Implementation Concepts

The ITS concepts recommended for implementation in the Dulles Corridor are those that provide the greatest benefit to the Corridor's transit passengers and designated transit operator. These concepts ranked highest in the prioritization and screening process discussed earlier in the "Process" section. The implementation concepts are grouped into four functional packages, which are: Traveler Information, Electronic Payment, Safety and Security, and Operations. The concepts are represented in the center circle of Exhibit 1, and are listed below by their respective package grouping:

Traveler Information Package

- Transit Vehicle Tracking
- Parking Facility Information
- Wayside/In-station Traveler Information
- In-vehicle Traveler information

Security/Safety Package

- On-board Transit Security
- Transit Facility Security
- Parking Facility Security

Electronic Payment Package

- Electronic Fare Payment
- Parking Facility Electronic Payment

Operations Package

- BRT Station Lane Access Control
- BRT Precision Docking System
- Transit Vehicle Mechanical Safety Monitoring and Maintenance
- Traffic Signal Priority Study
- Emergency Response

This section discusses each of the implementation concepts, recommends implementation phasing and layout, identifies benefits, and presents estimated implementation and annual operations and maintenance (O&M) costs. There is little quantitative benefits information available for ITS; therefore the benefits information provided is qualitative. Information for cost estimates was obtained from ITS vendors, transit agencies, the National ITS Architecture Cost Analysis, the U.S. DOT ITS Cost Repository, ITS literature, and experts in the field. Cost estimates are order of magnitude, ballpark figures and are for planning purposes only. The estimates represent the maximum cost for stand alone systems and are likely to be significantly lower based on the selected operator's existing technology infrastructure. The cost estimates will be refined and the cost effectiveness of concepts will be measured as the project proceeds towards implementation.

Unless otherwise stated, the following rules of thumb were used in estimating capital installation and integration costs, and annual O&M costs:

- Installation and integration costs are estimated at 25 percent of capital costs for the initial implementation, and 20 percent of capital costs for subsequent deployments of the system.
- Annual O&M costs are estimated at 50 percent of capital costs.

The O&M value provided is the maximum annual O&M cost for a particular phase. For example, the amount of equipment to operate and maintain during Phase IV may decrease over the period. The O&M value provided for Phase IV is based on the year in which there is the largest amount of equipment to operate and maintain. The number of buses in service in year 2006 may be 139. The number of buses in 2011 may be 97. Therefore, the annual O&M cost provided for Phase IV is based on the capital cost of the 139 buses. **Cost estimates and a summary of implementation phasing are provided at the end of each package section.**

TRAVELER INFORMATION CONCEPTS

The traveler information concepts provide real-time transit vehicle schedule information at transit stops and real-time occupancy information at parking facilities. It also provides next-stop location information to passengers on-board transit vehicles. Transit vehicle tracking provides real-time location input to the transit information technologies. The traveler information concepts increase customer convenience, save passengers time, relieve uncertainty and anxiety, help travelers make smart decisions, and build customer loyalty and confidence. Each of the traveler information concepts is discussed below.

Transit Vehicle Tracking

Transit vehicle tracking, which includes automatic vehicle location (AVL) and computer-aided dispatching (CAD) functions, provides real-time location information for schedule adherence, dispatch, and traveler information. Often, other ITS applications interface or are integrated with the transit vehicle tracking system. These applications include a silent alarm for alerting dispatchers of emergencies, vehicle engine probes to alert drivers and dispatchers of potential engine problems, automatic passenger counters (APC), and in-vehicle traveler information systems (automated next-stop annunciation). For this project, however, the transit vehicle tracking system provides vehicle location, schedule adherence, and dispatching functions. The ITS planning and multi-modal coordination concepts were incorporated into the transit vehicle tracking concept. Therefore, the transit vehicle tracking system also includes transit planning and multi-modal coordination computing functions. The major components of the transit vehicle tracking system are provided below. It is recommended that Global Positioning System (GPS) technology be used for location referencing. It is assumed that the current radio system is used for communications.

