the response of residents and drivers to information on DMS boards showed that 53 percent said, "I altered my travel patterns in some way because of the information" and 33 percent said, "I changed my travel route because of information."

6.6 Cost

Below are the unit costs estimated for the DMS and HAR systems.

Table 6.1 – Estimated Costs for ATMS06
(Traffic Information Dissemination Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
DMS		20	48 – 120	2.4 – 6.0
DMS Support Structure		20	100 – 150	5.0
HAR			16 – 32	0.6 – 1.0
Roadside Message Sign	Fixed with flashing beacons	20	50 – 75	2.5 – 4
TMC Hardware	One workstation	5	5 – 10	0.25 – 0.5
TMC Software	COTS	5	18 – 22	0.9 – 1.1
TMC Integration		20	90 – 110	4.5 – 5.5
TMC Labor	One operator			90 – 110
TMC to Device Communications	DS0	20	0.5 – 1	0.6 – 1.2
TMC to ISP	DS1	20	0.5 – 1	4.8 – 8.4

6.7 Implementation, Operation, and Maintenance Issues

The selection of DMS technology, products, and locations should be made taking into consideration several site-specific factors. The final selection of the best DMS technology/product should be based on such factors as the required sign functionality, day and night visibility, reliability, maintenance requirements, capital cost, technology maturity, energy consumption, and environmental sensitivity.

The issues that need to be considered when selecting a specific location for a DMS sign and its controller include: diversion points, viewing distance, viewing time, viewing angle, viewing obstacles, signing, clear zone requirements, and maintenance and operational considerations.

DMS display elements that need to be specified include character size, legend and background colors, matrix type (character matrix, line matrix, or full matrix), and the number of characters per line. Other issues to be specified include the support structure type, communications media, power backup, sign access for maintenance purposes, and others.

An important consideration is the compatibility with the National Transportation Communications for ITS Protocol (NTCIP). The DMS NTCIP standard is one of the most mature NTCIP standards. Agencies around the country are starting to specify and procure DMS that are compatible with NTCIP standards.

There are two issues associated with visibility of DMS: 1) target value, which is the ease with which the sign is first noticed by the motorist, and 2) legibility, which is the ease with which the message can be read. In addition to DMS technology, the visibility of DMS depends on several factors including viewing distance, viewing time, viewing angle, and viewing obstacles.

Narrow viewing cone angle is one of the main disadvantages of the pure light emitting technologies such as the fiber optic with shutters and LED signs. The optimal optical performance of fiber optic and LED DMS can be achieved within a viewing cone angle of six degrees and 7.5 degrees, respectively, from the on-axis centerline of the sign.

As stated earlier, the hybrid DMS technologies have wide viewing angles. While within the cone of vision of the employed light-emitting technology (LED or fiber-optics), the motorist can rely on this technology to read the sign. Closer to the sign, the motorist passes through the light-emitting technology cone of vision and relies more on the reflective material to read the sign.

The HAR system must operate on a clear frequency without interference from adjacent frequencies, during both daytime and nighttime conditions. Thus, all existing HAR and other AM radio station frequencies in use must be documented in order to determine available frequencies for the HAR system.

Each HAR station needs to be located so that a 2.5- to 3.0-mile radius from the antenna site will be within the intended HAR coverage area. Good line-of-sight must be available between the antenna site and all important reception areas. The location of the HAR station(s) must allow adequate coverage upstream of the critical decision points to give motorists enough time to divert in the case of incidents.

The selected HAR station locations must have few physical obstructions such as high-tension power lines, tall buildings, or trees. The sites must be located at least 30 meters (100 feet) from overhead power lines and commercial radio transmitter sites. In addition, the site must be located as far as possible from any potential re-radiating structures. The site soil type and geology should provide a good conductive ground plane. Soil should be free of sand, rock, mud, and tree roots. The coverage area of the HAR station should be of a size that allows a passing motorist to hear the complete audio message at least twice. Typically, the length of a HAR message is no longer than 60 seconds.

Accurate real-time data is critical for information dissemination systems. A library of DMS messages should be developed early. DMS and HAR control can be shared by several agencies. Thus, the system must be flexible to allow the sharing of control. Agreements between the involved agencies are needed.

This market package relies on mature technologies. DMS and HAR have been in use around the country for many years. HAR implementations are less common than DMS implementations, partly due to poor broadcast quality and the delayed messages of early HAR implementations.

7. Regional Traffic Control (ATMS07)

7.1 Overview

This market package advances the Surface Street Control and Freeway Control Market Packages by adding the communications links and integrated control strategies that enable integrated inter-jurisdictional traffic control. The market package provides for the sharing of traffic information and control among TMCs to support a regional control strategy. The nature of optimization and extent of information and control sharing is determined through working arrangements between jurisdictions. This package relies principally on roadside instrumentation supported by the Surface Street Control and Freeway Control Market Packages and adds hardware, software, and wireline communications capabilities to implement traffic management strategies that are coordinated between allied TMCs. Several levels of coordination are supported from the sharing of information through the sharing of control between TMCs.

7.2 Products/Services

This market package's technologies include center-to-center communications, region-wide control algorithms, and information management. TMC regional control provides capabilities, in addition to those provided by the Freeway and Signal Control Market Packages, for analyzing, controlling, and optimizing area-wide traffic flow. These capabilities provide for area-wide optimization by integrating control of a network signal system with freeway control. The optimization considers current demand as well as expected demand with a goal of providing the capability for real-time control while balancing inter-jurisdictional control issues to achieve regional solutions. The TMC communicates with other TMCs in the region in order to receive and transmit traffic information from other jurisdictions within the region.

7.3 Benefits

Regional control provides additional improvements in various measures of effectiveness compared to basic freeway control. However, these additional improvements have not been quantified yet.

7.4 Cost

The software and integration costs for regional control is estimated by the *NITSA* to be between $300,000 and $440,000. The additional labor required for regional control is estimated to be about $200,000 per year. This is the labor cost of two operators at 50 percent of their time, a transportation engineer at 50 percent of his/her time, and a software maintenance contract. A DS3 line is required for computer-to-computer communications between two TMCs. DS0 lines are required for communications with other agencies.

7.5 Implementation, Operation, and Maintenance Issues

Inter-jurisdictional coordination is critical for this market package. Boundaries of responsibilities should be set between the involved agencies. Control and information access privileges and associated security considerations should be addressed.

A center-to-center communications protocol is needed for traffic information and ITS device control sharing. NTCIP center-to-center standards are expected to mature in the next few years. However, the existing legacy systems that are not NTCIP compliant should be considered. To implement the NTCIP center-to-center communications standards, two basic methods can be used:

- Keep the center-to-center protocol software separate from the existing transportation management software. This involves a loosely coupled connection between the two software packages, which may make use of an existing data interface available in the TMC. This approach avoids or minimizes the need for changes to the existing software.

- Tightly couple the center-to-center protocol and management software with the existing transportation management software. This involves alteration of the existing software to provide the integration. This option provides a more integrated application but may cost more.

The loosely coupled approach might be more cost-effective to connect existing centers with other centers, since it makes use of existing software/hardware. However, the tightly coupled approach and its additional benefits can be obtained much more economically when it is provided as part of a new system development or upgrade.

8. Incident Management System (ATMS08)

8.1 Overview

This market package manages both predicted and unexpected incidents so that the negative impact to the transportation network and traveler safety is minimized. Examples of predicted incidents include construction activities, maintenance activities, and special events. Examples of unexpected incidents include crashes, stalls, spilled truckloads, and regional transportation emergencies (flooding, hurricanes, and HAZMAT emergencies).

Incident management involves five major phases. These phases are incident detection, incident verification, incident response, incident clearance, and queue dissipation. Real-time data required for incident detection and verification are collected using traffic detectors, probe vehicles, and/or CCTV camera surveillance and through regional coordination with other TMCs and EMCs, weather service entities, construction activities' scheduling agencies, and event promoters. Information from these diverse sources is collected and correlated to detect and verify incidents and to implement an appropriate response to these incidents.

The IMS Market Package supports traffic operations personnel in developing an appropriate response in coordination with emergency management and other incident response personnel. The market package also assists the operator by monitoring incident status as the response unfolds. Coordination with the emergency management personnel might be through direct computer-to-computer communications, remote access of the computer systems, or through person-to-person communications. The coordination can also extend to tow trucks and other field service personnel.

8.2 Products/Services

Incident management consists of the following components:

- TMC incident detection provides traffic managers the capability to detect and verify incidents. This capability includes analyzing and reducing the collected data from various sources.

- Roadway incident detection provides the incident detection capability that resides at the roadside. For example, video image detectors have been produced with built-in incident detection algorithms allowing the actual detection function to be at the roadside rather than at the center.

- TMC incident dispatch coordination/communications provides the capability to appropriately formulate an incident response to minimize the incident potential, incident impacts, and/or resources required for incident management. The response includes proposing and facilitating the dispatch of emergency response and service vehicles as well as coordinating the response with all appropriate cooperating agencies.

- Emergency Response Management develops and stores emergency response plans and manages overall coordinated responses to emergencies. This equipment package tracks the availability of resources and assists in the appropriate allocation of those resources for a particular emergency response. This package provides coordination between multiple allied agencies before and during emergencies to implement emergency response plans and track progress through the incident. It provides vital communications links, which provide real-time information to emergency response personnel in the field.

Below is a description of incident management services/products.

8.2.1 Incident Detection and Verification

Incident management requires the detection of incident occurrence and verification of incident existence and location. Other required information includes the determination of incident cause, the nature of the incident, and the identification of the existing and forecasted congestion levels. A fusion of the data gathered from multiple sources is normally required to achieve timely and accurate detection.

To detect incidents, the TMC must communicate with various information sources and have a means for displaying, storing, analyzing, and reporting incident information.

Incident detection can be manual or automatic. Manual incident detection refers to having a system operator continuously observe CCTV video images and maps that show the congestion levels in the network based on traffic detector data. In addition, the operator can use information from other sources, such as cellular telephone calls, highway patrols, air patrols, and calls from emergency call boxes. Many agencies rely on the manual method to detect incidents. This is mainly due to the lack of sufficient field and/or central field equipment and/or due to the unreliability of the available automated incident detection algorithms.

Several automatic incident detection algorithms are available to determine the occurrence of incidents based on traffic detector data. Incident detection algorithms are normally based on volume, occupancy, and/or speed. Three parameters are used to evaluate the performance of an incident detection algorithm. These parameters are detection rate, detection time, and false alarm rate. Incident detection algorithms are normally exercised at the TMC. In recent years, however, video image detectors have been produced with roadside incident detection capabilities.

8.2.2 Incident Response and Clearance

Incident response includes the activation, coordination, and management of appropriate personnel, equipment, communications links, and information media. The effectiveness of the incident response is a function of the use of appropriate techniques and how well these techniques are managed. Some of the focus areas include:

- Ensuring the availability of needed response equipment in a timely manner;

- Establishing institutional arrangements to facilitate coordination and cooperation of incident response and clearance activities among the partners; and
- Establishing legislation supporting vehicle removal policies or other clearance activities.

Several types of equipment are available to help with on-site response, ranging from items that improve the management of resources to special-use equipment that reduces the incident response and clearance times. These include:

- Respondent identification arm bands and vests;
- Incident response and HAZMAT manuals;
- Total stations surveying equipment, which utilizes infrared surveying technology to measure distances critical to a crash investigation;
- Inflatable air bag systems to right overturned vehicles;
- Incident response equipment storage sites located close to key locations with high crash profiles; and
- Tow truck/removal crane contracts that can achieve minimum response times by using a rotation list of wrecker services or by securing a bid contract for service.

In addition to special equipment to facilitate on-site response, incident management includes a number of management strategies that can be developed and invoked, as necessary, to assist in the response process. Included are service patrols, emergency response vehicle parking coordination, on-site traffic control, the formation of incident response teams, and adopting effective vehicle removal laws. Other important strategies in the incident response process include information dissemination, alternative route diversion techniques, modifying freeway control strategies, work zone traffic management, and special events traffic management.

8.3 Benefits

Results from the TransGuide system in San Antonio, Texas, indicated that incident management reduced the response time by 19 to 21 percent (five to six minutes) with an estimated annual benefit to cost ratio of 1.65:1 in time and fuel savings.

The evaluation of an automated incident detection and verification system for the Gowanus Expressway in Brooklyn, New York, indicates that the system reduced the time required to detect and clear incidents from 90 to 31 minutes (66 percent reduction).

Results from the Atlanta Showcase project in Atlanta, Georgia, indicated the following:

- Incident verification time was reduced from 4.2 to 1.1 minutes;
- Response time was reduced from 9.5 to 4.7 minutes (50 percent); and
- Clearance time was reduced from 40.5 to 24.9 minutes (38 percent).

An evaluation of a freeway electronic surveillance project on a 42-mile network in Los Angeles, California, indicated that incident delay was reduced by 65 percent due to the implementation of the system.

An evaluation of a project in Richardson, Texas, where a surveillance video link was provided to city towing contractors to improve response, indicated that the total time to clear an incident was reduced by five to seven minutes on average.

One of the most successful incident management strategies is the service patrol. Many studies around the nation have indicated that service patrol programs generate high benefit to cost ratios, while enjoying extremely positive public perception.

8.4 Cost

Below are the unit costs estimated for incident management:

Table 8.1 – Estimated Costs for ATMS08
(Incident Management System Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $/Year)	O&M Cost (1000 $/Year)
Video Monitor and Wall	Five 19" monitors and wall monitors (3 x 3 = 9)	5	40.5 – 49.5	2.025 – 2.475
Hardware for Detection/ Verification	Four servers, five workstations, and two laser printers	5	81.7 – 119.3	4.085-5.965
Integration for Incident Detection		20	90 – 110	4.5 – 5.5
Software for Incident Detection	Software is COTS	5	90 – 110	4.5 – 5.5
Labor for Incident Detection	Four @ 100K and One @ 150K			630 – 770
Monitor for Incident Response	One 19" monitor	5	2.7 – 3.3	.135 - .165
Hardware for Incident Response	One workstation	5	2.7 – 3.3	.135 - .165
Integration for Incident Response		20	180 – 220	
Software for Incident Response	COTS	2	13.5 – 16.5	0.675 – 0.825
Labor for Incident Response	One @ 100K			90 – 110
Communications to Dispatch	DSO	20	0.5 – 1	0.6 – 1.2

8.5 Implementation, Operation, and Maintenance Issues

Several agencies have a vested interest in incident management including state and city transportation agencies, highway patrol, fire and emergency medical services, HAZMAT contractors, other emergency agencies, towing services, metropolitan planning organizations (MPOs), special events promoters, ISPs, and media representatives. Coordination between these agencies is essential to the success of incident management.

There is a need to develop lines of communication, cooperation, and trust within and between the various agencies involved in the incident management process. A key to effective incident management lies in the ability of multiple agency partners to coordinate and cooperate before, during, and after an incident. One of the most critical activities that must occur early in the incident management development process is consensus building among the partners. One way to facilitate this level of cooperation is for each partner to develop a true understanding of the goals, responsibilities, and capabilities that the other partners have within the incident management process. Also, there is the need for a critical review of the current and possible involvement of various agencies in incident management. Formal agreements of understanding and cooperation may need to be written and signed by the upper management of each agency.

Developing an incident response plan is an important activity for facilitation of improved incident management activities within the region. Incident management plans and strategies should be in place before the implementation of technology begins. These plans must be detailed documents that specify key partner roles, communications links, detailed traffic management procedures, resources (and their locations), and logistics.

After plan development and implementation are achieved, there is a need for continued coordination for the refinement of plans and strategies. Incident management training and exercises should be conducted regularly. Evaluations of incident handling practices should also be conducted regularly.

Legal ramifications pertaining to agency involvement in incident management must be assessed. IMS rely on mature technologies with rapid development in the areas of incident detection and incident dispatch coordination/communications. Roadway devices such as video image processing sensors are being introduced with roadside incident detection capabilities. New algorithms are being developed and tested for detecting incidents for surface streets. An evaluation should be made of these algorithms to determine their performance.

Although incident detection algorithms are being improved, transportation agencies have found that non-automated low-cost incident detection sources are also effective in detecting incidents. Thus, strategies should be developed to improve the ability of agencies to collect information and detect incidents based on these sources. The emerging Enhanced 911 (E-911) cellular location technologies will allow rapid detection of incidents and their locations.

Implementation of common voice communications frequencies among agencies responding to incidents is needed. This implementation requires participating agencies to overcome institutional and jurisdictional barriers.

Incident management programs face difficulty because of the limited operational funds that typically must be allocated annually. Thus, funding plans should be set for the life of the project.

Diversion route plans are an effective way to manage incident congestion. However, there should be enough capacity on alternate routes to accommodate the diverted traffic. In addition, inter-jurisdictional cooperation is required between freeway management and surface street management agencies. Signal control needs to be adjusted to respond to diversion.

HAZMAT incident responses are supported by current technologies. However, institutional arrangements are required to implement such systems. More details regarding HAZMAT management is given in the discussion of the CVO9 market package.

9. Traffic Forecast and Demand Management (ATMS09)

9.1 Overview

This market package includes advanced algorithms, processing, and mass storage capabilities that support historical evaluation, real-time assessment, and forecasting of the transportation network performance.

The package includes transportation network models that support the prediction of travel demand patterns and link travel time forecasts. The source data would come from the TMC historical and real-time database as well as from other TMCs and agencies in the region. In addition to short-term forecasts, this market package provides long-range forecasts that can be used in transportation planning and transportation demand management.

This market package provides data that supports the implementation of transportation demand management programs and policies managing both traffic and the environment. Information on vehicle pollution levels, parking availability, and vehicle occupancy is collected to support these functions. Demand management can also be coordinated with the Toll Administration, Transit Management, and Parking Management Subsystems.

9.2 Products/Services

Traditional transportation planning analysis cannot asses the impacts nor capture the benefits of ITS. These analyses assume no day-to-day variability in demands and no incidents or weather effects. They also do not consider the effect of advanced lTS strategies on system performance and driver route/mode/trip time choice. In addition, new models and analysis tools are needed to run in real-time at transportation centers to support ITS operation, allowing the system to make more intelligent management decisions and providing the users with the conditions expected in the network in the near-term future. The following is a quick review of some of the available models in the market and some models that are currently under development:

9.2.1 DYNASMART

This is a dynamic traffic assignment/simulation model developed by a team led by the University of Texas in Austin for the Federal Highway Administration (FHWA). The model combines advanced network algorithms and models of trip-maker behavior in response to information. In order to provide reliable estimation of network conditions, the model provides prediction of network flow patterns over near and medium terms, and routing information to guide travelers through the network.

9.2.2 DynaMIT

DynaMIT is another dynamic traffic assignment/simulation model. The model is being developed at the Massachusetts Institute of Technology for the FHWA. The system has been created to evaluate the design of a traffic surveillance and control system for Boston's Central Artery.

9.2.3 Paramics

This is a suite of high performance software tools for microscopic traffic simulation developed in Scotland. Individual vehicles are modeled in fine detail, providing very accurate estimates of traffic and transit network conditions. The model enables an interface between drivers and ITS.

9.2.4 Vissim

This is a German product that models transit and traffic flow on a microscopic level and allows the modeling of ITS devices. The model is one of the best models to simulate transit operation and preemption strategies.

9.2.5 AimSun2

This is a Spanish model that simulates urban and interurban transportation networks that contain ITS devices.

9.2.6 TRANSIMS

This model is now under development by Los Alamos National Lab. The model uses household trip generation and traffic simulation to analyze transportation/ITS planning issues.

9.2.7 ITS Deployment Analysis Toll (IDAS)

This is a post processor to current transportation demand models that allows estimation of ITS benefits based on previous project experience.

9.3 Benefits

This market package allows an optimized deployment of ITS. The evaluation models allow the optimization of the allocation of the available budget throughout the life-cycle of the project. When implemented in real-time, the models allow assessment of the impacts of various control strategies, resulting in the selection of better ITS strategies for the forecasted network conditions. They will provide a better estimate of user reactions to ITS strategies and allow the dissemination of near-term future traffic conditions to travelers. Demand management strategies will improve the operation and safety of transportation networks.

9.4 Costs

Table 9.1 – Estimated Costs for ATMS09
(Traffic Forecast and Demand Management Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Hardware	Two workstations	5	8	
Software	Off-the-shelf and developed	5	150	
Integration with Other TMC Services		20	180	
Integration with ISP		20	180	
TMC to PS Communications		20	4	
Transportation Engineers/Analysts	Two @$100,000			200
Maintenance of System Components				10
DS3 Communications				40

9.5 Implementation, Operation, and Maintenance Issues

This market package requires extensive and continued database management efforts to maintain historical and real-time data that are required for demand forecasting and management. Reduction and fusion of data collected from different sources are critical for this market package.

For demand management, inter-jurisdictional coordination is required between agencies including traffic management, parking management, toll administration, transit management, event promoters, and ISPs. This coordination will allow the deployment of system-wide demand management strategies.

The required technologies for this market package are mature with rapid innovation. Further developments in information management and algorithms are expected. Dynamic traffic assignment/simulation models such as DYNASMART and DynaMIT are still in the testing stage. Transportation demand models that consider ITS applications, such as TRANSIM, are in the development stage but are expected to be available in the next few years.

The computer hardware and software requirements of the selected computer packages need to be considered part of the TMC requirements. In addition, personnel with background in network modeling and demand management will be needed.

10. Electronic Toll Collection (ETC) (ATMS10)

10.1 Overview

ETC allows for electronic payment of highway tolls through the application of in-vehicle, roadside, and communications technologies to process toll payment transactions.

This market package provides toll operators with the ability to collect tolls electronically and detect and process violators. DSRC between the roadway equipment and the vehicle is used.

10.2 Products/Services

ETC systems perform toll collection, reconciliation, enforcement and control, and auditing as follows:

- **Toll Collection** – ETC uses AVI technology to identify vehicles as they pass specified points within a barrier or ticket toll collection system. Automatic vehicle classification (AVC) is normally used where the toll structure varies with vehicle type, axle count, weight, and other vehicle characteristics.

- **Reconciliation** – The Reconciliation Subsystem provides a means to count, and probably classify, vehicles that pass through a toll lane during a given time segment. This count is then compared to the transaction count generated by the Toll Collection Subsystem for the same period. This system allows violations or lost funds to be identified. Traffic detectors are used to count vehicles entering and exiting the toll lane.

- **Enforcement** – The enforcement system includes violation cameras and CCTV cameras. The enforcement system must be integrated with toll collection and reconciliation to identify violators. With ETC, vehicles are moving through at high speeds. Thus, the enforcement system must be able to react quickly to a valid or invalid indication.

- **Audit and Control** – This system turns the lane open sign on or off, performs diagnostics to identify problems, and conducts a detailed audit.

The first three of the above functions reside in the toll plaza lane and are performed by field devices tied together to a lane controller. The Audit and Control Function usually resides in the plaza building(s) and/or at the agency administration building.

Below is a discussion of the technologies and products currently available for the AVI, AVC, and Enforcement Subsystems.

10.2.1 Automatic Vehicle Identification (AVI)

AVI refers to the various components and processes of the toll collection system with which the toll equipment is able to determine ownership of the vehicle for the purpose of charging the toll to the proper customer. AVI technology can be categorized as laser, radio frequency, and infrared. The most widely used AVI technologies are those that use radio frequency.

There are three types of ETC tag technologies:

- **Tags** – These are devices located in or on the vehicle and are used with an in-lane antenna/reader to communicate vehicle-identifying information to the ETC. Two types of tags are available: read-only and read/write tags. In the read-only tags, the information stored in the tag is fixed and cannot be changed. Read/write tags contain an updateable area on which the antenna/reader may encode information (such as point of entry, date/time of passage, etc.). Tags have been in use for several years and are manufactured by a variety of vendors including Amtech, Combitech Traffic Systems, Denso Corporation, Efkon, Mark IV Industries, Micro Design AS, and SIRIT.

- **Smart Tags –** The difference between the smart tags and the regular tags is that they contain a microprocessor, which maintains account balance information that is updated each time the smart tag is used. Smart tags have not been used extensively. Manufacturers of this technology include AT/Comm and Mitsubishi Heavy Industries.

- **Smart Cards and a Transponder** – The smart card is an integrated circuit device, which contains a microprocessor and memory and stores account balance information. The transponder is a device located in the vehicle that interfaces to the smart card and allows the smart card to communicate with the in-lane antenna/reader. Smart cards' manufacturers include AT&T, DigiCash, GemPlus, Giesecke & Devrient, and ORGA. The radio frequency transponders used with smart cards are manufactured by Amtech, Cegelec CGA, Combitech Traffic Systems, Efkon, Marconi, Mark IV Industries, and Mitsubishi Heavy Industries.

Smart cards allow for more sophisticated data security measures than read-only and read-write tags. They are programmable and, therefore, are less dependent on current standards. In addition, they can be integrated with other EPS such as parking, gas, and telephone services.

10.2.2 Automatic Vehicle Classification (AVC)

AVC systems for classification of vehicles range from simple treadles that count axles by sensing the pressure of tires crossing them to more sophisticated systems such as WIM and infrared detectors. Below is a description of the available technologies. Depending on the information needed to calculate the correct toll fees, an AVC may need to determine vehicle height, number of axles, presence of dual tires, and vehicle weight to distinguish between vehicle classes. Various technologies are used to determine vehicle classification including:

- **Inductive Loops** – These are used to classify vehicle presence based on the metallic mass of the vehicle. Manufacturers include 3M, Diamond Traffic, Golden River, Mayfield, and Peek Traffic Systems.

- **Treadles** – These are pressure-sensitive devices placed in frames installed in the road bed and are used to determine the number of axles and wheels of passing vehicles. The following types of treadles are available:

  - Electromechanical treadles are in widespread use for low-speed applications; however, they are reported to be inaccurate at speeds over 55 MPH. They also have a high maintenance cost. Manufacturers include Cubic and The Revenue Markets Inc.

  - Resistive rubber treadles are similar to electromechanical treadles, but use resistive rubber rather than metal for contact closure. They operate accurately at speeds from two to 80 MPH and have lower maintenance costs than metallic units. Manufacturers include International Road Dynamics and Technotel.

  - Optical treadles utilize infrared beams inside a tube. These devices are reported to be accurate at higher speeds and have a long life and low cost of maintenance. Manufacturers include Trindel.

  - Piezoelectric treadles utilize a special material inside a tube that generates an electric current when subjected to pressure caused by an axle crossing the treadle. The devices are reported to be accurate at speeds over 5 MPH and recent developments have made them accurate even in the 0-5 MPH range. Manufacturers include Peek Traffic Systems, The Revenue Markets Inc., and Traffic 2000 Ltd.

- **WIM Devices** – These are pressure-sensitive devices generally placed in frames installed in the road bed and are used to determine the axle weight of vehicles. The following are available WIM technologies:

  - Bending plates are devices that utilize a bending plate to determine the axle weight of a vehicle. Manufacturers include PAT and Peek Traffic Systems.

  - Capacitive strips use axle weights that are calculated based on the degree of pressure on the strip. Manufacturers include Golden River.

  - Piezoelectric sensors are devices that utilize special material inside a tube. The material generates a varying electric current proportional to the weight of the axle crossing the sensor. Manufacturers include Diamond Traffic, PAT, Peek Traffic Systems, and Philips.

- **Light Curtains** – These devices emit multiple horizontal light beams to measure vehicle presence and profile. A transmitting tower sends light beams across the lane to a receiving tower. As a vehicle breaks the light beams, a two-dimensional profile of the vehicle can be produced. Manufacturers include Banner, CGA-Alta, and Scientific Technologies Inc.

- **Scanning Devices** - These devices generate radiation at various frequencies to detect vehicle presence and profile. Scanning devices which may be useful in AVC applications include the following:

  - Ultrasonic scanners are devices that are subject to distortion from air turbulence and changes in temperature and humidity. Manufacturers include Cubic.

  - IR Scanners – Manufacturers include Computer Recognition Systems, Inc., Elsydel, MBB SensTech, and Schwartz Electro-Optics.

  - Laser Scanners – Manufacturers include Schwartz Electro-Optics.

- **Video Image Processing** – These devices use video image detection technology to determine vehicle length, width, and height. Manufacturers include Golden River.

10.2.3 Video Enforcement Systems

Video enforcement systems are available to:

- Determine when and where a toll violation has occurred;

- Record the image of violating vehicles. These images include location, date, time, and violation type. The rear view of the vehicle and a clear view of the license plate are required; and

- Process the recorded violation information into the appropriate violation notices.

In general, a video enforcement system includes a camera, visible or infrared image lighting devices, image capture computing system, and violation triggering devices.

Below are the technologies currently specified for video enforcement systems:

- **Digital Imaging** – These are video-based systems that utilize the digital capture and storage of images. Digital systems feature the ability to digitize images, store them electronically, and transmit them to remote locations.

- **License Plate Recognition (LPR)** – LPR allows the video enforcement system to automatically determine where in the image the license plate is located, read the license plate number and state, and store this information with the transactions. This can reduce the need for manual intervention in the violation process and greatly reduce the operating cost of the ETC system. However, certain limitations with LPR have limited its use in video enforcement system and most systems in use or under development do not currently use LPR.

The major problem with automatic LPR extraction is its level of accuracy. This is due to the lack of standards for license plate uniformity, dirty plates, damaged plates, obstructions, plates mounted incorrectly, temporary or missing plates, and differences in vehicle design and license plate position. As a result of these factors, LPR systems often require manual intervention to read images and confirm the results of the LPR.

10.3 Benefits

The benefits of ETC have been demonstrated in several evaluation studies. The capacity of the toll lane depends on several factors including the type of toll collection (manual, machine, ETC, or mixed-use), the use of a gate or metering light, and the type of transaction that takes place. It is expected that toll lane capacity ranges from 350-400 vehicles per hour for manual toll lanes to 1,800 vehicles per hour for express ETC lanes with no barriers. However, the capacity of a dedicated ETC in a conventional toll plaza is expected to be between 1,000-1,200 vehicles per hour due to geometry constraints that prevent vehicles from traveling at freeway speed.

A study on the Tappan Zee Bridge toll plaza in New York found that an ETC lane peak capacity is 1,000 vehicles per hour compared to manual toll lanes that can accommodate 400-450 vehicles per hour. An evaluation of the Holland toll plaza in Florida estimated that the capacity of the toll lane before the ETC installation was 500 vehicles per hour. The capacity of the ETC lane (with no gate) is estimated to be 1,600 vehicles per hour. However, the measured throughput was 1,270 vehicles per hour because there were not enough tagged vehicles in the stream. Evaluation studies also indicated improvements in vehicle waiting times and emissions due to ETC installation.

Florida's Turnpike District calculated a 2.03:1 benefit to cost ratio if only ten percent of vehicles at a toll plaza use ETC.

A study in Canada found that ETC could reduce the cost of staffing tollbooths by 43.1 percent, money handling by 9.6 percent, and roadway maintenance by 14.4 percent.

It was found that each image reviewer could process approximately 100 images per hour. This includes the entering of the plate information into data fields associated with the image. With LPR, this rate could go up to 150 images per hour because the image reviewer only needs to check and/or correct the LPR results. At a staff cost of $25,000/year, the estimated payback period of LPR is four months.

10.4 Cost

The following are the estimated unit costs for this market package:

Table 10.1 – Estimated Costs for ATMS10
(Electronic Toll Collection Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Toll Administration Software		10	40	5
Toll Administration Hardware		20	12	
DS3 Communications Line		20	4	50
DS0 Communications Line		20	1	7
Electronic Toll Reader	Per lane	10	4	0.2
Structure		20	10	
High-Speed Enforcement Camera	Two lanes per camera	10	7	0.5
ETC Software		10	7	
ETC Hardware				
DS1 Communications Line		20	1	7

10.5 Implementation, Operation, and Maintenance Issues

Inter-jurisdictional coordination is required between toll administration, traffic management, enforcement agencies, and financial institutions. Coordination and agreements between these agencies should be developed ahead of time. In areas with more than a single toll collection authority, compatible tag technologies allows a seamless transaction process and enhances convenience to motorists. Agreements to share “back office” toll processing between multiple agencies hold promise.

Other institutional issues include concerns about the loss of privacy. The practice of confidential encryption should be used to reassure users who have privacy concerns. Privacy concerns are also associated with video enforcement systems. When the system takes one or more full view images of a vehicle going through the lane, it is possible that the image will contain the driver and/or other passengers. Any image that contains a person could be viewed as an invasion of privacy. This is especially the case when the system takes images of every vehicle and discards those of non-violators later. To avoid these types of potential privacy issues, the image captured is generally constrained to the general plate area of the vehicle and, if possible, only to vehicles identified as violators.

Regulatory constraints are also associated with this market package. New regulations need to be set regarding toll payments and violations.

The technologies required to implement this market package are maturing quickly. However, there is a lack of adopted interoperability standards. Technology standards are needed to support an open architecture. The industry resisted standardization for many years to protect their market.

A detailed marketing plan is a key to the acceptance and success of ETC systems. A decision needs to be made regarding the merit of discounting tolls to encourage the use of ETC. Smart card technology will allow the use of the card for multi-purpose payment. This requires agreements between the involved public and private sector agencies.

As stated above, conventional toll lanes converted to ETC operations accommodate fewer vehicles than do lanes designed for ETC operations. Thus, as demands on ETC lanes increase, consideration should be given to upgrading the lanes from conventional designs to faster ETC lanes. It is also important to determine the proper mix of ETC and manual lanes to allow for optimal operation.

This market package allows the implementation of the probe vehicle equipment package using AVI technologies. Coordination between the two market packages is needed.

For nighttime operation of the video enforcement system, the required added illumination has to be factored into the process to obtain clear images. The type of illumination must be selected along with the camera to produce the required nighttime visibility.

For video enforcement systems, a truck that is composed of a semi-tractor and a trailer poses a special problem since the trailer obscures the rear plate, which is traditionally used for video enforcement systems. The solution to this problem is to capture an image of the front plate. A problem with this approach is patron distraction because of the illumination system for nighttime operation. Vendors have used strobe lights on an angle of various types, but no generally acceptable technology is in use.

Important institutional considerations for video enforcement systems include legal authority and relationships with other toll operators and the law enforcement and judicial communities. It may be necessary to sponsor new legislation to allow for violation processing needs. Other considerations include reciprocal processing agreements with other agencies, requirements of court prosecution, and law enforcement agency information needs. It is advisable to conduct a comprehensive review of legal authorities, agreements, and relationships.

11. Virtual TMC and Smart Probe Data (ATMS12)

11.1 Overview

This market package provides for the special requirements of rural road systems. Instead of a central TMC, the traffic management is distributed over a very wide area (e.g., a whole state or collection of states). Each locality has the capability of accessing available information for the assessment of road conditions.

The package also provides the capability of using vehicles as smart probes that can measure road conditions and provide this information to the Roadway Subsystem for relay to the Traffic Management Subsystem and, potentially, direct relay to following vehicles.

11.2 Products/Services

Below is a review of existing portable ATMS systems that have been implemented around the country.

11.2.1 Surveillance and Delay Advisory System, New Jersey

This project included the development and testing of a surveillance and delay advisory system (SDAS) for application in congested rural areas on SR 55 in New Jersey. The SDAS included several techniques that could be used on rural highways to give travelers advance information on congestion on the road ahead of them. It is designed to address congestion problems in work zones or at approaches to major attractions. Important considerations for its design are reliability, level of maintenance, and cost. The SDAS employs three different data collection technologies to collect travel time information: WIM, video, and radar subsystems. The system gathers data from a test zone, computes travel times, and transmits delay messages to motorists who are headed toward the zone.

11.2.2 Mobile Surveillance and Wireless Communications Systems, California

This was an ITS operational test in southern California. The primary tasks of these system surveillance trailers are to acquire video imagery and traffic data, transmit metering rates to a ramp meter trailer, and transmit traffic flow data and imagery to the relay site. The major components of the surveillance trailer are a video image detector; two pan and tilt black-and-white cameras; one pan, tilt, and zoom color camera; one fixed black-and-white security camera; a 170 controller; wide and narrow bandwidth spread spectrum radios for video and data transmission; a telescoping 30-foot (9.1-meter) mast; a security system; and a propane-powered electrical generator and power supply system.

The ramp meter trailer retransmits the metering rates to portable signal heads on the ramp and controls the meter-on sign. The major components of the ramp meter trailer are two traffic signal heads, a ramp meter-on sign, narrow band spread spectrum radios for data reception, and solar-powered electrical recharging systems for one signal head and the meter-on sign. The relay site on the Union Bank Building in Santa Ana, California, supports trailer locations along the I-5 reconstruction zone in Orange County, California. Video imagery and data received at the relay site are retransmitted to the TMCs.

11.2.3 Portable Traffic Management System, Minnesota

The portable traffic management system application for a smart work zone was developed by the Minnesota Department of Transportation with support from FHWA. The project partners also included the University of Minnesota, ADDCO, ISS, Vano Associates, BRW, and the SRF Consulting Group. The portable traffic management system integrates existing, off-the-shelf, and emerging traffic management technologies into a wireless, portable traffic control system. It operates in a work zone and provides traffic engineers with speed, volume, and incident detection data that are communicated to the traveling public so that they may make informed travel decisions.

As developed for the work zone application, the portable traffic management system consists of portable skids that contain a video image detector system, DMS, central processing unit, and spread spectrum radio communications. The skids are placed in strategic locations in the work zone and, when linked to one another by the spread spectrum radio, form nodes in the portable traffic management system network. The nodes can include both vehicle detection devices and driver information devices.

The portable traffic management system consists of four subsystems: vehicle detection and surveillance, traffic control center, driver information, and communications. The vehicle detection and surveillance subsystem contains cameras and a video image processor. Video cameras placed at strategic locations in the work zone provide real-time traffic flow information to traffic management personnel. The video image processor analyzes the camera imagery to produce traffic volume, speed, incident detection, and alarms that indicate vehicle intrusion into the work zone. The camera is mounted at the top of a tower.

11.2.4 Rural Smart Work Zone, Iowa

During the 1997 I-80 reconstruction in Iowa, traffic engineers acted to mitigate the impact of traffic incidents in the work zone and to reduce the number of secondary traffic accidents. The increased incidents and secondary accidents were caused by reduced work zone capacity, which combined with peak period demand to create traffic backups that brought about the accidents. Prior to the development of the Rural Smart Work Zone, traffic monitoring was provided by a single person in a roving vehicle who responded to observed incidents. The single roving vehicle technique, by itself, was inadequate for the large reconstruction area.

The Rural Smart Work Zone consists of an incident detection unit equipped with a Whelen microwave Doppler sensor to measure vehicle speed and a camera to acquire images of the traffic flow. When speeds drop below 35 MPH, the incident detection unit automatically places a series of four cellular telephone calls, three to activate ATIS devices (namely, two mobile DMS and a HAR) and one to notify the roving vehicle. The camera operates independently of the speed sensor. The images from the camera can be viewed (for example, at the TMC) by calling the camera via cellular telephone. The images are transmitted by cellular communications as well. The viewer can select the image refresh rate up to a maximum of once every two to three seconds.

11.3 Benefits

The following benefits are expected from implementing smart workzone projects:

- Increased worker safety;
- Increased traveler safety;
- Increased work zone efficiency; and
- Long-term cost savings for the traveler and the operating agencies.

The Minnesota Department of Transportation felt that the system resulted in both increased safety and improved flow of traffic through the work zone.

In Nebraska, local transportation groups will deploy over twenty ITS technologies in interstate work zones. It is expected that several, if not all, of these technologies will provide substantial reductions in traffic delays, stops, and crashes experienced at interstate work zones. For example, it is estimated that the smart work zone technologies to be deployed in work zones on I-80 in Nebraska as part of the initiative will provide road users with a savings of $1 million in accident costs and $10 million in travel time costs. These savings would yield a benefit to cost ratio of more than 50:1. These estimates are based on work zone average daily traffic of 35,000 vehicles per day, project durations of 30 days, and the 1996 average crash severity rates (i.e., 0.7 fatal, 35.4 injury, and 44.1 property-damage-only crashes per 100 million vehicle-miles) on I-80 in Nebraska. If the technologies perform as expected, similar benefits will be realized in future interstate work zones in Nebraska and the other three states as a result of the initiative.

11.4 Cost

The cost depends on the sophistication of the system. The cost for a mobile trailer that performs network surveillance and traffic information dissemination activities is between $80,000 and $100,000, based on information obtained from a vendor of these devices. More sophisticated systems are more expensive

11.5 Implementation, Operation, and Maintenance Issues

Many issues that were discussed for the Freeway Management Market Package are also applicable to this market package. Mobile TMC systems might have to use wireless communications technologies. Some agencies are still concerned about the use of these technologies for video and data communications. In addition, these technologies require a line of sight between communicating points. However, several systems have implemented these technologies successfully for video and data communications.

In mobile systems, it might not be possible to achieve the optimal location and mounting of the field devices. In addition, limited experience exists with these systems, particularly the smart probe vehicle concept.

It was mentioned that one agency has identified potential locations for their mobile ITS field devices. These locations were then supplied with communications lines and power. As needs arose, the units were moved to the most appropriate locations among the pre-selected and pre-wired sites. Such a configuration would eliminate the need for wireless communications and solar power.

12. Railroad Grade Crossing Management (ATMS13, ATMS14, and ATMS15)

12.1 Overview

The *NITSA* divides railroad grade crossing management into three market packages:

- **Standard Railroad Grade Crossing (ATMS13)** – This market package manages highway traffic at highway-rail intersections (HRIs) where operational requirements do not dictate more advanced features (e.g., where rail operational speeds are less than 80 MPH). Both passive (e.g., the crossbuck sign) and active warning systems (e.g., flashing lights and gates) are supported. These traditional HRI warning systems may also be augmented with other standard traffic management devices. The warning systems are activated when notified by interfaced wayside equipment of an approaching train. The equipment at the HRI may also be interconnected with adjacent signalized intersections so that local control can be adapted to HRI activities. Monitoring of the HRI equipment and interfaces is performed and detected abnormalities are reported to both highway and railroad officials through wayside interfaces and interfaces to the Traffic Management Subsystem.

- **Advanced Railroad Grade Crossing (ATMS14)** – This market package manages highway traffic at HRIs where operational requirements demand advanced features (e.g., where rail operational speeds are greater than 80 MPH). This market package includes all capabilities from the Standard Railroad Grade Crossing Market Package and augments these with additional safety features to mitigate the risks associated with higher rail speeds. The active warning systems supported by this market package include positive barrier systems that preclude entrance into the intersection when the barriers are activated. Like the Standard Railroad Grade Crossing Market Package, the HRI equipment is activated when notified by wayside interface equipment, which detects, or communicates with, the approaching train. In this market package, the wayside interface equipment also provides additional information about the arriving train so that the train's direction of travel, its estimated time of arrival, and the estimated duration of closure may be derived. This enhanced information may be conveyed to the driver prior to, or in context with, warning system activation. This market package also includes additional detection capabilities that enable it to detect an entrapped or otherwise immobilized vehicle within the HRI and provide an immediate notification to highway and railroad officials.

- The Railroad Operations Market Package (ATMS15) provides an additional level of strategic coordination between rail operations and TMCs. Rail operations provide train schedules, maintenance schedules, and any other forecast events that will result in HRI closures. This information is used to develop and forecast HRI closure times and durations, which may be used in advanced traffic control strategies or to enhance the quality of traveler information.

12.2 Products/Services

At public highway-rail crossings, there are two basic types of warnings: passive warning devices and active warning devices. Passive warning devices are static traffic control devices indicating the presence of an at-grade crossing. These include crossbucks (white reflectorized X-shaped signs with "RAILROAD CROSSING" in black lettering), advance warning signs (round yellow signs indicating "R x R"), and pavement markings. Active highway-rail crossing devices indicate the presence of an approaching train. These include flashing signals, automatic gates, and other similar devices activated by a train passing over a detection circuit or, in some instances, by manually operated devices. Nearly every type of active warning device for highway-rail crossings uses the rails to conduct the necessary electronic signal. As a train approaches a crossing, its wheels interact with a track electrical circuit. At a predetermined distance from the crossing, this interaction activates the crossing signals. With constantly improving technology, the control equipment for active warning devices has become more sophisticated. The two basic types of modern control equipment are motion detectors and constant warning time devices. To minimize crossing signal activation time, motion detectors are utilized when train movements are usually slow-speed switching moves. Constant warning time devices are used when train speeds vary significantly.

The following is a discussion of projects that have implemented ITS technologies at railroad crossings. The discussion is based on information included in a paper entitled *"The Use of ITS to Improve Safety and Mobility at Highway-Rail Grade Crossings"* by Amy Ellen Polk. This paper was originally presented at the California Public Utilities Commission's Annual State Railroad Meeting, held in San Diego, California, on August 13-17, 2001.

12.2.1 Guidestar In-Vehicle Warning System, Minnesota

This project was performed as a partnership between the Minnesota Department of Transportation, 3M Corporation, and Dynamic Vehicle Safety Systems. The system used wireless antenna that receives train detection information and transmits the information to approaching vehicles. The in-vehicle display alerted drivers using both visual and audible signals.

12.2.2 Baltimore Light Rail Transit "Second Train Coming", Maryland

This project, conducted by the Maryland Mass Transit Administration, includes a DMS that warns drivers and pedestrians of situations where a second train is approaching the crossing soon after an initial train has cleared the crossing. This project was funded by a grant from the Transit Cooperative Research Project of the TRB.

12.2.3 San Antonio AWARD, Texas

This project was conducted by the Texas Department of Transportation and was part of the San Antonio Metropolitan Model Deployment Initiative. Acoustic sensors and radar speed detectors were placed upstream of three locations near an intersection in San Antonio. These sensors detected the presence, length, and speed of trains approaching the crossings. The durations of blockage were calculated, and the predicted delays were then disseminated to travelers using DMS, the Internet, kiosks, and in-vehicle displays. Emergency service vehicles such as ambulances used the delay information to plan their routes in real-time.

12.2.4 Four-Quadrant Gate System, Connecticut

The Connecticut Department of Transportation tested a system that warns the engineer if an obstacle, such as a stopped vehicle, is blocking the crossing in time to bring the train to a complete stop. The particular crossing geometry made grade separation neither a feasible nor a cost-effective option. The Federal Railroad Administration and the Connecticut Department of Transportation funded the $1 million project.

12.2.5 Gary-Chicago-Milwaukee Corridor, Illinois

This is an in-vehicle warning system conducted by the Illinois Department of Transportation in partnership with a team lead by Raytheon and including Cobra Electronics, Calspan SRL, and the Metro Transportation Group as subcontractors. The advisory in-vehicle warning systems were installed in 300 vehicles, including school buses, emergency service vehicles (police, fire, EMCs), and commercial vehicles that regularly traverse the study area. The in-vehicle receiver was capable of operating in three modes: audible only, visual only, and combination audible/visual.

12.2.6 Los Angles Light Rail Transit "Second Train Coming," California

The Los Angeles County Metropolitan Transportation Authority tested a system that uses DMS to warn pedestrians in situations where a second train is approaching the crossing. This project was funded by a grant from the Transit Cooperative Research Project of the TRB. The system was tested at one crossing in Los Angeles, California.

12.2.7 Long Island Railroad, New York

The New York State Department of Transportation partnered with Alstom Signaling to develop an intelligent grade crossing that provides a constant 30-second warning time to drivers, regardless of the train’s speed or type, by activating both the crossings’ active warning signals as well as nearby DMS. A combination of conventional loop detectors and high-tech video-based sensors detected if a vehicle was stalled on the tracks, if traffic backed up onto the tracks, or if a vehicle was unable to exit the crossing area. The intelligent grade crossing system could turn the traffic signal lights to green, allowing vehicles to exit the crossing, thus clearing the queue from the crossing. If the crossing was blocked for any reason, a signal was sent to the locomotive engineer in time to stop the train, or slow the train down as much as possible, before it reached the crossing. A back-up system that was equipped with positive train control could also stop or slow the train automatically if necessary. If an equipped emergency vehicle needed to cross the tracks, it could send a message via wireless communications to the intelligent grade crossing. The intelligent grade crossing then caused the train to safely brake prior to the crossing, if the train's speed and distance allowed. Otherwise, the request was denied until the train had passed. The intelligent grade crossing minimized gate down times therefore making operation of the signal system more reliable to drivers. DMS displays included "Train Approaching," "Crossing Delay," "Exit Lane Blocked," and "Train in Station".

12.3 Benefits

Preliminary findings from the evaluation of an in-vehicle warning system in Illinois show that, although test participants recommended several human factor improvements, the system was helpful in focusing drivers' attention to the presence of an on-coming train. Simulation of the AWARD system installed in San Antonio estimated that incorporation of information on crossing blockages into traveler information and traffic management efforts results in modest (16 – 19 percent) decreases in travel time delay for affected motorists. The tests of "second train warning" signs in Maryland and California showed a dramatic reduction in risky behavior of drivers (36 percent) and a modest reduction in risky behavior of pedestrians (14 percent). (Source: *"The Use of ITS to Improve Safety and Mobility at Highway-Rail Grade Crossings"* by Amy Ellen Polk, presented at the California Public Utilities Commission's Annual State Railroad Meeting, held in San Diego, California, on August 13-17, 2001.)

12.4 Cost

The following are the estimated unit costs for these market packages:

Table 12.1 – Estimated Costs for ATMS13, ATMS14, and ATMS15
(Railroad Grade Crossing Management Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Rail crossing Four-Quad Gates/Signals		20	115 – 130	4.25 – 4.85
Rail Crossing Train Detector	Two-track crossing with two 0.5 mile communications	20	16.0 – 21.5	0.77 – 1.03
Rail Crossing Controller		10	8.0 – 10.0	0.4-0.5
Pedestrian Warning Signal/Gate		20	10 – 15	0.2 – 0.3
Trapped Vehicle Detector	Including poles/controllers	10	25 – 30	1.25 – 1.5
Central Software		5	18 – 22	1.8 – 2.2
Integration		20	90 – 110	
Labor				50

12.5 Implementation, Operation, and Maintenance Issues

Advanced railroad grade crossing management implementations are still in the experimentation stages. Limited deployments of these technologies currently exist. More research and testing is needed.

HRI ITS standards are currently being deployed. Standards are essential to the success of integrating new technologies in HRI.

Innovative financing must be found and coordinated. In addition, railroad companies will assist in investing in ITS technologies if their exposure to liability is lessened.

Applications of ITS technologies to railroad crossings are expected to be beneficial in both rural and urban areas. Many crossings in rural areas are passive. Passive crossings may become much safer using ITS technologies that communicate directly to vehicles from the roadside.

High levels of technology reliability are required for this market package. Any new technology chosen must meet fail-safe tests.

Inter-jurisdictional cooperation is required between traffic management, railroad management, railroad companies, and emergency management.

13. Parking Facility Management / Regional Parking Management (ATMS16 and ATMS19)

13.1 Overview

The Parking Facility Management Market Package provides enhanced monitoring and management of parking facilities. The equipment included assists in the management of parking operations, coordinates with transportation authorities, and supports electronic collection of parking fees by collecting current parking facilities' status data and sharing the data with ISPs and TMCs.

The Regional Parking Management Market Package supports coordination between parking facilities to enable regional parking management strategies.

Parking management systems can be divided into two types of systems: Parking Guidance Information Systems and Electronic Parking Payment Collection/Enforcement Systems.

Parking Guidance Information Systems provide information about parking availability to drivers. Several such systems are available in the market and have been implemented in the United States and abroad. Electronic Parking Payment Collection/Enforcement Systems utilize AVI equipment to allow vehicle operators to pay parking tolls without stopping their vehicles and without the use of cash. For enforcement purposes, AVI equipment, vehicle classification sensors, and height detectors are used to restrict access to the parking facilities to certain types of vehicles, certain vehicles, or certain drivers. Equipment such as tags, smart cards, and LPRs can be used for AVI.

13.2 Parking Guidance Information Systems

Parking Guidance Information Systems provide parking availability information to drivers. They consist of central hardware/software, surveillance, communications, and information dissemination subsystems. These systems monitor the supply of parking spaces and provide tools for managing parking demand by providing directions to available parking spaces. The results are more efficient use of parking space, reduced delay in the time spent searching for parking, and reduced delays to the surrounding transportation network.

Parking availability information is typically presented as a status, such as "Full", "Number of Spaces Available," "Closed," and "Almost Full". Additional information that may be provided includes the type of parking facility, directional arrows, regulatory information, and operational information.

Parking Guidance Information Systems can be for a single facility or for a regional system. Regional systems support coordination between parking facilities to enable regional parking management and information dissemination strategies. This allows communications and coordination between equipped parking facilities and also supports regional coordination between parking facilities and traffic and transit management systems. Information including current parking availability, system status, and operating strategies can be shared to enable parking facility management that supports regional transportation management strategies.

Parking Guidance Information Systems require equipment that counts the number of vehicles entering and exiting the parking facility and, depending on the requirements and design of the system, the number of vehicles within the facility. Vehicle counts could be collected using a detection technology such as inductive loops or a non-intrusive vehicle detection technology. The counts could also be obtained by counting the parking facility gate openings or the number of people with parking toll tags or smart cards. Detection technologies that are not capable of counting slow moving vehicles, such as Doppler Microwave Radar, are not suitable for Parking Guidance Information Systems.

A controller unit is generally required to calculate the number of available parking spaces and transmit the information to the central computer. The controller unit could be a controller unit manufactured by the Parking Guidance Information System vendor, Type 170 controller and cabinet, a personal computer-based interface, or custom equipment manufactured by some other vendor.

In general, Parking Guidance Information Systems use a combination of static signs and DMS to disseminate information to motorists regarding the availability of parking spaces. Various DMS technologies have been used including fiber optic, LED, and prism. Other information devices, such as HAR, trailblazers, and ATIS, may be used in lieu of or in combination with DMS.

Parking Guidance Information Systems normally utilize personal computers at the central location, although some systems operate using a mini-computer at the center. A typical installation of the central hardware includes an off-the-shelf personal computer equipped with a keyboard, mouse, and color monitor. Additional hardware is required to provide communications with the parking facilities and, possibly, with other TMCs in the region.

The central software provides several functions. These functions include transmitting messages to DMS, monitoring equipment status, modifying operation parameters, the programming/ retrieving/modifying of DMS messages, receiving counts from parking facilities, recommending appropriate DMS messages, providing database management functions, providing various types of reports, and providing real-time displays of system conditions.

Various communications technologies can be used to transmit information between the parking facilities and the parking management center and between the center and other transportation centers in the region. These include leased telephone services, twisted pair cable, fiber optic cable, and wireless technologies.

The following are sample Parking Guidance Information Systems:

- SIEMENS/EAGLE’s Parking Guidance System;
- DAMBACH Parking Guidance System;
- Infotonic Girod Parking Guidance System;
- AM Sign Corporation Parking Management System;
- Secom International Parking System; and
- Toshiba Advanced Car and Parking System.

13.3 Electronic Parking Payment Collection/Enforcement

Electronic payment collection/enforcement systems allow automatic payment of the parking fee without the need for stopping and without the need for cash payment. In addition, these systems allow the automatic control of access to parking facilities by allowing only authorized vehicles or certain classes of vehicles to access the facilities. Systems are also available to assist enforcement agencies in their parking meter monitoring efforts.

Electronic payment collection/enforcement systems have the potential to reduce queues and delays at parking lot entrances and exit lanes by increasing the lanes’ service rates. In addition, these systems have the potential to reduce fee collection costs and enhance audit control by centralizing user accounts. Finally, the systems can provide better and less costly access control and enforcement of parking facilities.

In general, an electronic payment collection/enforcement system consists of some or all of the following components: an AVI system, central computer software/hardware, vehicle classification sensors, parking meter space monitoring devices, and a communications subsystem.

Electronic parking fee payment and electronic access control of parking facilities utilize AVI equipment similar to the equipment utilized for ETC. For electronic fee payment, the AVI technologies allow vehicle operators to pay tolls without stopping their vehicles and to pay for parking without the use of cash. Equipment such as tags and debit/credit cards can be used. LPR systems can also be used for this application. For electronic access control, the AVI technologies are used to restrict access to the parking facilities.

Various vehicle classification sensor types can be used to restrict the entrance of certain classes of vehicles to a parking facility. These can also be used to determine the fee for each vehicle depending on the vehicle class.

A communications system is used between the parking lot equipment and a central computer, located either in the parking lot facility or in the parking management center. In addition, communications links might be used between the central computer and financial institutions in the case of EPS.

The functions of the central software/hardware depend on the type of the electronic payment collection/enforcement system. In the case of EPS, the central computer enables automatic processing of financial transactions and external coordination with other institutions/agencies. In the case of parking access management, a central computer can be used to update and manage a database of authorized vehicle identifications and transmit this information to the field.

As stated above, transponders similar to those used for highway ETC or smart cards can be used for parking toll collection. Below is a review of some of the products that support ETC parking and access enforcement:

- Amano-Cincinnati, Inc.;
- McGann Software Systems, Inc.;
- Identity handsFree;
- The Confident System;
- The Amtech System;
- The Nortech Autotag System;
- Denso System; and
- Pearpoint Access Control System, which uses license plate readers.

ETC vendors reviewed in Section 9 also provide equipment suitable for parking management applications.

13.4 Benefits

In a survey conducted in Leeds, U.K., it was found that approximately 70 percent of drivers were aware of the existence of parking information systems and that at least one-sixth of drivers had used the system at least once. In Nottingham, U.K., it was found that 63 percent of drivers were aware of a radio-based parking information system.

In Frankfurt, awareness of a parking guidance system after three months of operation was found to be 80 percent. It was estimated that at any given time, 20 percent of the motorists trying to park would be using the system to help them find a space. (Source: Axhasen, K.W. et al., "*Effectiveness of the Parking Guidance Information System in Frankfurt AM Main*," a report prepared by the University of London for Transportation Studies and the Transport Studies Unit, University of Oxford.)

13.5 Cost

The following are the costs estimated for parking management.

Table 13.1 – Estimated Costs for ATMS16 and ATMS19
(Parking Facility Management/Regional Parking Management Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Entrance/Exit Detection		10	2 – 5	0.2 – 0.5
Tag Readers		10	2 – 5	0.2 – 0.5
Billing/Pricing Software		10	10 – 15	1 – 2
Parking Monitoring System		10	14 – 46	
Hardware	Central hardware	5	2 – 11.5	0.2 – 1.15
TMC to Parking Facility	DS3	20	3 – 5	24 – 72
Parking to Financial	DS0	20	0.5 – 1	0.6 – 1.2
Parking to ISP	DS1	20	0.5 – 1	4.8 – 8.2

The costs above do not include the costs of parking information dissemination devices such as DMS.

13.6 Implementation, Operation, and Maintenance Issues

Several of the issues discussed for the ETC and Information Dissemination Market Packages are also applicable to this market package.

14. Reversible Lane Management (ATMS17)

14.1 Overview

This market package provides for efficient management of reversible lane facilities. In general, this market package includes the technologies that were discussed in the Freeway Management Market Package for freeway lane control management. However, it also includes technology requirements that are specific to reversible lane management.

14.2 Products/Services

As with other types of dynamic mainline control, reversible lane management uses lane-use control signs, hydraulically or electrically controlled lifting gates, pop-up delineators, movable lane barriers, and surveillance technologies. However, special consideration should be given when selecting ITS technologies for reversible lane management applications, as discussed below.

In addition to standard surveillance capabilities, this market package requires sensory functions that detect wrong-way vehicles. In addition, any technology used for traffic surveillance must be able to detect traffic on the reversed lane and shoulder. This is important because some detection technologies must be installed facing traffic. Such technologies are not appropriate for reversible lane operation.

Enforcement cameras could be used to identify violators. Based on this identification, the system needs to be able to take the appropriate action in response to a violation.

Reverse lane operations require an extensive barricade plan to close ramps for prevention of wrong-way movements. The arrangement of the barricades to close either the upstream or the downstream end of a ramp must effectively discourage wrong-way movements. The arrangement of the barricades must also force a driver to consciously maneuver around the barricades.

The MUTCD mandates certain colors for raised pavement markings relative to driving direction. The raised pavement markings are beneficial in low light and inclement weather conditions. However, the use of regular raised pavement markings is not adequate in the case of reversible lane operation. If white raised pavement markings are displayed to drivers in the contra-flow direction, this action will violate MUTCD requirements. Switchable (on/off and different color) LED raised pavement markings could be used to address this concern.

Comprehensive static and dynamic signing plans are needed for reversed lane operation. The location and content of these signs must be carefully determined to serve the operation of the reversed lanes at all times.

When selecting DMS technology and locations for reversible lane applications, it is important to consider the sign visibility for vehicles that use the reversible lane in both directions of travel. In particular, fiber-optic and LED signs have a very narrow cone of vision. If the number of lanes is increased in a given direction, the signs might not be legible to the vehicles on the outside lane, especially when the roadway has a divided median.

14.3 Benefits

Reversed lane operations, if carefully designed, can increase the freeway capacity in the peak direction by more than 2,000 vehicles per hour per lane.

14.4 Cost

The following are the costs estimated for reversible lane management:

Table 14.1 – Estimated Costs for ATMS17
(Reversible lane Management Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Gates	Per location	20	125	2
DMS	Per location	20	60	3
Loop Detectors (double set)	Per location	5	7	0.7
Wireline to DMS (0.5 mile up station)		20	7	
Software and Hardware On-Site		20	35	
Software and Integration		10	200	
Central Hardware		5	5	
DS1 Communications		20	1	7
Controller Software Upgrade		5	40	
Maintenance			12	12
Labor				100

14.5 Implementation, Operation, and Maintenance Issues

Careful consideration should be given to the benefits of reversed lane operation. Although the capacity of the freeway mainline might increase at certain locations, integrated system-wide analysis might indicate that the increase in throughput might generate a bottleneck downstream of the reversed lane section. The bottleneck could be at the freeway mainline, ramps, or surface streets. In this way, a problem can be created that is more serious than the original problem. Traffic analysis, including demand forecasting and simulation modeling, will be able to identify these problems and determine solutions to address these problems.

The design of the system should ensure safety and prevent wrong-way movements to the maximum degree possible. Reconfiguration of ramp and intersection operations will be required.

Coordination between state and city agencies, enforcement, and ISPs are needed. Public education campaigns are needed to describe the concept to the public and ensure user acceptance and understanding of the system.

15. Road Weather Information System (RWIS) (ATMS18)

15.1 Overview

This market package monitors current and forecasted road and weather conditions using a combination of weather service information and data collected from environmental sensors deployed on and about the roadway. The collected road weather information is monitored and analyzed to detect and forecast environmental hazards such as icy road conditions, dense fog, and approaching severe weather fronts. This information can be used to more effectively deploy road maintenance resources, issue general traveler advisories, and support location specific warnings to drivers using the Traffic Information Dissemination and Traveler Information Market Packages. Weather information collection and management was expanded into two new market packages in the *NIITSA, Version 4.0*, to provide a more complete view of this area.

Several transportation agencies around the country provide weather-related roadway conditions to motorists over the telephone. These telephone services either provide the information for the whole region or for the specific route selected by the caller using an automatic menu. The messages are either prerecorded by a live operator or are provided using computer speech synthesis technology. Most of the information is gathered from maintenance crews that either call the information center with information or enter the information in a database that is accessible from the center. Transportation agencies that operate these systems have indicated that during bad weather conditions, they receive thousands of calls and normally, under these conditions, the number of calls exceed the system capacity by several folds.

15.2 Products/Services

15.2.1 Surface Systems, Inc.

Surface Systems, Inc., is by far the largest producer of ice detection systems in the United States, having sensors in 33 states and 100 percent of the market share at airports. The Surface Systems, Inc., in-pavement detector, SCAN, measures temperature, determines whether the road surface is wet or dry using capacitive techniques, and measures conductivity to determine salinity which indicates the freezing point and amount of chemicals already on the roadway. The data is combined either at the roadway site or at a central computing center with information from a remote weather station to provide the user with information on road freezing conditions.

15.2.2 System Innovations, Inc.

The weatherScene product by System Innovations, Inc., provides temperature, baraometric pressure, wind speed, direction, and visibility. A traffic monitoring passive acoustic unit provides count and speed. Sensors in the pavement provide road temperature, wet/dry conditions, ice/snow, and chemical de-icing information. Other capabilities can be added including water depth and flow.

15.2.3 Climatronics

This sensor, called Frensor by Climatronics, provides an output of pavement temperature and conditions, accurate to plus/minus 0.5 degrees Centigrade.

15.2.4 Vaisala

This is a UK-based company that produces several weather sensor products including wind sensors, present weather and visibility sensors, ice warning and prediction products, rain detectors, and humidity and temperature probes.

15.2.5 1Nu-Metrics RTWIN

RTWIN is a wireless traffic and weather monitoring system that combines wireless in-road traffic monitors, on-site weather sensors, and video that continuously collects and reports information to the center. The system uses spread spectrum communications and Solar or AC power.

15.2.6 MeteoStar

MeteoStar Point Data Collection System provides data collection using standard modems, wireless Internet, radio modems, and satellites. The system can be delivered in conjunction with MetroStar LEADS software to enable ingest and processing of a complete range of inputs including local sensors plus WMO data and system-based sensors such as radar and lightning systems. The system can be delivered with an intranet server.

15.2.7 Coastal Environmental Systems

Coastal Environmental Systems produces weather detection instruments and integrated traffic control devices. Surface sensors report on the surface conditions, detecting ice, snow, rain, etc. The system also monitors other parameters, including the speed of traffic. Based on these conditions, the system can determine the speed limit to suit the existing conditions.

15.2.8 North and South Dakota Weather Forecasting System

The system was initially developed by the University of North Dakota for use in North and South Dakota, and was recently expanded into Minnesota and Montana. The system uses current technologies in weather forecasting, weather analysis, telecommunications, and road condition monitoring to produce a weather information system.

While weather observations provide valuable information to the traveler, there is a need for a system that provides forecasted conditions for a later segment of the travel path, particularly in rural areas. The FHWA funded this research to evaluate and demonstrate how current technologies can be used to produce precise spatial and temporal weather information that can be integrated into an ITS for safer and more efficient operations. The system merges technologies from meteorology, computer science, wireless telecommunications, road weather monitoring, and forecasting into a single decision support system.

Information used in weather forecasts are gathered from the National Weather Service, the Federal Aviation Administration, radio transmitting wind speed sites, upper air observations sites, North Dakota Agricultural Weather Network, University of North Dakota Department of Atmospheric Sciences, polar orbiting weather satellites, and private sector lightning detection networks via the Internet. In addition, information from a roadway and road surface condition observation system (SCAN by Surface Systems, Inc.) was used to obtain air temperature, relative humidity, precipitation, and road surface temperature.

The system has an interface to a computer telephony system that provides road condition information to callers using interactive voice response (IVR) systems. This system is referred to as #SAFE traveler information system. Cellular companies in the region offer the service free to their customers, with the majority of the companies dropping airtime fees as well.

15.2.9 FORETELL Field Operational Test

FORETELL is a multi-state initiative covering the Upper Mississippi Valley region funded in part by the FHWA. The mission of the FORETELL field operational test is to create a RWIS fully integrated within a wider set of ITS services to enhance safety and facilitate travel throughout North America. FORETELL collects, forecasts, and distributes highly specific road weather information that is pertinent to highway and trucking professionals, transit operators, everyday commuters, long-distance travelers, and all other road users.

15.2.10 Highway Closure and Restriction System

The Arizona Department of Transportation developed the highway closure and restriction system, which allows construction and maintenance offices throughout the state to input roadway closure or restriction information. Every five minutes, the highway closure and restriction system compiles data from multiple databases regarding roadway closures, accident/incident information, weather information, and construction activities. The information is then disseminated through the Internet, by telephone or via touch screen kiosks.

15.3 Benefits

In a major urban area, a one-day shutdown due to heavy snowfall can cost tens of millions of dollars. Approximately 7,000 people per year lose their lives and 450,000 people incur injuries during adverse weather conditions. Over 17 percent of all fatal crashes occur during severe weather conditions. Of these, 60 percent happen in rural areas.

An automatic fog-signaling system was implemented in the Netherlands. Based upon the visibility distance calculated, a speed limit is set for the roadway. The system was found to result in an additional decrease of about 5 to 6 MPH in speed and a slight reduction in the standard deviation of speed.

A preliminary evaluation of the safety benefits of the #SAFE roadway conditions traveler information system discussed in Section 15.2.8 above indicates very promising initial results. The results indicate a drop in property damage, injury, and fatal weather related crashes in South and North Dakota.

15.4 Cost

The following are the unit costs associated with the market package.

Table 15.1 – Estimated Costs for ATMS18
(Road Weather Information System Market Package)

Item	Description	Lifetime (years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Flood Warning Detectors		20	42	0.4
Visibility Sensors		10	20	0.3-0.6
Roadside Weather Station		25	10-50	1.9-4.1
DS0 Communications			0.5-1.0	0.6-1.2
Software		20	25	0.4-2.5
Central Hardware		5	7	
Labor				50

15.5 Implementation, Operation, and Maintenance Issues

Hundreds of ice detection systems have been installed in the United States and throughout the world. However, some transportation agencies are still concerned with the reliability of these systems and their liability if an erroneous message is given to the public. In many cases, maintenance crews use the ice detection systems to determine when and where to apply chemicals or salt to the roadways to prevent icing.

Information from different sources needs to be combined to provide a better decision support system for road weather management and information dissemination. There is a need to build consensus at the local, regional, and national levels to strengthen the relationship between meteorologists and transportation professionals. In addition, coordination is required within state and local transportation agencies, such as between maintenance and travel management offices.

There is a need to develop practices to optimize system operation. Outreach and training activities of maintenance personnel are essential.

Procedures need to be established to collect data from the meteorological community in a format that is conducive for further processing to obtain information tailored for road operations.

Economic gains from deploying such systems must be evaluated. Such gains will lead to privatization efforts of the systems and partnerships with the private sector.

16. Traveler Information (ATIS1, ATIS2, ATIS7)

Three traveler information equipment packages are discussed in this section. These packages are the Broadcast Traveler Information, Interactive Traveler Information, and Traveler Service Yellow Pages and Reservations Market Packages.

16.1 Broadcast Traveler Information

This market package provides the user with a basic set of ATIS services; its objective is early acceptance. It involves the collection and dissemination of traffic conditions information, advisories, general public transportation information, toll and parking information, incident information, and air quality and weather information. This information is disseminated using a wide-area broadcast communications medium.

This market package is different from the Traffic Information Dissemination Market Package, which provides the more basic HAR and DMS information dissemination capabilities. The dissemination of information using DMS or HAR is effective and popular but has limitations. Information updates might not be available where and when they are needed for a particular trip. In addition, the disseminated information might not be relevant to all trips. The Broadcast Traveler Information Market Package allows the supply of a large quantity of continuous real-time data that, when combined with intelligent receivers, can be presented in many formats.
This market package consists of:

- Central equipment that allows the collection, processing, viewing, and dissemination of travel information;
- Communications systems for information dissemination; and
- Technologies that are used for presentation of information to travelers.

The market package relies on other market packages, such as the Network and Probe Surveillance Market Packages, to gather traffic information.

Traveler information systems distribute information using several communications technologies. The most widely used are wireless broadcasts (such as FM subcarriers and cellular data broadcasts), electronic data lines to remote terminals, and telephone advisory messages.

Collecting traffic data has historically been the task of public authorities although private firms distributing traffic information to radio and television stations often use their own means to collect the data. The growing trend is to fuse the public sector data with the value-added private data/services and disseminate it from a central point.

The equipment that can be used for information presentation to travelers can be classified into:

- **Personal Basic Information Broadcast** – This equipment package provides the capability for travelers to interface with the traveler information center and receive formatted traffic advisories in their homes, places of work, major trip generation sites, personal portable devices, and over multiple types of electronic media, such as facsimile machines, portable AM/FM radios, pagers, and personal computers.

- **Remote Basic Information Broadcast** – This equipment package provides the capability for travelers to interface with the traveler information center and receive formatted traffic advisories at remote locations using devices such as kiosks.

- **Basic Vehicle Reception** – This equipment package provides the capability for travelers to interface with the traveler information center and receive formatted traffic in their vehicle, such as an in-vehicle AM/FM radio with data subcarrier and perhaps connected to a dash-mounted display.

16.2 Interactive Traveler Information

This market package provides tailored information in response to traveler requests. Both real-time interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on a submitted profile are supported. The traveler can obtain current information regarding traffic conditions, transit services, ride-share/ride-match, parking management, and pricing information. A range of two-way wide-area communications systems may be used to support the required digital communications between traveler and ISP.

The traveler can access information prior to a trip or en-route using a variety of interactive devices including:

- Remote Traveler Support Equipment, such as interactive television and kiosks;
- Personal Information Access Equipment, such as cellular telephones, interactive televisions, personal computers, and pagers with alpha displays; and
- In-vehicle equipment.

16.3 Traveler Services Yellow Pages and Reservations

This market package enhances the Interactive Traveler Information Market Package by making infrastructure provided yellow pages and reservations services available to the user. In general, traveler services refer to non-traffic related information describing characteristics and locations of traveler services. This information may be in a static database or a dynamic database, where information on rates and availability is constantly updated. Traveler services information is often provided in combination with the information on traffic conditions provided by the interactive traveler information.

Further information may include the location, operating hours, and availability of services such as parking, auto repair shops, and hospitals and police facilities. It may also include information regarding recreational landmarks, restaurants, special events, camping information, hotels, and other relevant areas of tourist activity. Information pertaining to various modes of transport can also be provided including air, sea, and rail transportation.

The same interactive traveler information user equipment can be used in this market package. As with interactive trip information, multiple ways for accessing information can be used either while en-route in a vehicle using wireless communications or pre-trip via wireline connections. Travelers can access the data from home, work, shopping centers, airports, and other locations through a variety of ways including the Internet, interactive telephone, television, and other means.

16.4 Traveler Information Products/Services

This section provides descriptions of some of the ATIS products available in the market.

16.4.1 The Internet

Travelers in many cities in the United States can now access real-time traffic information via the Internet. Most of these sites have been designed in collaboration with local transportation authorities or nationwide traffic information providers. The information is usually displayed on a map, color-coded to identify network speeds, congestion levels, or incident locations. In addition, some of these sites include CCTV photographs, updated as frequently as every few seconds, but more commonly every few minutes. Detailed information regarding incidents could be available, including an incident description, status report, and estimated duration. A few sites also offer trip-planning tools, such as travel-time estimation and route planning for any given origin and destination in the local traffic network. Most sites supplement this information with road construction updates and critical link conditions.

16.4.2 Information Kiosks

Advancements in interactive kiosk technology have resulted in an increase in speed, ease of use, and reduction in costs. These devices have been used to provide information about traffic and transit, including real-time traffic conditions, real-time transit information, transit route planning, ride-sharing, special events, weather information, airline schedules, and other information. Many kiosk projects are funded through public agencies. However, some kiosk projects are owned and operated by private agencies. Private agencies have relied on advertising as the revenue source.

16.4.3 Traffic Station Personal Traffic Advisor

This is a subscription service that allows users on the move to call in 24-hours a day for route specific reports. In addition, the users can fill a profile of daily and commonly used routes and they will then be alerted about unexpected conditions that affect their travel via the Internet, digital television, telephone, wireless phones, pagers, personal digital assistants (PDAs), and palm personal computers.

16.4.4 Traffic Master In-Vehicle Traffic Alert

This family of products by Trafficmaster is a range of simple in-vehicle receivers that help drivers steer clear of traffic congestion. This is done by alerting the driver of slow moving vehicles up to 15 miles, or two junctions, ahead of the congestion. The system uses a global system for mobile (GSM) communications telephone service to deliver local reports based on vehicle location. The service is available in Britain and is being extended to Germany.

16.4.5 Traffic Master Speech-Based System

These are portable and integrated speech-based systems that receive information from UHF beacon technology. The system interrupts the vehicle's audio system to provide live location specific reports. The service is available in Britain and is being extended to Germany.

16.4.6 Etak Traffic Touch

Etak Traffic Touch delivers up-to-the-minute notifications of adverse traffic conditions for defined routes and areas via palm personal computers. Etak charges a subscription fee of 16 cents a day for the service.

16.4.7 Etak Traffic Check Television Program

Traffic Check provides viewers with data that is relevant to them as soon as the information becomes available. It offers detailed descriptions and maps locations for each reported incident. Speed data is provided where available. The option is given to carry customized real-time information to specific parts or to the overall broadcast service area. Traffic Check may also be incorporated in Internet sites. Currently, the system is available in five major cities in the United States.

16.4.8 SmartRoute SmartTraveler System

This system allows individuals to be called, paged, or e-mailed with personalized traveler information. The system is operated in several major cities around the country.

16.4.9 OracleMobile by SmartRoute and Oracle Corp.

OracleMobile will provide access to the SmartTraveler system information using the wireless Internet market. OracleMobile will give access to twenty leading Internet sites.

16.4.10 SmartTravelerTV by SmartRoute

SmartTravelerTV provides a cable television program containing accurate, route-specific traffic, transit, and weather information that is broadcast continuously to keep travelers up-to-date about their commutes. The program is transmitted live from the local SmartTraveler operations center.

16.4.11 AT&T PocketNet Phone

This is a cellular telephone with cellular digit packet data digital service that includes a web browser supported by Unwired Planet. With it, users can receive alerts and query routes set up using Traffic Angel or they can view traffic situations by region in various cities.

16.4.12 TrafficNet by Cue

Cue provides real-time traffic information in 30 markets across North America. The service is delivered to the Clarion AutoPC as well as through a variety of handheld devices including CUE's traffic pager. The service is real-time and route-specific, permitting the customer to filter out traffic information that is not related to a specific commute.

16.4.13 PathFinder by VODAVI

The system uses speech recognition to connect a person with a central computer database via a telephone. The system provides real-time traffic management information, weather conditions, electronic toll renewals, and personalized route information.

16.4.14 General Motors OnStar

The General Motors' OnStar offers traveler services in addition to personal safety and security. The system utilizes wireless communications and GPS satellite technology. The General Motors' OnStar service is being offered on the majority of the General Motors' fleet. Drivers may contact an OnStar Center "Advisor" using a voice-activated cellular phone for traveler service information. Examples of these services include locating the nearest gas station, making hotel and restaurant reservations, and getting theater tickets. In addition, OnStar provides services such as system diagnostics, remote door entry and alarm control, and immediate "mayday" service when an accident occurs.

16.5 Traveler Information Systems Projects

The following are examples of operational tests that include interactive traveler information equipment:

- **Atlanta Kiosk** – This project included 140 computer systems in kiosks located in public locations. The kiosks display traffic information from the ATMS and transit schedule and status information from the Metropolitan Atlanta Rapid Transit Authority's Transit Information Center. The kiosks also display information from the Atlanta Traveler Information Showcase server, airlines, the Weather Channel, the Atlanta Regional Commission, and the Georgia Department of Industry, Trade and Tourism. Most of the original kiosks are currently operational.

- **Minnesota Genesis Project** – Incidents, congestion, and planned events were broadcast to commercially available pagers and PDA users in a portion of the Twin Cities in Minnesota. This operational test ended in January 1996.

- **Seattle Wide-Area Information for Travelers (SWIFT)** – SWIFT provides travel information via FM subcarrier high-speed data systems to travelers equipped with digital watches, in-vehicle devices, and personal computers. The system uses a FM subcarrier network developed by Seiko Communications Systems, Inc. Receivers can tune to any properly equipped station in the existing FM broadcast band, eliminating the need for special frequencies to deliver traveler information.

- **San Francisco Bay Area TravInfo** – TravInfo provides a free public service of real-time traffic information through a telephone line. Data is also disseminated in a digitized form through both a modem-based landline data server and FM subcarrier-based wireless data broadcast systems. Private ISPs provide additional traveler information services.

- **Minnesota Trilogy** – The Trilogy operational test provided real-time travel information about network conditions to a sample of commercial delivery fleets, bus transit operators, and private citizen commuters. Although the project has ended, a radio broadcast, a cable television broadcast, and a web page continue to distribute real-time data.

- **Atlanta Driver Advisory Service** – The Atlanta Driver Advisory Service was designed to provide traveler information, including congestion, incidents, weather, sports scores, current movies, traveler services, in-vehicle signing, and two-way messaging. The project provided information to 170 specially equipped vehicles in the Atlanta, Georgia, metropolitan area.

- **Driver Information Radio Experimenting with Communications Technology (DIRECT)** – The DIRECT test evaluated several low-cost methods of communicating traveler information to motorists in the Detroit, Michigan, metropolitan area.

- **SmartTraveler** – SmartTraveler is an ATIS project in the Boston area that was developed by public and private entities. The project delivers real-time, on-demand, location-specific traffic and transit information to travelers. Information is disseminated through the telephone using a toll-free number.

- **Yosemite Area Traveler Information System** – This system provides current information about facilities, activities, traffic, and weather for a five county region containing and surrounding the Yosemite National Park. The Yosemite Area Traveler Information System utilizes a communications network consisting of a large database made available through in-vehicle computer systems, where tourists can obtain current information on traffic and weather conditions, as well as the status of transportation and recreational facilities throughout the entire Yosemite region.

16.6 Benefits

Surveys performed in Seattle and Boston indicated that when provided with traveler information, 50 percent of travelers would change route of travel and 45 percent would change travel time. Additionally, five to ten percent of travelers would change travel mode based on traveler information.

In London, studies indicate that 38 percent of callers to a computerized route planning system change their routes based on provided real-time information.

The ARTIMIS project in north Kentucky and Cincinnati, Ohio, offers a phone information service. More than 99 percent of the users surveyed said they benefited from the system by avoiding congestion. Sixty-five percent said they would be willing to pay for the traveler information services.

The Genesis project in Minneapolis, Minnesota, delivered incident information via alphanumeric pagers. Sixty-five percent of the users reported using the services daily. When users became aware of incidents, they chose alternate routes of travel in 42 percent of the situations. Users reported discovering incident information more than half of the time via pager versus 15 percent of the time via radio or television.

In Martin County, California, a commuter survey indicated that 69 percent of the respondents stated they would divert, saving an estimated 17 minutes each, if pre-trip information with the best routes were provided to them.

During the development of the *NITSA*, a simulation study predicted travel time savings of eight to twenty percent for congested conditions due to the use of traveler information systems. For traffic conditions not quite congested, the predicted travel time savings were seven to twelve percent.

16.7 Cost

The costs required at the Transit Information Center include the following:

Table 16.1 – Estimated Costs for the Transit Information Center for ATIS1, ATIS2, and ATIS7
(Traveler Information Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Basic Facility, Communications			3200	400 – 800
ISP Hardware	Two servers, five workstations	5	40.5 – 49.5	0.81 – 0.99
System Integration		20	90 – 110	
ISP Software	COTS database and traffic analysis software	20	275 – 550	13.75 – 27.5
Map Database Software	COTS	2	15 – 30	630 – 770
FM Subcarrier Lease/Year				120 – 240
ISP Labor	Staff of three			175 – 250
ISP Hardware Upgrade for Interactive Information	Two workstations / one server	5	18.9 – 23.1	0.38 – 0.46
ISP Software Upgrade for Interactive Information	Trip planning software	20	250 – 500	12.5 – 25.0
Added Labor for Interactive Information	One staff			50 – 75
Yellow Pages Workstations	Two	5	18.9 – 23.1	0.38 – 0.46
Automated Reservations	Software	20	100 – 200	8 – 16
Labor	One staff			50 – 75
Yellow Pages Database Software		20	250 – 500	8 – 16
Communications	Two DS0 and one DS1	20	1.5 – 3	6 – 10.6
Communications Upgrade for Interactive Information	DS1	20	0.5 – 1	4.8 – 8.4
Communications Upgrade for Yellow Pages	DS0	20	0.5 – 1	0.6 – 1.2

The costs associated with a kiosk at a remote location is:

Table 16.2 – Estimated Costs for Remote Location Kiosks for ATIS1, ATIS2, and ATIS7
(Traveler Information Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Information Kiosk		7	10 – 50	1 – 5
Kiosk Integration with Systems		7	2.2 – 27.4	12.5 – 25.0
ISP to Kiosk	DS1	20	0.5 – 1	4.8 – 8.4
Kiosk Upgrade to Interactive		5	5 – 8	0.5 – 0.8

The costs associated with personal information access devices include:

Table 16.3 – Estimated Costs for Personal Information Access Devices for ATIS1, ATIS2, and ATIS7
(Traveler Information Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Basic PDA		7	0.25 – 0.45	0.005 – 0.008
Advanced PDA for Interactive		7	0.50 – 0.75	0.010 – 0.015
Modem and Antenna for PDA		7	0.18 – 0.25	0.004 – 0.005
PDA with Wireless Modem	Software is COTS	5	1.33	
Software Upgrade for Interactive		7	0.10 – 0.20	0.002 – 0.004
GPS / DGPS		7	0.50 – 0.80	0.025 – 0.04
GIS Software		7	0.10 – 0.15	0.005 – 0.0075
Wireless Communications				0.18 – 0.2
Monthly Payment for Interactive	To ISP			0.06 – 0.12

The costs associated with in-vehicle equipment include:

Talbe 16.4 – Estimated Costs for In-Vehicle Equipment for ATIS1, ATIS2, and ATIS7
(Traveler Information Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
In-Vehicle Display		7	0.005 – 0.1	0.001 – 0.002
Communications Equipment		7	0.2 – 0.4	0.004 – 0.008
Interactive Software and Hardware		7	0.10 – 0.15	0.06 – 0.12
Wireless Communications				0.18 – 0.2
Monthly Payment for Interactive				0.18 – 0.2

16.8 Implementation, Operation, and Maintenance Issues

User responses to using pre-trip traveler information systems have been generally positive. Drivers generally appreciate receiving traffic information that gives them a chance to make decisions regarding their travel behavior as long as they perceive the information to be accurate, timely, and inexpensive. However, it has been found that where real-time pre-trip and en-route traveler information exists, many people are still unaware of its existence and its potential benefits. Thus, there is a need to better advertise deployed ATIS services.

Successful deployment of this market package relies on the availability of real-time traveler information from roadway sensors, probe vehicles, and/or other sources. The overall effectiveness of the system depends more on the timeliness and usefulness of the information provided than on the technology delivering it. Information that is unreliable or inaccurate will not be beneficial to the public and could ultimately undermine the credibility of the system. Procedures must be in place to ensure information quality. Guidelines must be established to determine what conditions are reported to travelers and the acceptable levels of reliability. Standard protocols should be developed for defining and describing traffic conditions and locations to achieve consistency.

The use of E-911 cellular phone location identification for travel time estimation may provide a low cost alternative for data collection. This will most likely have a significant effect on ATIS deployments and the desire of the private sector to be involved in ATIS projects.

ATIS has the potential of including public and private sectors. This usually requires the use of public-public and public-private partnerships. A business plan should be developed for ATIS systems to define the target market, define the information to be collected, determine how to distribute the information, determine the fund sources and fund use, and estimate the costs of doing business. The business plan should also describe the business structure, goals and risks/rewards in the market, and prove that good business opportunities exist. The business plan must be flexible and consider the regional needs and technologies.

A large number of public and private agencies could participate in ATIS projects. Most likely, these agencies have different views regarding the ATIS project. It is important to recognize the differences and create a decision-making process that accounts for these differences.

As stated above, the existence of an infrastructure to collect the required data for ATIS is an important issue in ATIS development. Some private partners might be willing to provide their own monitoring techniques to meet the needs of their customers.

Several legal issues are associated with ATIS projects' business plans. The lead public agency must determine if it has the legal authority to undertake the desired actions. Also, it is important to determine if the mixture of public and private actions and relationships are legal. Some of the legal/administrative issues to be addressed are the distribution of money, intellectual property rights, and who will have access to the information and how.

Other issues include the views of the political leaders toward privatization, the opinion of area citizens and leaders on potential ATIS-related goals (e.g., social equity and equal access to information), and the level of technical expertise in the public sector.

A business relationship needs to have its own formal agreement, such as a memorandum of understanding (MOU) or a contract. There are several models for structuring the business plans for ATIS projects. These models differ in who performs the consolidation/fusion of information, who pays for that, and who provides the information to the public.

The ATIS market packages are generally market driven. Their advancement will most likely depend on how much users are willing to pay for them. An uncertain profit estimate has constrained private investment in ATIS businesses.

Households are increasingly connected to the Internet. Thus, providing reliable and timely information through the web will continue to be an important part of any ATIS deployment.

There have been safety concerns associated with the use of cellular telephones while driving. Further research is needed to address these concerns and determine standards for safe use of in-vehicle information devices.

17. Route Guidance (ATIS3, ATIS4, ATIS5, and ATIS6)

17.1 Overview

Route guidance systems can be autonomous (static) device-based systems, dynamic device-based systems, or dynamic ISP-based systems. Below is a discussion of these systems.

17.2 Autonomous Route Guidance (ARG)

This market package enables route planning and detailed route guidance based on static, stored information. No communication with the infrastructure is assumed or required. Identical capabilities are available to the traveler outside the vehicle by integrating a similar suite of equipment into portable handheld devices. This market package relies on in-vehicle sensors, location determination, computational equipment that calculates the shortest path between two points, map databases, and interactive driver interface equipment. This market package consists of the following equipment:

- The Personal ARG Equipment Package provides ARG in the absence of real-time information. It does not factor information provided by the infrastructure into its route selection and guidance algorithms. Handheld navigators are currently available in the market.

- The Vehicle ARG Equipment Package provides route planning and turn-by-turn route guidance. It provides ARG in the absence of real-time information and does not factor information provided by the infrastructure into its route selection and guidance algorithms. Some systems can be operated by voice commands and include speech interfaces that read directions and describe points of interests.

- The Vehicle and Personal Location Determination Equipment Package determines current vehicle or personal location information utilizing such technologies as GPS, dead reckoning, and/or map matching technologies.

Many car manufacturers around the world are offering or planning to offer static route guidance as an option in their cars. Examples of these products are listed later in this section.

17.3 Dynamic Route Guidance (DRG)

This market package offers the user advanced route planning and guidance, which is responsive to current conditions. The package combines the Personal ARG User Equipment Package with a digital receiver capable of receiving real-time traffic, transit, and road condition information. The user equipment considers this information when providing route guidance.

This market package includes the same equipment included in the ARG Market Package. In addition, it includes the basic travel broadcast equipment package described above to broadcast the real-time information required for DRG.

DRG systems are available in the market. Traffic information can be received using cell-based or broadcast communications technologies.

17.4 ISP-Based Route Guidance

This market package offers the user advanced route planning and guidance that is responsive to current conditions. Different than the DRG Market Package, this market package moves the route planning function from the user device to the ISP or the TIC. This approach simplifies the user equipment requirements and can provide the infrastructure better information regarding travelers' planned origins, destinations, and routes on which to predict future traffic. In addition, it allows route diversion and control strategies which optimize system as well as user performance. The package includes both en-route and pre-trip route guidance. The package includes two-way data communications and optionally also equips the vehicle with the databases, location determination capabilities, and display technology to support turn-by-turn route guidance.

This market package consists of the following equipment:

- The Infrastructure-Provided Route Selection Equipment Package provides specific directions to travelers by receiving origin and destination requests from travelers, generating route plans, returning the calculated plans to the users, and then potentially logging the route plans with the Traffic Management Subsystem. This capability is provided using equipment such as a workstation type processor and software for route planning and traffic measurements along with additional communications capabilities including dialup lines, personal communications system (PCS) telephones, and wireless data transceivers. This equipment shall have, as a prerequisite, the capabilities of the interactive infrastructure information.

- The In-Vehicle Provider Equipment Package coordinates with an ISP-based route planning service to select a suggested route plan that is tailored to the driver's preferences. Coordination continues during the trip so that the route plan can be modified to account for new information and vehicle probe data can be returned to the ISP. Many equipment configurations are possible including basic systems that provide only a route plan to the driver as well as systems that include the necessary on-board equipment to provide turn-by-turn route guidance following the selected route.

- The Personal Guidance Equipment Package coordinates with an ISP-based route planning service to select a suggested route plan that is tailored to the traveler's preferences using personal handheld equipment. Coordination may continue during the trip so that the route plan can be modified to account for new information. Many equipment configurations are possible including systems that provide a basic route plan to the traveler as well as more sophisticated systems that can provide transition by transition guidance to the traveler along a multi-modal route plan.

- The Remote Interactive Information Reception Equipment Package provides the capability for travelers to interface with the ISP Subsystem Infrastructure Equipment Packages including Interactive Infrastructure Information, Infrastructure-Provided Route Selection, Yellow Pages and Reservations, and Dynamic Ridesharing. These capabilities shall be provided using the Remote Traveler Support Subsystem equipment, such as interactive television and kiosks, and communications media and equipment, such as CCTV and wireline and wireless data transceivers.

- As with DRG systems, the Personal and Vehicle Location Determination Equipment Package’s required business models and dynamic route assignment models for route guidance are in the development stages. Furthermore, it relies on large amounts of accurate real-time data that do not currently exist.

17.5 Integrated Transportation Management/Route Guidance

This market package allows a TMC to continuously review and optimize a traffic control strategy based on near real-time information on intended or provided routes for a proportion of the vehicles within their network. The market package also offers the user advanced route planning and guidance, which is based on forecasted conditions taking into consideration current transportation management strategies. The market package would utilize the individual and ISP route planning information to optimize ramp metering and signal timing while at the same time providing updated signal timing information to allow optimized route plans. Recent advancements in real-time dynamic traffic assignment models such as Dynamit and DynaSmart will support this market package.

17.6 Route Guidance Products/Services

Below are examples of route guidance products.

17.6.1 Lexus Navigation System

The Lexus autonomous navigation system is available on the LS 400, GS 400, and GS 300. It provides directions to 400,000 nationwide points of interest and directs drivers to their destinations, turn by turn. The system offers touch-screen scrolling, allows zooming in and out, and includes voice guidance. Up to 100 desired destinations can be programmed and stored in the system.

17.6.2 Sumitomo Electric VICS/ATIS

Sumitomo Electric produces a system that can be used as an instrument-based autonomous or DRG system. The DRG system can receive information using various transmission media (infrared, radio beacon, and FM multiplex). The navigation system combines map-matching, GPS, gyroscope, and speed sensors. The system also includes a CD-ROM with information on points of interests.

17.6.3 American GMC Corporation Navigation Systems

The in-vehicle navigation system uses a combination of GPS and independent vehicle navigation modes. The personal palm navigator uses a GPS sensor embedded in the palm navigator. An optimal route planning and selection function is integrated in the navigator.

17.6.4 Odyssey by InfoGation Corporation

Odyssey offers GPS satellite tracking and a NAVTECH map database with points-of-interest. Traveler voice commands operate most functions. Speech interface reads direction. Odyssey operates on the Clarion AutoPC with the Windows CE operating system.

17.6.5 Magellan 750NAV by Magellan

This ARG system includes directions to street addresses and points of interests. The system uses GPS satellite tracking combined with vehicle independent positioning and map matching.

17.6.6 TravRoute

This system by TravRoute is an ARG system that covers all of the United States at both the street and highway levels. Highway level details are also included for Canada and Mexico.

17.6.7 Hitachi VICS

This dynamic navigation system can use a number of communications methods for transmission. These include radio-wave beacons that cover a narrow communications area and use radio waves, infrared beacons that cover a narrow communications area, and light and FM multiplex broadcasts that cover a wide communications area and use FM multiplex and FM broadcasting.

17.6.8 BIRDVIEW Navigation by Nissan

Nissan provides an autonomous and instrument-based DRG called "BIRDVIEW." The system has a unique display that adopts a viewpoint above and behind the vehicle and presents a field of vision extending all the way to the horizon. The system is available on DVD-ROM in Japan, allowing higher speed access, more searchable data, and more realistic displays. Nissan has expanded BIRDVIEW to North America and Europe. The system can offer DRG by providing real-time information using FM multiplex broadcasts and roadside optical and radio beacons.

17.6.9 Ali-Scout System

The Ali-Scout system is an ISP-based route guidance system that was developed in Germany. It consists of three components: a central system, a roadway beacon network, and an in-vehicle navigation unit. The central system maintains a digital database of the transportation network, as well as a set of profile tables that contain the link travel times for each link in the database. Separate profiles exist for weekdays and weekends. Each profile is divided into five-minute intervals. Ali-Scout accumulates the travel times collected by probe vehicles over time, weighing recent data more than older ones. Ali-Scout then uses this information to compute the fastest route for each vehicle. The system has the capability to predict the traffic conditions in the immediate future (e.g., the next five minutes) and can use these predictions to estimate the fastest routes.

17.6.10 Trafficmaster System

The system uses GSM communications cell broadcast to transmit live traffic information to a vehicle-based DSG system. The broadcast includes predictions of link travel time for the next hour to allow for better guidance. The system is a standard feature on the Jaguar 'S' type. The system is available in Britain and will be available in Germany.

17.6.11 VDO Dayton

The system uses GPS signals to determine vehicle location. The integrated electronic compass and electronic tachometer provides additional data for the system. The system uses a Road Data System-Traffic Message Channel to deliver real-time information to drivers. Drivers enter their destinations and the system provides pictographic or map display and spoken instructions. The system can include CD-ROMs with detailed navigation information for Europe, the United States, Canada, and Australia.

17.7 Route Guidance Projects

Instrument-based dynamic traffic guidance projects include:

- **TravTek** – This system provided traveler information to 100 specially equipped vehicles in the Orlando area. Each in-vehicle system had a two-way communications link to the operation centers via a hands-free cellular phone. The vehicles were configured three ways: providing yellow pages information only, providing added route guidance and planning capabilities, or including all services and navigation features plus display of real-time traffic information and route-planning around congestion. The in-vehicle systems, loaded with databases, featured a navigation map showing all roads in a five-county, 1,200 square mile area as well as an American Automobile Association (AAA) Florida Tourbook and Orlando tourist information on hotels, restaurants, attractions, and special events. Touch-screens allowed drivers to do everything from searching for Italian restaurants to mapping the route from Orlando's airport to their hotels. Once a specific system was selected, the system automatically calculated the best and fastest route to that destination, factoring in real-time traffic conditions.

- **Advance Driver and Vehicle Navigation (ADVANCE)** – This project demonstrated the use of an in-vehicle ATIS in the northwest suburb of Chicago. The system provided drivers with a fast route to their destination over the arterial streets using an in-vehicle route guidance system. The system provided route guidance using a static database of travel times and dynamic information on traffic conditions. The operational testing took place in 1995 using 30 vehicles.

An example of an ISP-based dynamic traffic guidance system is:

- **FAST-TRAC** – This operational test in Oakland County, Michigan, combines the Ali-Scout DRG system, a traffic information management system, and the SCATS adaptive signal control system. One hundred (100) beacons were installed and 500 volunteer drivers participated in the operational test. The overall feedback of the route guidance system was very positive.

17.8 Benefits

The Pathfinder operational test consisted of an in-vehicle navigation system with real-time traffic information. An evaluation of the system indicated that drivers more likely to divert increased by 40 percent with Pathfinder.

TravTek consisted of DRG in Orlando, Florida. Thirty-eight percent of TravTek rental car users found the device helpful in finding their destinations, as did 63 percent of local drivers. Compared to a control test in which drivers used standard printed road maps to find their way, TravTek was shown to reduce travel time by 19 percent and to reduce the number of accidents involving tourists.

A simulation study estimated twelve, five, and two percent reductions in hydrocarbonsa, carbon dioxide, and nitrogen dioxide emissions when 50 percent of the vehicles are equipped with route guidance.

In Japan, instrument-based DRG systems reduced travel time by 15 percent.

17.9 Cost

No central equipment is required for the ARG. For the instrument-based DRG, only the basic and interactive traveler information is required at the center. The following are the costs at the center associated with the ISP-based DRG Market Package. This market package also requires the central interactive and basic traveler information equipment. The costs for the traveler information market packages are presented below.

Table 17.1 – Estimated Center Costs for ATIS3, ATIS4, ATIS5, and ATIS6
(Route Guidance Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Map Database Upgrade for ISP Route Guidance	Two workstations/one server	2	100 – 200	
ISP Software Upgrade for ISP Route Guidance	Route selection software	20	250 – 500	12.5 – 25.0
Added Labor for ISP Route Guidance	One staff			50 – 75

The costs associated with remote access using kiosks are estimated as follows:

Table 17.2 – Estimated Costs for Remote Access Kiosks for ATIS3, ATIS4, ATIS5, and ATIS6
(Route Guidance Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Kiosk Upgrade to Interactive		5	5 – 8	0.5 – 0.8

The costs associated with personal access devices include:

Table 17.3 – Estimated Costs for Personal Access Devices for ATIS3, ATIS4, ATIS5, and ATIS6
(Route Guidance Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Advanced PDA for Interactive		7	0.50 – 0.75	0.010 – 0.015
Software Upgrade for Interactive		7	0.10 – 0.20	0.002 – 0.004
GPS/DGPS		7	0.50 – 0.80	0.025 – 0.04
Wireless Communications				0.18 – 0.20
Monthly Payment	To ISP			0.12 – 0.18
GIS Software		7	0.10 – 0.15	0.005 – 0.0075

In addition, the costs associated with in-vehicle equipment include:

Table 17.4 – Estimated Costs for In-Vehicle Equipment for ATIS3, ATIS4, ATIS5, and ATIS6
(Route Guidance Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
In-Vehicle Navigation		7	0.05 – 0.10	0.001 – 0.002
Processor		7	0.2 – 0.4	
Wireless Communications		7	0.25 – 0.50	0.18 – 0.20
Monthly Payment	To ISP			0.12 – 0.18

Note: Costs associated with equipment required for the interactive traveler information at the center, remote access, and personal access are not included in the tables above.

17.10 Implementation, Operation, and Maintenance Issues

The implementation, operation, and maintenance issues discussed in Section 16 for other ATIS are also applicable to these market packages.

DRG systems have come under fire recently in the United Kingdom. Local authorities with responsibility for surface street networks are concerned that wide use of these systems will lead to a massive displacement of traffic off main roads and onto arterial streets, often residential routes. To address this problem, the DRG systems should consider the highway class, vehicle class, and the effect on adjacent streets of the diversion.

DRG systems have been implemented only recently. Information about user acceptance and compliance with the information as functions of user class, trip type, trip length, congestion level, information dissemination devices and information accuracy still needs to be studied.

The effects of market penetration on the system and user travel times need to be assessed. Dynamic traffic assignment models that take into consideration near-term forecasts of traffic flow are in the deployment stage. The efficiency and suitability of these models for real-time route guidance applications are still to be tested.

18. In-Vehicle Signing (ATIS9)

18.1 Overview

This market package supports distribution of traffic and travel advisory information to drivers and customers through in-vehicle devices. It includes short-range communications between roadside equipment and the vehicle and wireline connections to the Traffic Management Subsystem for coordination and control.

Signing may include audio and/or video signage. A combination of signage (i.e., both audio and video) can be provided to support the Americans with Disabilities Act (ADA) requirements for the hearing and visually impaired.

18.2 Products/Services

In-vehicle signing products have begun to appear in the market. One of these products is the roadside data information system by Transintel Corporation. The system provides easy-to-read on-board display units with audio and visual alerts. The information provided by the system includes:

- Electronic traffic signs including speed limits, lane controls, and low clearance;
- Advisory information including rest areas, service plazas, and points of interest; and
- Real-time safety alerts including road conditions, detours, and accident information.

Another system is an Italian system called the Deep View system by Easy Drive s.r.l. The system is based on a network of radar and infrared sensors installed on the road, detecting and tracking all moving vehicles. During low visibility conditions, the system provides warnings of stopped vehicles, objects, or tailbacks. A simple and easy-to-read console delivers messages to motorists.

18.3 Benefits

The benefits of in-vehicle signing have not been quantified yet. However, it is expected that these systems will increase safety, particularly in bad weather conditions.

18.4 Cost

The *NITSA* estimated the unit costs of the roadside equipment required for the in-vehicle signing market package to be around $1000.

18.5 Implementation, Operation, and Maintenance Issues

The in-vehicle signing devices started to enter the market only recently. Thus, there is limited experience with these devices. Issues that need further investigation include safety, reliability, liability, regulations, human factors, and standards.

19. Emergency Management (EM1, EM2, EM3, and FL EM4)

19.1 Overview

Emergency management services improve the response time to emergencies, thereby saving lives and reducing property damage. In the *NITSA*, Emergency Management is classified into three market packages: the Emergency Response, Emergency Routing, and Mayday Support Market Packages. Florida has also identified the additional Evacuation Management Market Package.

19.2 Emergency Response

The Emergency Response market package provides the computer-aided dispatch systems (CAD), emergency vehicle equipment, and wireless communications that enable safe and rapid deployment of appropriate resources to an emergency. Coordination between Emergency Management Subsystems supports emergency notification and coordinated response between agencies.

The Emergency Management Subsystem includes hardware and software for tracking emergency vehicles. Public safety, traffic management, and many other agencies may participate in the coordinated emergency response. Wide-area wireless communications will be utilized between the Emergency Management Subsystem and emergency vehicles to enable an incident command system to be established and supported at the emergency location.

Most emergency response agencies use CAD systems to effectively manage their fleet resources. AVL devices are being used by some agencies to supplement their CAD systems. The use of CAD, AVL, and geographic information systems (GIS) will support emergency vehicle fleet management and allow more efficient use of resources.

19.3 Emergency Routing

This market package supports dynamic routing of emergency vehicles and coordination with the Traffic Management Subsystem for special emergency vehicle priority on the selected route(s). The ISP Subsystem supports routing for the emergency fleet by providing real-time traffic conditions and possibly optimal routes assigned to the vehicles. An example of the dynamic emergency vehicle route guidance systems is the system produced by NEC Corporation in Japan. The market package also supports signal preemption. Local signal preemption is the most widely used type of emergency routing equipment. Below are examples of available signal priority systems. These same technologies can be used for freeway control preemption.

- **Opticom Priority Control System by 3M** – This system uses high-energy infrared technology to grant authorized vehicles momentary right-of-way at signalized intersections.

- **STROBECOM II Modular Optical Preemption System by Tomar Electronics, Inc.** – This is an optical preemption system.

- **EMTRAC Spread Spectrum Preemption System by Econolite Control Products, Inc. –** This is a microprocessor-based spread spectrum radio-controlled system with a patented line of radio receivers and transmitters.

- **SONEM 2000 Traffic Signal Priority Support System by Sonic Systems Incorporated** – This preemption is activated when microphones at the intersection detect the vehicle's siren (frequency and period). The system is capable of identifying a vehicle's siren in all three standard modes – yelp, wail, and high/low.

- **EPS-II Digital Siren Detection System by Emergency Preemption Systems, Inc. –** The EPS-II is a siren (waveform) activated traffic signal preemption system. It has been engineered to recognize the frequency and pattern unique to each make and type of siren.

19.4 Mayday Support

Mayday Support allows the user (driver or non-driver) to initiate a request for emergency assistance and enables the Emergency Management Subsystem to locate the user and determine the appropriate response. The Emergency Management Subsystem may be operated by the public sector or by a private sector provider. The request from the traveler needing assistance may be manually initiated or automated and linked to vehicle sensors. The data is sent to an EMC using wide-area wireless communications with voice as an option.

The technologies that are required for this market package include location determination, cell-based and fixed communications, and driver and traveler interfaces. These technologies are mature with rapid innovation. Mayday support systems could be mobile or fixed. Fixed systems include motorist aid call boxes. Examples of mobile mayday support systems are the systems being developed by the General Motors Corporation (the On-Star system), Ford, NEC Corporation, Denso Wireless, Nissan Corporation, and Matsushita Communication Industrial.

Some of the functions supported by the On-Star system include automatic notification of air bag deployment, emergency services, roadside assistance, stolen vehicle tracking, accident assistance, remote door unlock, parked vehicle location determination, remote service diagnostics, and hands-free communications. Most of the systems allow automatic, voice, or emergency reporting with the touch of a button.

Accurate incident locations are obtained through AVL technologies such as GPS. E-911 location technologies will become available (see below) in the near future and will play a major role in mayday systems. Below is a discussion of the E-911 requirements.

In 1996, the FCC adopted rules to stimulate the application of wireless technology to improve E-911 systems. The rules require wireless carriers not just to deliver 911 calls to emergency dispatchers, but also to provide E-911 service, which includes reporting the location of the emergency call. The E-911 requirements were divided into two phases. Phase I requires wireless carriers to deliver the telephone number of the handset originating a 911 call and the location of the cell site or base station receiving the 911 call to the designated Public Safety Answering Point (PSAP). Phase II requires carriers to deliver more specific latitude and longitude location information to the PSAP.

In the *E-911 Third Report and Order* issued in 1999, the FCC revised its rules to allow emerging handset-based location technologies to compete with network-based technologies. The FCC established a separate set of accuracy and deployment requirements applicable to handset-based solutions. Handset-based solutions are held to tighter accuracy requirements (165 feet for 67 percent of calls, 500 feet for 95 percent of calls) but are allowed to be phased-in over time, as new or upgraded handsets are put in service, until full deployment is reached. Network-based solutions (which provide ALI for all handsets, not simply those that are ALI-capable) are allowed to meet a less stringent accuracy requirement (330 feet for 67 percent of calls, 1000 feet for 95 percent of calls).

19.5 Evacuation Management

This market package was identified for the coordination needs of traffic demand during hurricane evacuations. There are no such user services in the *NITSA, Version 4.0*, so FDOT's Central Office decided to develop the user-identified Evacuation Management Market Package for Florida's needs. These services include:

- Evacuation Coordination;
- Emergency Management Coordination;
- Weather Information Applications;
- Intermodal Freight; and
- Work Zone/Construction Traffic Management.

- The Evacuation Coordination User Service was developed and added to the Emergency Management User Services. Following the same structure as the *NITSA*, user service requirements were developed to define system functions that are required to provide the Evacuation User Service.

19.6 Benefits

In Albuquerque, New Mexico, a map-based CAD system was installed to manage the ambulance company fleet. The system allows the dispatch center to send ambulances to the exact location of an emergency and provide guidance on how to get to that location. The system increased the company efficiency by ten to fifteen percent.

In Palm Beach County, Florida, emergency vehicle signal preemption was estimated to cut the response time by twenty percent.

Mayday systems provide an increase in the chance of crash survival, in addition to having an important effect on motorist's peace of mind.

It was found that an 8.45-minute reduction in response time could lead to an eleven percent reduction in fatalities.

19.7 Cost

The following are the unit costs associated with this market package:

Table 19.1 – Estimated Costs for EM1, EM2, and EM3
(Emergency Management Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Signal Preemption Receiver	Per intersection (two total)	5	2 – 8	0.05 – 0.20
Controller Upgrade		10	2 – 5	
On-Board Navigation		7	2.8	
On-Board Route Guidance		7	0.10 – 0.15	0.002 – 0.003
Communications Equipment		10	0.3 – 2.0	0.02
On-Board Display		7	0.05 – 1.00	0.001 – 0.002
EMC Basic Facility			3200	400 – 480
EMC Hardware	Three workstations	10	15 – 30	0.3 – 0.6
EMC Hardware		10	70 – 150	0.5 – 3.5
EM Labor				50 – 165
EM Communications		20	5 – 10	2.5 – 5.0

19.8 Implementation, Operation, and Maintenance Issues

Integration of emergency agency CAD system operations across jurisdictional boundaries should be investigated. This will be facilitated by the implementation of common location description standards and will require resolution of institutional issues. The integration can be time-consuming, difficult, and costly because current CAD systems are proprietary and interface standards have not yet been defined.

AVL system deployment is essential to fleet management. However, increased AVL implementation will require future reduction in system costs. In addition, there is a general dislike of such systems by organized labor.

In a field operation test of GPS-based AVL technology, this technology experienced difficulties in enclosed spaces or urban canyons. However, the increased availability of differential GPS and the recent elimination of selective availability are expected to significantly increase positional accuracy.

Mayday systems continue to be most common in more expensive vehicle models and in rental cars. More widespread use of these systems is needed to achieve their full potential.

Cellular communications have problems in areas with limited cellular coverage. However, cellular coverage is expanding around the country.

The mayday central hardware/software must have sufficient speed to deal quickly with multiple mayday calls. The system should be able to display streets, landmarks, bodies of water, and jurisdictional boundaries in the vicinity of incidents.

Traffic and emergency management agencies need continuous coordination with each other and an understanding of one another's resources. Common voice communications standards will facilitate emergency response.

Mayday devices, as with other AVL and AVI technologies, generate public privacy concerns. These concerns should be taken into consideration.

As stated above, the FCC has approved network-based and handset-based location technologies. A network-based solution may require access to information available only from the local carriers, complicating the ability of privatized mayday centers to obtain the information. However, with handheld technologies, the mayday center may be able to receive information directly from the phone.

20. Fleet and Freight Administration (CVO1 and CVO2)

20.1 Overview

The Fleet Administration Market Package keeps track of vehicle location, itineraries, and fuel usage with the Fleet and Freight Management Subsystem (carrier operation centers). The vehicle has an AVL system and a processor to interface with sensors that monitor vehicle operation (such as fuel gauge and brake) and to the wireless communications data link. The Fleet and Freight Management Subsystem can provide the vehicle with dispatch instructions and can process and respond to requests for assistance and general information from the vehicle via the wireless data link.

The Freight Administration Market Package tracks cargo and cargo conditions. This information is communicated to the Fleet and Freight Management Subsystem via wireless communications. Interconnections are provided to intermodal shippers and intermodal freight depots for tracking the cargo from source to destination.

20.2 Products/Services

The technologies that are used for the Fleet and Freight Administration Market Packages include:

20.2.1 Electronic Trip Recorders/On-Board Computers

These computers automatically monitor and record information on performance of vehicle engines, driving patterns, vehicle and driver hours of service, vehicle maintenance, arrivals and departures, loading and unloading times, and other functions.

20.2.2 Routing and Dispatching Systems

These include the computer hardware/software used to plan, optimize, and monitor load consolidation, vehicle routing and dispatching, backhauling, and other functions. The hardware and software associated with this market package are located in the Fleet and Freight Management Subsystem. Routing and dispatching systems could be based on static data or on a combination of dynamic and static data.

20.2.3 Automatic Vehicle Location (AVL)

This equipment enables real-time identification of a vehicle's location relative to a map. In general, it includes on-vehicle devices that use signals from satellites or from ground-based radio transmitters to obtain a vehicle's exact position and then transmit that information to the dispatcher.

20.2.4 Mobile Communications System

This communications system keeps the drivers in constant contact with their dispatchers and clients. It includes radios, cellular telephones, and text transmission/reception devices that allow drivers to communicate with each other, with dispatchers, and with customers. Leading-edge carriers provide large clients with direct access to their computers and provide automated menus and reporting for small clients.

20.3 Benefits

A survey of Maryland motor carriers found that over 36 percent of respondents felt that having information about traffic and road conditions is valuable.

A Scandinavian company uses GPS-based tracking of vehicles in combination with a remotely accessed on-board computer. The system reduced wasted mileage and emissions and resulted in a 15 percent increase in freight carried.

A study of real-time diversion of truckload carriers predicted an additional productivity improvement of six percent.

Additional evaluation results can be found in the ITS Benefits Database produced by the USDOT's JPO for ITS.

20.4 Cost

The following are the costs associated with the Fleet and Freight Management Market Packages.

Table 20.1 – Estimated Costs for CVO1 and CVO2
(Fleet and Freight Administration Market Packages)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Vehicle Location Interface		20	10	
Vehicle Tracking and Scheduling		20	60	6
Digital Communications	Three per FMS	5	1.1	
System Integration		20	400	
Communication to ISP, TMC, Payment Instrument, and Maintenance Facility	Cost depends on technology; assume leased DS0			0.6 –1.2
Workstation	One	10	5	
On-Board Trip Monitoring		10	2.0	0.05
Wireless Communications for Trip Monitoring				0.18
On-Board Cargo Monitoring		10	0.47	0.03
Wireless Communications for Cargo Monitoring				1.2

20.5 Implementation, Operation, and Maintenance Issues

A survey of commercial vehicle carriers indicates that mobile communications technologies are the most widely used fleet management technology, followed by routing and dispatching and on-board computers. AVL was the last prevalent technology. (*See "Commercial Vehicle Fleet Management and Information Systems,"* prepared for FHWA by Cambridge Systematics, Inc, and ATA Foundation Private Fleet Management Institute, October 1997.) In general, carriers' ITS investment decisions are influenced by several factors. These factors include the carriers' desire to maximize revenue per mile and trip, minimize unladen mileage, equipment availability, maximize equipment utilization, minimize fleet operating costs, driver availability, backhaul opportunities, drivers' hours-of-service limits, driver home time, importance of particular accounts, shipment origins and destinations, HAZMAT routing considerations, inventory management, pick-up and delivery times/dates, and size of shipments. It appears that each motor carrier's consideration of these factors drives its decision of investment in ITS.

Some carriers, especially the smaller companies, cannot afford to purchase ITS technologies. This is particularly true since the costs of many technologies are still high.

It appears that existing ITS technologies satisfy most if not all carrier needs. However, ITS technologies are dynamic and evolving. These technologies are becoming increasingly powerful. Two major growth areas in fleet and freight management are expected to be ATIS services for commercial vehicles and intermodal freight operations.

21. Electronic Clearance (CVO3)

21.1 Overview

This market package provides for automated clearance at roadside check facilities. The roadside check facility communicates with the Commercial Vehicle Administration Subsystem via wireline communications to retrieve infrastructure snapshots of critical carriers, vehicles, and driver data to be used to sort passing vehicles.

This package allows acceptable drivers/vehicles/carriers to pass roadside facilities at highway speeds using transponders and DSRC to the roadside. The safety status, credentials, and weights of the vehicles are checked to ensure that they are within acceptable limits.

21.2 Products/Services

21.2.1 Automatic Vehicle Identification (AVI)

Optical, audio, and other radio frequency technologies can be used for automated identification of vehicles. These systems were discussed in the ETC Market Package (ATMS10) section. DSRC is normally used for data transmission between commercial vehicles equipped with tags (transponders) and roadside readers. The tags normally include vehicle identifiers. It can also include prior screening information.

21.2.2 Weight-in-Motion (WIM)

WIM is used to measure approximate vehicle weight. This equipment is discussed in more detail in the WIM Market Package (CVO6).

21.2.3 Automatic Vehicle Classification (AVC)

AVC devices are used to classify vehicles based on their number of axles. These systems were discussed in the ETC Market Package (ATMS10) section.

21.2.4 Vehicle Tracking Loops

Inductive loops can be used to track vehicles as they proceed through the electronic screening site. This allows accurate signal indications for the approaching vehicle.

21.2.5 Automated Signing

This includes lane signals and DMS that deliver required messages to drivers. Roadside controllers automatically control these devices. Precise control and unambiguous displays are required to deliver the correct messages to drivers.

21.3 Benefits

Allowing safe and legal carriers to bypass without stopping can reduce congestion at weight and inspection stations. An evaluation of the Help/Crescent Project indicates reductions in tax evasion ranging from $0.5 to $1.8 million per year. Overweight loads could be reduced by five percent leading to a savings of $5.6 million annually. Operating costs for a weigh station could be reduced by up to $169,000, with credentials checking adding $4.3-$8.6 million and automated safety inspections adding $156,000 to $781,000 in savings due to avoided accidents per year.

Benefit to cost analyses found that the benefit to cost ratio of the market package is 4.8 to 7.2.

21.4 Costs

The following are the costs associated with this market package:

Table 21.1 – Estimated Costs for CVO3
(Electronic Clearance Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
On-Board Hardware		10	0.35	
On-Board Software		10	0.3	0.01
Wireless Communications		10		0.18
Communication to Enforcement and DMV	DS0		0.5 – 1.0	0.6 – 1.2
Communications to Government Administration and Planning	DS1		0.5 – 1.0	4.8 – 8.4
Central Processor and Integration		20	20 – 40	2
Additional Staff				75
Station Signal and Beacons		10	20 – 30	2
Station Structure		20	50 – 75	
Station Processor/Integration		10	200	4
Station Workstation			15 – 30	2
Communications		20	20 – 40	2

21.5 Implementation, Operation, and Maintenance Issues

Based on experience with this market package, it can be concluded that the deployment of electronic clearance is technologically feasible and the key components of this market package are available, mature, and being used by the motor carrier industry.

The institutional barriers involved in building ITS/CVO enforcement applications are greater than the technological problems. Key concerns include the lack of state and regional forums to bring together all the parties involved, the motor carrier industry's opposition to weight-distance taxes, and the need to protect the confidentiality of motor carrier business transactions.

The growth of Electronic Clearance is expected to continue. However, carrier enrollment is heavily dependent on solving interoperability issues between states and establishing the required level of uniformity between carriers. One issue that generates interest is establishing interoperability with other applications such as ETC. In addition, carriers are interested in operational interoperability between states including criteria to enroll and permit trucks to bypass weigh stations.

PrePass, NORPASS, and Green Light are three systems that provide electronic clearance services. The three systems use three different business models. PrePass uses private capital for system implementation then recovers costs through user fees per bypass. NORPASS uses state capital for implementation and charges an annual administration fee. Green Light is constructed and administrated by the Oregon Department of Transportation and offered to users at no charge. One issue under discussion is whether there is a need for a single business plan among all states.

22. CV Administrative Processes (CVO4)

22.1 Overview

This market package provides for electronic application, processing, fee collection, issuance, and distribution of CVO credential and tax filing. Through this process, carriers, drivers, and vehicles may be enrolled in the electronic clearance program provided by the CVO3 Market Package, which allows commercial vehicles to be screened at mainline speeds at commercial vehicle check points (see Section 21.0). Through this enrollment process, current profile databases are maintained in the Commercial Vehicle Administration Subsystem and snapshots of this database are made available to the commercial vehicle check facilities at the roadside to support the electronic clearance process.

22.2 Products/Services

22.2.1 Applicant Software

Carriers/Applicants' software allows a motor carrier to enter credentials applications and send the applications to the state credentials interface. The software also processes the responses coming from the credentials interface.

The FHWA has sponsored the concept of software packages that can perform the above functions. This package is called the Carrier Automated Transmission (CAT) system. The original concept of the CAT requires the use of the American National Standards Institute's (ANSI) X12 Electronic Data Interchange (EDI) standards. However, the use of the emerging extensible markup language (XML) standard instead of the EDI standards is allowed.

States in the CVISN Model Deployment initiative are currently sponsoring the development of websites for credentials, applications, and responses.

22.2.2 State Software

Commercial products are available that can support different credentialing activities such as the International Registration Plan (IRP), International Fuel Tax Agreement (IFTA) registration and tax filing, oversize and overweight permitting, HAZMAT permitting, and route planning.

States participating in the CVISN Model Deployment Initiative are working with commercial product vendors to enhance their systems to support open interface standards and new operational concepts.

22.3 Benefits

State agencies will be the primary beneficiaries of this market package. Minnesota reports that it has been able to reduce its workforce from more than 25 people to nine due to the implementation of the market package. An analysis performed in Maryland indicates a benefit to cost ratio of 1.93:3.

Private carriers will also benefit from this market package. The benefits were estimated for private carriers in labor costs for administrative compliance functions per vehicle as follows (*Source: ATA Foundation, Assessment of Intelligent Transportation Systems/Commercial Vehicle Operations Users Service: ITS/CVO Qualitative Benefit/Cost Analysis, June 1996*):

- Small fleet size (1-10 units): $83;
- Medium fleet size (11-99 units): $55; and
- Large fleet size: (>99 units): $22.

22.4 Costs

The followings are the costs to commercial vehicle administration agencies.

Table 22.1 – Estimated Costs for Commercial Vehicle Administrative Agencies for CVO4
(CV Administrative Process Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Wireless Communications		5	0.5 – 1.0	
Electronic Credential Purchase Software		20	20 – 40	
Post-Trip Processing Database Management		20	40 – 100	1.2
Processor and Integration		20	200	4
Workstations		10	15 – 30	0.3
Communications to Roadside and Financial Institution	DS0	20	0.5 – 1.0	0.6 – 1.2
Communications Lines to Freight Management	DS1	20	0.5 – 1.0	4.8 – 8.4
Additional Staff	Four			300

The costs to freight management include:

Table 22.2 – Estimated Costs for Freight Management for CVO4
(CV Administrative Process Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Wireless Communications		5	0.5 – 1.0	
Electronic Credential Purchase Software		20	20 – 40	
Database Management		20	60 – 140	1.2
Processor and Integration		20	215	4
Workstations		10	15 – 30	0.3
Communications Lines to Data Loading	DS1	20	0.5 – 1.0	4.8 – 8.4
Additional Staff	Four			300

22.5 Implementation, Operation, and Maintenance Issues

Maryland, Virginia, and Kentucky successfully implemented this market package. Technical challenges are associated with integrating new applications (such as SAFER, CAT software, and web applications) with legacy systems (such as licensing, insurance, fee payment, and invoicing).

As stated above, two standards can be used for data transmission: EDI or XML. Decisions must be made on which of the two standards to use. EDI is well established while XML is more appropriate for web applications.

Another decision to be made is whether to use specialized computer programs like CAT or web applications. It appears that multiple solutions including these two, as well as paper-based systems, will be needed for this market package.

Building in-house technical capabilities has been a challenge facing many agencies that want to implement these systems. There is a shortage of qualified personnel familiar with the systems.

Although end-to-end IRP and IFTA processing had only a limited deployment, it holds promise for significant cost savings to states and carriers. However, challenges and costs associated with connection to legacy systems need to be resolved. Key technology challenges include developing and implementing communications standards and protocols and establishing uniform identifiers for motor carriers, vehicles, and drivers.

Institutional barriers need to be considered for this market package. These barriers include the lack of support from top leadership of affected agencies and the motor carrier industry, the lack of coordination among agencies, and the lack of uniform regulations and policies across states.

23. International Border Electronic Clearance (CVO5)

23.1 Overview

This market package provides for automated clearance specific to international border crossings and ports of entry to the United States. This package augments the electronic clearance package by allowing interfaces with customs-related functions and permitting required entry and exit from the United States.

The market package can be used by government agencies such as customs and immigrations to check compliance with import/export and immigration regulations. With this market package, these agencies, as well as carriers and service providers, are able to generate and process the entry documentation necessary to obtain release of vehicles, cargo, and drivers across international borders (or reports), report the results of the crossing event, and handle duty fee processing.

23.2 Products/Services

The products used for international border crossings can be classified into short-range systems and wide-area systems.

23.2.1 Short-Range Systems

Several technologies can be use for short-range communication between commercial vehicles and roadside systems (at port entrances or border crossings). These include laser systems, radio frequency tags, and smart cards. Laser technology has several disadvantages such as sensitivity to dirt and weather conditions and ease of forgery and is not recommended for this purpose.

Short-range communications technologies provide notification of the arrival and departure of transponder equipped commercial vehicles. The trip/load number stored on the transponder is transmitted to a central system for processing. The central system responses are written back to the transponder by the roadside system.

23.2.2 Wide-Area Systems

Wide-area systems transmit information to a communications node and then to the central system. These systems can be divided into land-based and satellite-based systems. Land-based systems include cellular and personal communications (PCS)-based systems and private mobile radio networks.

23.3 Benefits

A simulation study of a transponder-based system indicated that significant benefits would result from a full deployment of the system on the American/Canadian border. Trucks saved an average 66 percent overall in inspection time while the average time for autos in the system decreased 35 percent. On the Canadian side, time for trucks in the system was reduced by 40 percent.

A field operational test demonstrated the ability of ITS services to improve safe and legal border crossings between Detroit, Michigan, and Windsor, Ontario, Canada. The system identified and processed trucks, crews, cargo, and commuter vehicles quickly and facilitated electronic payment. A simulation study showed that the system could reduce time at the customs station by 50 percent.

23.4 Cost

Prerequisite equipment for this market package includes in-vehicle electronic clearance equipment (included as part of the Electronic Clearance Market Package), and the Fleet Management System equipment included as part of CV Administrative Processes. These costs are not included in the table below. The table below includes the additional costs required for the International Boarder Electronic Clearance Market Package.

Table 23.1 – Estimated Costs for CVO5
(International Border Electronic Clearance Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
CV Vehicle Detection		10	50 – 75	2.5 – 4.0
Station Signal and Beacon		10	20 – 30	1.3 – 2.0
Station Structure		20	50 – 75	
Station Processor and Integration		20	180 – 215	3.6 – 4.3
Workstations		10	15 – 30	
Wireline Communications to Beacon/Signal		20	20 – 40	
Communications	Two DS0		1.0 – 2.0	1.2 – 2.4
International Database Management Add-On			20 – 40	
Additional Processing and Integration			20 – 40	
Additional Staff	Two			150

23.5 Implementation, Operation, and Maintenance Issues

Given the critical nature of border crossing processing, additional requirements are associated with this market package to ensure reliability and security.

The deployment of border crossings will require the carriers' implementation of ITS technologies.

Adoption of some technologies will require institutional changes in adopting a single electronic inspection database and identification process. There will also be a need for a bi-national process.

24. Weigh-in-Motion (WIM) (CVO6)

24.1 Overview

This market package provides for high speed WIM with or without AVI attachment. Primarily, this market package provides the roadside with additional equipment, either fixed or removable. If the equipment is fixed, then it is thought to be an addition to the Electronic Clearance Market Package and would work in conjunction with the AVI and AVC equipment of the Electronic Market Package in place.

24.2 Products/Services

24.2.1 Bending Plate

These systems utilize plates with strain gauges bound to the underside. The system estimates the static load based on the measured dynamic load and calibration parameters. Bending plate WIM systems consist of one or two scales and two inductive loops. The scales are placed in the travel lane perpendicular to the direction of travel.

24.2.2 Piezoelectric Sensors

These sensors use Piezoelectric WIM systems to detect a change in voltage caused by pressure exerted on the sensor by an axle that is proportional to the axle's weight. By measuring the electric charge generated by the sensor, the dynamic load is obtained. The static load is calculated based on this dynamic load and by using calibration parameters. The typical system consists of at least one sensor placed in the travel lane perpendicular to the direction of traffic and one inductive loop.

24.2.3 Load Cell

These systems use a single load cell with two scales to detect an axle and weigh both the right and left side of the axle simultaneously. As a vehicle passes over the load cell, the system records the weights measured by each scale and sums them to obtain the axle weight. The typical system consists of the load cell and at least one inductive loop and one axle sensor.

24.3 Benefits

The benefits of this market package are discussed as part of the Electronic Clearance Market Package listed above.

24.4 Cost

Prerequisite equipment for this market package includes in-vehicle electronic clearance equipment (included as part of the Electronic Clearance Market Package). The costs of this equipment are not included in the table below. The table below includes the additional costs required for the WIM Market Package.

Table 24.1 – Estimated Costs for CVO6
(Weigh-in-Motion Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
WIM Load Cell – Fixed (Software Included)		10	10 – 15	1.0 – 1.5
Interface to Roadside Facility		10	4 – 6	
Wireline Communications (Local Line)		10	1 – 2	.1

24.5 Implementation, Operation, and Maintenance Issues

Issues associated with the Electronic Clearance Market Package are associated with this market package.

25. Roadside and On-Board CVO Safety (CVO7 and CVO8)

25.1 Overview

The Roadside CVO Safety Market Package provides for automated roadside safety monitoring and reporting. It automates commercial vehicle safety inspections at the Commercial Vehicle Check Roadside Element. The capabilities for performing the safety inspection are shared between this market package and the On-Board CVO Safety Market Package (CVO8). The basic option, directly supported by this market package, facilitates safety inspection of vehicles that have been pulled in, perhaps as a result of the automated screening process provided by the Electronic Clearance Market Package. In this scenario, only basic identification data and status information is read from the electronic tag on the commercial vehicle. The identification data from the tag enables access to additional safety data maintained in the infrastructure, which is used to support the safety inspection, and may also influence the pull-in decision if system timing requirements can be met. More advanced implementations, supported by the On-Board CVO Safety Market Package, utilize additional vehicle safety monitoring and reporting capabilities in commercial vehicles to augment the roadside safety check.

The On-Board CVO Market Package provides for on-board commercial vehicle safety monitoring and reporting. It is an enhancement of the Roadside CVO Safety Market Package and includes roadside support for reading on-board safety data via tags. This market package uses the same communications links as the Roadside CVO Safety Market Package and provides the commercial vehicle with a wireless link (data and possibly voice) to the Fleet and Freight Management and the Emergency Management Subsystems. Safety warnings are provided to the driver as a priority with secondary requirements to notify the Fleet and Freight Management and Commercial Vehicle Check Roadside Elements.

25.2 Products/Services

Today, many states use a variety of software applications for exchanging safety information electronically. These applications are discussed below.

25.2.1 State Central Systems

These systems include the Commercial Vehicle Information Exchange Window (CVIEW) and SAFETYNET systems. CVIEW is a state system that collects information from CV credentialing and tax systems and exchanges information with the state roadsides and with the SAFER system. CVIEW does on a state level what SAFER does nationally. It has the potential to consolidate safety, registration, taxation, and permit information. The SAFETYNET software is an automated information management system designed to assist motor carrier safety offices in monitoring the safety performance of interstate and intrastate commercial motor carriers.

25.2.2 State Roadside Systems

The ASPEN system is a system developed by FMCSA. ASPEN uses pen- and laptop-based computer software and communications for roadside driver/vehicle inspection. This system improves the accuracy and availability of inspection information. ASPEN executes on both portable pen-computers and police cruiser mounted laptops. The ASPEN inspection data can be transmitted to the state SAFETYNET system or to the SAFER Data Mailbox.

25.2.3 National Central Systems

The Motor Carrier Management Information System is the national system that consolidates and processes motor carrier safety data from sources throughout the United States. It operates on a mainframe computer at the Transportation Computer Center at USDOT headquarters in Washington, D.C. The Motor Carrier Management Information System provides many types of consolidated data and reports back to state and federal SAFETYNET systems, mostly by electronic means. Information from the Motor Carrier Management Information System is available to industry and the public via written request, a toll free number, or the Internet. The Motor Carrier Management Information System, via the SAFER system, supplies a carrier's identification and safety data to the ASPEN Inspection Selection System.

FMCSA has implemented the Performance Registration Information Systems Management system. The system links motor carrier information, including inspection information, with registration and licensing information.

25.2.4 On-Board Safety Monitoring

On-Board safety monitoring senses the safety status of a commercial vehicle (e.g., brakes, tires, alertness). This information is determined automatically at mainline speeds.

These tasks will be linked to the Society of Automotive Engineers' development of the J1939 vehicle "data bus" standard.

25.3 Benefits

A study by the Roads and Traffic Authority of New South Wales, Australia, estimated the benefit to cost analysis of roadside safety systems to be 2.5:1.0.

In Maryland, the overall benefit to cost ratio was estimated to be 3.17:4.83. The benefit to cost analysis was estimated to range between 1.41 and 1.66 for state agencies and between 6.49 and 10.71 for commercial motor carriers.

25.4 Cost

Prerequisite equipment for the Roadside CVO Safety Market Package includes roadside and in-vehicle electronic clearance equipment (included as part of the Electronic Clearance Market Package). The costs for this equipment are not included in the table below. The table below includes the additional costs required for the Roadside CVO Safety Market Package.

Table 25.1 – Estimated Costs for CVO7
(Roadside CVO Safety Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Citation and Accident Recording Adds-On		20	20 - 40	1
Handheld Safety Devices	Three per location	5	3 – 5	0.3 – 0.4
Roadside Vehicle I/F		20	0.5 – 1.0	
Wireless Communications to Handheld Devices		20	20 – 40	
Station Processor		20	20 – 40	0.8 – 1.6
Wireless Communications from Data Loading			1.2 – 1.8	
Safety Administration Database			23 – 40	
Software and Integration			20 - 40	0.1

The table below includes the additional costs required for the In-Vehicle CVO Safety Market Package assuming that the Roadside CVO Safety and Fleet Management Market Packages are in place.

Table 25.2 – Estimated Costs for CVO8
(On-Board CVO Safety Market Package)

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Additional Software and Processor for Warning		10	0.5 – 1.0	0.01
Data Storage		10	0.3 – 0.5	0.01
On-Board Vehicle Sensors		10	0.2 – 0.4	0.01
On-Board Driver Sensors		10	0.4 – 0.8	0.01

25.5 Implementation, Operation, and Maintenance Issues

As of December 1999, 84 percent of states were using ASPEN and more than half were connected to the SAFER system. By the year 2000, fifteen states were participating in the Performance Registration Information Systems Management.

Although all states use the data reporting features of ASPEN, most states do not use ASPEN ISS (which gives a safety rating for each carrier) to select vehicles for inspection, due to laws that do not allow stopping vehicles without probable cause. In addition, there are technical limitations with entering carrier identifications and making decisions while the vehicle is approaching the site.

Difficulties associated with roadside safety inspections also include costs, the availability of wireless communications, and technical issues associated with computer system integration.

The technologies for on-board driver monitoring systems are still under development, but the work in this area is promising. It is expected that the type and amount of safety information obtained from these systems is likely to change quickly. However, the costs of these technologies are still high.

26. HAZMAT Management (CVO10)

26.1 Overview

The HAZMAT Management Market Package integrates incident management capabilities with commercial vehicle tracking to assure effective treatment of HAZMAT-related incidents. HAZMAT tracking is performed by the Fleet and Freight Management Subsystem. In order to adequately protect people, public-sector law enforcement, fire departments, emergency medical services, and others require accurate and timely information when responding to a HAZMAT incident. A recent study found that HAZMAT incident information was not provided in a timely and reliable manner in about 25 percent of the truck incidents and ten percent of rail incidents.

The Emergency Management Subsystem is notified by the commercial vehicle if an incident occurs and coordinates the response. The response is tailored based on information that is provided as part of the original incident notification or derived from supplemental information provided by the Fleet and Freight Management Subsystem. The latter information can be provided prior to the beginning of the trip or gathered following the incident, depending on the selected policy and implementation.

26.2 Products/Services

Two approaches have been tested to implement HAZMAT incident management. One of the approaches was to allow incident responders to access carriers' databases. As a result, delays and dependency on shipping papers and manifests could be reduced or eliminated. The second approach attempts to enhance access to data by storing information electronically in transponders and placing them on the HAZMAT shipment. The electronic information would replicate that which is required in shipping papers. Information would be gathered, processed, and stored in an operations center and placed in the electronic tag.

Three USDOT field operational tests were conducted to evaluate the above two approaches:

- **Tranzit Xpress Systems (TXS)** – This project was conducted in northeast Pennsylvania. The system consisted of a system of computer hardware/software designed for use by public agencies and private transport firms involved in HAZMAT transportation. The system had three separate components. The information dispatching/operations center collected HAZMAT information from the shipper and stored the information in the system. The center maintained communications with the vehicles and kept track of their locations. The on-vehicle electronics included hand-held personal computers with GPS, tags attached to the cargo, and required mobile communications. The system allowed either the driver or emergency response personnel to obtain information about the cargo.

- **TXS II** – This project, operating in Philadelphia, demonstrates the same HAZMAT identification and tracking technologies as TXS. This project is intended to demonstrate improved HAZMAT incident response and to develop an open system design in accordance with the *NITSA* for incident response.

- **Operation Respond** – Operation Respond demonstrates a HAZMAT identification and monitoring system called the Operation Respond Emergency Information System (OREIS). The OREIS software allows communications between HAZMAT carriers and emergency response units. Participating carriers established a database of information about the identification and content of their HAZMAT shipments. In the case of incidents involving a registered HAZMAT shipment, police and fire personnel can quickly obtain details of the shipment involved. The dispatcher can obtain the details of the shipment and the suggested response protocol.

26.3 Benefits

The operational tests discussed above have indicated significant potential to reduce response times and assist in response to HAZMAT incidents. Reducing the time spent identifying the HAZMAT and implementing the correct response have many benefits including minimizing environmental and public health impacts, minimizing resources expended by response agencies, and minimizing traffic impacts. The table below presents an estimate of the reduction in time based on a survey of system users.

Table 26.1 – Estimate of Time Reduction

Emergency Response Phase	First Responder Time Estimates (Minutes)		Carrier Time Estimate (Minutes)	
	Without TXS	With TXS	Without TXS	With TXS
Cargo Recognition and Identification	15.3	10.1	15.5	5.6
Response Team Notification of Incident	21.7	15.9	20.7	7.3
Time Required for Secondary Responders to Incidents	58.0	45.8	48.9	42.3

* Source: *"Hazardous Material Incident Response,"* prepared for the USDOT's FHWA by Booz. Allen & Hamilton, McLean, VA, September 1998.

26.4 Cost

Operation Respond is available to emergency management agencies on a subscription basis for $695 for the initial year and $350 per year thereafter. The cost includes installation of the software and training 911 dispatchers in its use. It also includes any software upgrades. Carriers are participating on a voluntary basis and pay the costs required to make the information available to Operation Respond.

The following are the additional costs estimated for this market package assuming other incident/emergency management and fleet management equipment is already installed.

Table 26.2 – Estimated Costs for HAZMAT Management

Item	Description	Lifetime (Years)	Capital Cost (1000 $)	O&M Cost (1000 $/Year)
Vehicle Tracking and Scheduling Enhancement		20	20 – 40	0.4 – 0.8
Wireline to ISP, Emergency Management, and TMC		20	1.5 – 3.0	
Workstation		10	5 – 10	0.1 – 0.2
Wireline Communications from Data Loading	DS0		0.5 – 1.0	0.6 – 1.2

* Source: *"Hazardous Material Incident Response,"* prepared for the USDOT's FHWA by Booz. Allen & Hamilton, McLean, VA, September 1998.

26.5 Implementation, Operation, and Maintenance Issues

One of the most important lessons learned from the TXS project is appreciation of the difficult and complex problem of remote integration of vehicle electronics for this market package. Various technical challenges are associated with transmitting shipment data on an emergency radio frequency in a synthesized voice and in a data stream as implemented in TXS.

Institutional issues are the main reason that the implementation of this market package has been slow. Institutional issues that need to be resolved include carrier participation, privacy and enforcement concern, and jurisdictional issues. To realize the full benefits of this package, widespread enrollment of carriers is needed. The greatest challenge will be enlisting the support and participation of the smaller or less technology-sophisticated carriers. These carriers have limited automation in record-keeping and fleet and cargo management.

Participating carriers raise the concern that these systems should not be used to invite greater scrutiny upon them than non-users. Another important issue that needs to be addressed is inter-jurisdictional cooperation across geographic and legislative boundaries.

27. ITS Data Archiving (AD1, AD2, and AD3)

27.1 Overview

ITS can generate considerable amounts of data. Often, ITS-generated data provides similar information to data traditionally used in transportation planning, operations, policy, safety, administrations, and research. In other instances, ITS-generated data offer new and extended applications. Thus, archiving ITS-generated data can provide a valuable resource for transportation engineering uses. By using archived ITS data, data collection costs for stakeholder applications can be reduced. In addition, the detailed nature of ITS-generated data allows more accurate analyses. The following is a list of data that are periodically collected by transportation agencies using traditional techniques:

- The regional MPO, local departments of transportation, and other planning offices, and the state transportation planning offices require data for congestion management, travel demand forecasting, and traffic analysis.
- Transportation system monitoring data including that required by the highway performance monitoring system (HPMS).
- Data required for air quality analysis and transportation plan conformity with air quality standards and goals. This includes data items such as vehicle-miles traveled (VMT), speed, and vehicle classifications.
- Data required for safety management including crash data, obtained mainly from police reports and entered in a statewide safety monitoring system.
- Data required for design, construction, and maintenance of pavement, bridge, and roadside management. This includes volume, vehicle classifications, and weights.
- Toll data including toll plaza lane usage, toll charges, and revenues.
- CVO data required for commercial vehicle enforcement and HAZMAT responses.
- Data required for transit management including scheduling, route delineation, surveys, counts, pricing, maintenance, management systems, and capital planning.
- Data required for transportation research such as the development of forecasting, simulation, and other analysis models.
- Data required for MPO/state freight and intermodal planning including freight transfer, goods movements, and port facilities.

- Land-use regulation and growth management data including land-use plans and zoning regulations, establishment of growth impact policies, and community economic development.

The following is a description of the three data archiving market packages included in the *NITSA* and a discussion of available technologies/products.

27.2 ITS Data Mart

This market package provides a focused archive that houses data collected and owned by a single public agency, private sector provider, research institution, or other organization. This focused archive typically includes data covering a single transportation mode and one jurisdiction that is archived for future use. It provides the basic data quality, data privacy, and data management for ITS archives. It also provides general query and report access to the Archive Data Users Subsystem.

27.3 ITS Data Warehouse

This market package includes all the data collection and management capabilities provided by the ITS Data Mart Market Package, discussed in the previous section, and adds the functionality and interface definitions that allow collection of data from multiple agencies and data sources spanning across modal and jurisdictional boundaries. It performs the additional transformations and provides the additional data management features that are necessary for all this data to be managed in a single repository with consistent formats. The potential for large volumes of varied data suggests additional on-line analysis and central data warehousing features that are included in this market package in addition to the basic query and reporting user access features offered by the ITS Data Mart Market Package.

27.4 Virtual Data Warehousing

This market package provides the same broad access to multi-modal, multidimensional data from varied data sources as in the ITS Data Warehouse Market Package, but provides this access using enhanced interoperability between physically distributed ITS archives that are each locally managed. Requests for data that are satisfied by access to a single repository in the ITS Data Warehouse Market Package are parsed by the local archive and dynamically translated to requests to remote archives which relay the data necessary to satisfy the request.

27.5 Products/Services

There are several information technologies that are applied to data archiving. These include, but are not limited to:

- **Relational Databases** – Relational databases that have been used for data archiving include IBM DB2 family, Informix, Microsoft SQL server, Oracle, Red Brick, and Sybase.

- **Multi-Dimensional Databases** – These are suitable for small-scale applications (i.e., data mart) as alternatives to relational database applications. An example of these is the Sybase IQ.

- **Data Warehousing Middleware** – These are a set of services that perform various functions in a distributed computing environment. Some types of middleware services include security, transaction management, and directory.

- **Data analyses and reduction technologies including querying, reporting, analyzing, mining, statistical processing, and GIS** – This equipment facilitates the discovery of information, patterns, and the correlation in large data sets.

27.6 Benefits

Archived ITS data cannot only replace or supplement "traditional" data sources but, because of their high level of temporal and spatial detail, also allow new forms of analysis to develop. Because traditional data collection activities are expensive to undertake, they are typically based on taking samples. ITS-generated data are continuously collected, or nearly so, thus greatly reducing sampling bias. Also, because of their continuous nature, variability in system performance and response can be studied. Finally, much ITS-generated data are available for very small time intervals, allowing for greater resolution in analyses and models.

In general, the benefits of central data warehousing include:

- Removal of temporal sampling bias from estimates and allowing the study of variability.

- Provision of detailed data needed to meet emerging planning requirements and to use in new modeling procedures.

- Supplementing, and in some cases replacing, existing data collection programs.

- Mutual interest in data generated by ITS will stimulate cooperation among stakeholders, complementing the integration of transportation systems in general.

- ITS-generated data can provide a valuable basis for evaluating the deployment of ITS within an area.

- ITS-generated data can support the creation and use of new system performance measures.

27.7 Cost

Implementing an ITS central data warehouse will involve development, operation, and maintenance costs. Because there is little precedent in the field, the costs of building, operating, and maintaining an ITS archival system are largely unknown. The estimated cost for a Nevada Department of Transportation project that included the design of central data warehouse and system integration with various agency partners in the Las Vegas Metropolitan Area was estimated to be around $225,000.

As an information management system, an implemented archived data system requires database administration, backup procedures, routine operation of quality control and summarization programs, responding to special users, maintaining existing codes, and developing new codes for new applications.

27.8 Implementation, Operation, and Management Issues

One issue to be considered is how to deal with data generated by legacy systems. Many of these systems have been developed with highly informal or no archiving functions. An investigation is needed to determine if these systems can be retrofitted to include formal archiving.

Quality control needs to be performed on the archived data. Missing and erroneous data should be detected. Agreements should be formulated to identify who is responsible for equipment repair when required.

Because of the massive amounts of ITS data, a decision must be made regarding what data should be archived and whether the data should be sampled or aggregated, or if all of the data should be stored.

One of the features of data archiving that distinguishes it from other user services is the large number of stakeholder groups. These stakeholders include public transportation agencies as well as private sector groups. Because of the large number of stakeholders, the development and use of archiving standards is a very important issue.

Another feature of data archiving that distinguishes it from other ITS user services is that it relies on data collected and used by other ITS functions. Thus, the developed archiving standards will be closely tied to the standards that support the other functions.

It is necessary that all of the identified stakeholders be involved in the early stages of the ITS planning and deployment process. Another issue that needs to be resolved is system access and ownership. Decisions must be made as to who owns the information, who maintains the information, and what access restrictions should be placed on the information. Privacy of individuals and firms should be preserved while maintaining the ability of certain stakeholders to identify individuals or firms in the data. There might also be some liability concerns with data archiving as to whether the archived data could be used against transportation agencies in either litigation or other adversial efforts.

28. Maintenance and Construction Management (FL MCO1)

28.1 Overview

Generally, key MCO activities include monitoring, operating, maintaining, improving, and managing the physical condition of the roadway, associated infrastructure equipment on the roadway, and the available resources necessary to conduct these activities. The functional areas addressed in the MCO Market Package are those that involve ITS technologies, integration with other transportation systems that are represented in the *NITSA*, and those that will benefit surface transportation efficiency and safety. The FL MCO1 Market Package is compatible with the *NITSA, Version 4.0*, MCO1 (Maintenance and Construction Vehicle Tracking) and MCO2 (Maintenance and Construction Vehicle Maintenance) Market Packages.

The MCO Market Package seeks to address selected MCO, particularly as the use of various ITS technologies (i.e., graphical information systems, automation, robotics, computer-aided dispatching, etc.) become more commonplace. As ITS and other sensing and information systems are added to current maintenance and construction procedures, they can also provide detailed data of value to enhance traffic management, traveler information, fleet management, and planning activities.

The MCO Market Package requires ITS-related systems and processes to have the capability to monitor, analyze, and disseminate roadway/infrastructure data for operational, maintenance, and managerial uses. It prescribes the need to coordinate and integrate MCO activities within diverse organizations in order to reduce costs, maintain or improve the efficiency and effectiveness of these activities, and increase the level of reusability of systems and technologies.

28.2 Products/Services

The service focus for the MCO Market Packages will be the following four functional areas:

- **Maintenance Vehicle Fleet Management** – Systems that monitor and track vehicle location, support enhanced routing, scheduling, and dispatching functions, and use on-board diagnostic systems to assist in-vehicle operations and maintenance activities.

- **Roadway Maintenance** – Systems that provide automated traffic monitoring, road surface and weather conditions information (from both roadside components and vehicles), contain coordinated dispatching, perform hazardous road conditions remediation, and have the ability to alert public operating agencies of changes in these conditions.

- **Work Zone Management and Safety** – Systems that ensure safe roadway operations during construction and other work zone activities and communicate with the traveler.

- **Roadway Maintenance Conditions and Work Plan Dissemination** – Systems that disseminate and coordinate MCO work plans to affected personnel and staff within and between public agencies and private sector firms.

29. Advanced Public Transportation System (APTS1, APTS2, APTS4, APTS5, APTS7, and APTS8)

29.1 Overview

The APTS market packages are suggested for the interoperation between RTMCs and transit authorities. These market packages are possible through utilizing the ATMS and ATIS market package bundles at the RTMCs. The user services should include Public Transportation Management, En-Route Transit Information, Personalized Public Transit, and Public Travel Safety.

29.2 Transit Vehicle Tracking (APTS1)

This market package monitors current transit vehicle locations using an AVL system. The location data may be used to determine real-time schedule adherence and update the transit system's schedule in real-time. Vehicle positions may be determined either by the vehicle (i.e., through GPS) and related to the infrastructure or it may be determined directly by the communications infrastructure. A two-way wireless communications link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed-route transit systems may also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the transit schedule and makes real-time schedule information available to the ISP Subsystem.

29.3 Transit Fixed-Route Operations (APTS2)

This market package performs vehicle routing and scheduling, as well as automatic driver assignment and system monitoring for fixed-route transit services. This service determines current schedule performance using AVL data and provides information displays at the Transit Management Subsystem. Static and real-time transit data is exchanged with ISPs where it is integrated with that from other transportation modes (i.e., rail, ferry, air, etc.) to provide the public with integrated and personalized dynamic schedules.

29.4 Multi-Modal Coordination (APTS7)

This market package establishes two-way communications between multiple transit and traffic agencies to improve service coordination. Multi-modal coordination between transit agencies can increase traveler convenience at transfer points and also improve operating efficiency. Coordination between traffic and transit management is intended to improve on-time performance of the transit system to the extent that this can be accommodated without degrading overall performance of the traffic network. More limited local coordination between the transit vehicle and the individual intersection for signal priority is also supported by this package.

29.5 Transit Passenger and Fare Management (APTS4)

This market package manages passenger loading and fare payments on-board vehicles using electronic means. It allows transit users to use a traveler card or other electronic payment device. Sensors mounted on the vehicle permit the driver and central operations to determine vehicle loads and readers located either in the infrastructure or on-board the transit vehicle allow electronic fare payment. Data is processed, stored, and displayed on the transit vehicle and communicated as needed to the Transit Management Subsystem.

29.6 Transit Traveler Information (APTS8)

This market package provides transit users at transit stops and on-board transit vehicles with ready access to transit information. The information services include transit stop annunciation, imminent arrival signs, and real-time transit schedule displays that are of general interest to transit users. Systems that provide custom transit trip itineraries and other tailored transit information services are also represented by this market packages.

29.7 Transit Security (APTS5)

This market package provides for the physical security of transit passengers. An on-board security system is deployed to perform surveillance and warn of potentially hazardous situations. Public areas (i.e., stops, park-and-ride lots, stations, etc.) are also monitored. Information is communicated to the Transit Management Subsystem using the existing or emerging wireless (vehicle to center) or wireline (area to center) infrastructure. Security related information is also transmitted to the Emergency Management Subsystem when an emergency is identified that requires an external response. Incident information is communicated to the ISP Subsystem.

30. Selection of Early Market Packages

The previous sections of this document present a review of the market packages selected for implementation for the principal FIHS limited-access corridors in *Technical Memorandum No. 2 – ITS Needs Model*. This technical memorandum is built on the technology review by examining these market packages to identify "early winners". Once identified, "early winners" can be formulated into statements of work or "early projects". These "early projects" will assist FDOT in the procurement and reservation of ITS funds for the *ITS Corridor Master Plans*.

In the discussion below, AVSS Market Packages are not included in the evaluation. These market packages are not candidates for early deployment. In general, the AVSS Market Package technologies are immature and still in the early stages of deployments.

30.1 Methodology

The following factors were considered in the selection of early market packages:

- The availability and maturity of the market package technologies include the products and services that support the estimated benefits of the market packages in previous deployments. It also includes consideration of the market penetration of the devices that are required to support the market package deployment. *Early market packages should not rely on technologies that do not exist or may be too costly and/or unreliable for commercial applications. In addition, high priority should be placed on market packages that have been implemented in several locations around the nation, which is an indicator of potential demand for these packages.*

- The estimated benefits of the market package were determined based on the ability of each market package to satisfy the five principle FHIS limited-access corridors' ITS goals and objectives. In *Technical Memorandum No. 2 – ITS Needs Model*, the following goals and objectives were identified:

    - Move people and goods safely;
    - Preserve and manage the system;
    - Enhance economic competitiveness;
    - Enhance quality of life and the environment; and
    - Deploy an integrated, effective system.

    The sub-objectives under each of the above high-level objectives can be found in the *ITS Needs Model*. *A high priority should be placed on market packages that provide a high level of benefits by satisfying the corridor ITS goals and objectives.* Table 30.1 presents the benefits analysis based on the first four objectives in the above list. The fifth objective is related to ITS deployments rather than ITS architecture. Thus, it was not considered in the evaluation of the market package benefits.

Table 30.1 – Market Package Benefits Analysis

Market Package Number	Market Package Name	Move People/ Good Safely	Preserve and Manage System	Enhance Economic Competitiveness	Enhance Quality of Life	Overall
APTS 1	Transit Vehicle Tracking	3	4	3	3	3
APTS 2	Transit Fixed-Route Operations	3	4	3	3	3
APTS 4	Transit Passenger and Fare Management	3	5	4	4	4
APTS 5	Transit Security	5	3	3	5	4
APTS 7	Multi-Modal Coordination	3	5	4	4	4
APTS 8	Transit Traveler Information	3	3	5	5	4
ATIS1	Broadcast Traveler Information	3	3	4	3	3
ATIS2	Interactive Traveler Information	3	3	4	3	3
ATIS3	Autonomous Route Guidance (ARG)	2	2	4	3	3
ATIS4	Dynamic Route Guidance (DRG)	3	3	5	3	4
ATIS5	ISP-Based Route Guidance	3	3	5	3	4
ATIS6	Integrated Transportation Management/Route Guidance	3	5	5	3	4
ATIS7	Yellow Pages and Reservations	1	2	5	4	3
ATIS8	Dynamic Ridesharing	2	2	2	4	3
ATIS9	In-Vehicle Signing	5	2	2	3	3
ATMS1	Network Surveillance	3	3	2	4	3
ATMS2	Probe Surveillance	2	3	2	4	3
ATMS3	Surface Street Control	3	5	4	4	4

Table 30.1 (Continued)

Market Package Number	Market Package Name	Move People/ Good Safely	Preserve and Manage System	Enhance Economic Competitiveness	Enhance Quality of Life	Overall
ATMS4	Freeway Control	3	5	4	4	4
ATMS5	HOV Lane Enforcement	1	4	2	2	2
	HOT Lanes	2	4	4	3	3
ATMS6	Traffic Information Dissemination (DMS)	3	3	3	3	3
	Traffic Information Dissemination (HAR)	3	3	3	3	3
ATMS7	Regional Traffic Control	3	4	3	3	3
ATMS8	Incident Management System (IMS)	4	5	4	4	4
ATMS9	Traffic Forecast and Demand Management	3	4	3	3	3
ATMS10	Electronic Fare Collection	3	4	4	3	4
ATMS12	Virtual TMC (Work zone)	4	4	3	3	4
	Smart Probe Data	2	3	2	4	3
ATMS13	Standard Railroad Grade Crossing	5	2	2	2	3
ATMS14	Advanced Railroad Grade Crossing	5	3	3	2	3
ATMS15	Railroad Operations Coordination	5	3	3	2	3
ATMS16	Parking Facility Management	1	1	4	3	2
ATMS17	Reversible Lane Management	4	4	3	3	4
ATMS18	Road Weather Information System (RWIS)	5	2	2	2	3
FL ATMS20	Speed Management	5	2	2	2	3
CVO1	Fleet Administration	4	3	5	3	4

Table 30.1 (Continued)

Market Package Number	Market Package Name	Move People/ Good Safely	Preserve and Manage System	Enhance Economic Competitiveness	Enhance Quality of Life	Overall
CVO2	Freight Administration	4	3	5	3	4
CVO3	Electronic Clearance	5	4	5	3	4
CVO4	CV Administrative Process	4	4	5	3	4
CVO5	International Border Electronic Clearance	3	4	5	3	4
CVO6	Weigh-in-Motion	5	4	5	3	4
CVO7	Roadside CVO Safety	4	4	5	3	4
CVO8	On-Board CVO Safety	4	4	5	3	4
CVO10	HAZMAT Management	5	4	5	5	5
EM1	Emergency Response	5	4	4	3	4
EM2	Emergency Routing	5	4	4	3	4
EM3	Mayday Support	5	4	4	3	4
FL EM4	Evacuation Management	5	4	3	4	4
AD1	ITS Data Mart	3	4	2	4	3
AD2	ITS Data Warehouse	4	5	3	5	4
AD3	ITS Virtual Data Warehouse	4	5	3	5	4
FL MCO1	Maintenance and Construction Management	1	4	2	4	3

- The market package synergy requirement is an important consideration in selecting early winners. *A market package is a candidate for early deployment if it is required for the implementation of other high priority market packages.*

- Institutional issues associated with the market packages include privacy concerns, inter-jurisdictional coordination, user acceptance, legal issues, and legislative issues. *The difficulty of resolving the institutional issues associated with the market packages should be considered when selecting early winners.*

- The level of difficulty of technical issues associated with the market packages includes implementation, operation, and maintenance. *The difficulty of resolving the technical issues associated with the market packages should be considered when selecting early winners.*

The ability of each market package to meet the above five criteria were assigned a rating between one and five. One indicates the lowest level of criteria satisfaction while five indicates the highest level of satisfaction. Furthermore, each criterion was assigned a weight reflecting its importance. The following table indicates the weights used in the analysis:

Table 30.2 – Weights Used in the Market Package Benefits Analysis

Criteria	Weight
Benefits	23
Maturity	34
Pre-Required Package	23
Institutional Difficulties	10
Technical Difficulties	10
Total	**100**

By multiplying a market package rating for a given criterion and the criterion weighting, a utility value can be obtained. By summing all utility values for each market package, a utility measure or a performance index can be obtained for the market package. The calculated utility measures were used in determining the early winners among the market packages.

30.2 Results

The analysis of the selection of early market packages is presented in Table 30.3. Based on the results presented in this table, the followings market packages are recommended for early market package deployment:

- Broadcast Traveler Information;
- Interactive Traveler Information;
- Autonomous Route Guidance (ARG);
- Network Surveillance;
- Probe Surveillance;
- Freeway Control;
- Traffic Information Dissemination (DMS);
- Traffic Information Dissemination (HAR);
- Regional Traffic Control;
- Incident Management System (IMS);
- Traffic Forecast and Demand Management;
- Electronic Fare Collection;
- Virtual TMC (Work Zone);
- Standard Railroad Grade Crossing;
- Advanced Railroad Grade Crossing;
- Railroad Operations Coordination;
- Road Weather Information System (RWIS);
- Speed Management;
- Fleet Administration;
- Electronic Clearance;
- CV Administrative Process;
- Weigh-in-Motion (WIM);
- Roadside CVO Safety;
- HAZMAT Management;
- Emergency Response;
- Emergency Routing;
- Mayday Support;
- Evacuation Management;
- ITS Data Mart;
- ITS Data Warehouse;
- Management and Construction Management;
- Transit Vehicle Tracking;
- Transit Fixed-Route Operations;
- Transit Passenger and Fare Management;
- Multi-Modal Coordination; and
- Transit Traveler Information.

Table 30.3 – Early Market Package Analysis

Market Package Number	Market Package Name	Move People/ Good Safely	Preserve and Manage System	Enhance Economic Competitiveness	Enhance Quality of Life	Overall
APTS 1	Transit Vehicle Tracking	3	4	3	3	3
APTS 2	Transit Fixed- Route Operations	3	4	3	3	3
APTS 4	Transit Passenger and Fare Management	3	5	4	4	4
APTS 5	Transit Security	5	3	3	5	4
APTS 7	Multi-Modal Coordination	3	5	4	4	4
APTS 8	Transit Traveler Information	3	3	5	5	4
ATIS1	Broadcast Traveler Information	3	3	4	3	3
ATIS2	Interactive Traveler Information	3	3	4	3	3
ATIS3	Autonomous Route Guidance (ARG)	2	2	4	3	3
ATIS4	Dynamic Route Guidance (DRG)	3	3	5	3	4
ATIS5	ISP-Based Route Guidance	3	3	5	3	4
ATIS6	Integrated Transportation Management/Route Guidance	3	5	5	3	4
ATIS7	Yellow Pages and Reservations	1	2	5	4	3
ATIS8	Dynamic Ridesharing	2	2	2	4	3
ATIS9	In-Vehicle Signing	5	2	2	3	3
ATMS1	Network Surveillance	3	3	2	4	3
ATMS2	Probe Surveillance	2	3	2	4	3
ATMS3	Surface Street Control	3	5	4	4	4
ATMS4	Freeway Control	3	5	4	4	4
ATMS5	HOV Lane Enforcement	1	4	2	2	2
	HOT Lanes	2	4	4	3	3
ATMS6	Traffic Information Dissemination (DMS)	3	3	3	3	3
	Traffic Information Dissemination (HAR)	3	3	3	3	3

Table 30.3 (Continued)

Market Package Number	Market Package Name	Move People/ Goods Safely	Preserve and Manage System	Enhance Economic Competitiveness	Enhance Quality of Life	Overall
ATMS7	Regional Traffic Control	3	4	3	3	3
ATMS8	Incident Management System (IMS)	4	5	4	4	4
ATMS9	Traffic Forecast and Demand Management	3	4	3	3	3
ATMS10	Electronic Fare Collection	3	4	4	3	4
ATMS12	Virtual TMC (Work Zone)	4	4	3	3	4
	Smart Probe Data	2	3	2	4	3
ATMS13	Standard Railroad Grade Crossing	5	2	2	2	3
ATMS14	Advanced Railroad Grade Crossing	5	3	3	2	3
ATMS15	Railroad Operations Coordination	5	3	3	2	3
ATMS16	Parking Facility Management	1	1	4	3	2
ATMS17	Reversible Lane Management	4	4	3	3	4
ATMS18	Road Weather Information System (RWIS)	5	2	2	2	3
FL ATMS20	Speed Management	5	2	2	2	3
CVO1	Fleet Administration	4	3	5	3	4
CVO2	Freight Administration	4	3	5	3	4
CVO3	Electronic Clearance	5	4	5	3	4
CVO4	CV Administrative Process	4	4	5	3	4
CVO5	International Border Electronic Clearance	3	4	5	3	4
CVO6	Weigh-in-Motion	5	4	5	3	4
CVO7	Roadside CVO Safety	4	4	5	3	4

Table 30.3 (Continued)

Market Package Number	Market Package Name	Move People/ Goods Safely	Preserve and Manage System	Enhance Economic Competitiveness	Enhance Quality of Life	Overall
CVO8	On-Board CVO Safety	4	4	5	3	4
CVO10	HAZMAT Management	5	4	5	5	5
EM1	Emergency Response	5	4	4	3	4
EM2	Emergency Routing	5	4	4	3	4
EM3	Mayday Support	5	4	4	3	4
FL EM4	Evacuation Management	5	4	3	4	4
AD1	ITS Data Mart	3	4	2	4	3
AD2	ITS Data Warehouse	4	5	3	5	4
AD3	ITS Virtual Data Warehouse	4	5	3	5	4
FL MCO1	Maintenance and Construction Management	1	4	2	4	3