- GPS receiver
- On-board computer (in-vehicle logic unit)
- Mobile data terminal
- Monitoring & dispatching workstation and software (central hardware and software)
- ITS planning computer hardware and software
- Multi-modal coordination computer hardware and software

Transit vehicle tracking provides the basis for real-time traveler information, automated annunciation, and emergency response. It increases operations efficiency and productivity, which decreases costs, and improves security and safety.

Implementation Phasing and Layout

It is recommended that 114 forty-foot buses be equipped with GPS AVL in Phase II. This is the total number of buses recommended in the Dulles Corridor Transportation Study for Phase II (44 local and 70 express buses). The central AVL/CAD system should be developed concurrently. The ITS planning computer hardware and software should also be implemented in Phase II.

It is recommended that an additional 2 forty-foot buses and 23 articulated buses be equipped with GPS AVL in Phase III. This is the number of additional buses recommended in the Dulles Corridor Transportation Study for Phase III (54 forty-foot local, 17 forty-foot non-BRT express, 45 forty-foot BRT express, and 23 articulated BRT express buses total).

It will require time for agencies in the area to reach agreements on multi-modal coordination activities, and for other transportation agencies to implement real-time monitoring functionality into their systems. Therefore, it is recommended that multi-modal coordination computer hardware and software be implemented in Phase III.

The deployment of AVL for rail systems is not necessary because vehicle tracking is integral to most rail signal control systems.

Parking Facility Information

This concept provides real-time parking availability information and navigational guidance for parking lots and garages. Information is typically provided via dynamic message signs in the vicinity of the parking facility and at the parking facility. Signage may specify the number of parking spaces or whether or not the facility is full. Signage may also direct drivers to the parking facility and to vacant sections of the facility. Signage may be located adjacent to arterials and freeways near the parking facility, at facility entrances, and inside the facility. The major components of the parking facility information system include the following:

- Parking DMS signs
- Highway DMS signs
- Vehicle detectors
- DMS controller
- System Server

The parking DMS signs are smaller units located on arterials and at the parking facility. The larger highway DMS signs are located on freeways.

Parking facility information provides customer convenience, saves customers' time, and relieves driver stress and uncertainty. It reduces unwanted and unnecessary mileage by guiding drivers directly to vacant lots and garages. This helps to reduce emissions and fuel consumption. Parking facility information also improves parking operations efficiency.

Implementation Phasing and Layout

It is recommended that parking facility information systems be implemented at the Wiehle Avenue, Herndon/Monroe, and Route 606 parking facilities in Phase II. Parking facility information systems should be implemented at the West Park, Reston, and Route 772 parking facilities in Phase III. These systems should be tied together and be controlled by one central system server. The central system will know the vacancy status of each facility, and if a lot is full, a driver will be instructed to park in one of the vacant facilities. The owner and operator of the parking facility information system will be determined at a later date.

For the cost estimate, the following assumptions were made:

- Two parking DMS signs per facility (one at the parking facility entrance and one on an arterial)
- Two highway DMS signs per facility (one on the Dulles Toll Road / Greenway, each direction, prior to the freeway exit to the parking facility)
- Two vehicle detectors per facility (one each at the parking facility's entrance and exit)

Wayside/In-station Traveler Information

This concept provides real-time arrival/departure information at transit stops and station platforms. Information can be displayed on monitors or DMS signs. Information displayed on signs can also be announced simultaneously over integrated speakers or a station's public address system. The system is controlled by a central server, which interfaces to the transit vehicle tracking system to provide real-time schedule information. Advertising and general public service announcements could also be provided over the system. The major components of a wayside/in-station traveler information system include the following:

- DMS signs or display monitors
- Central software
- System server

The central software is an algorithm that performs the estimated time of arrival of the transit vehicle at a designated stop. The central software includes stop location data.

Wayside/in-station traveler information provides customer convenience, saves customers' time, and relives traveler stress and anxiety by providing travelers a measure of the time until their bus or train arrives at the stop. If a traveler is informed that his/her bus or train will not arrive for an additional 20 minutes, for example, the traveler can perform a task or run an errand that he/she may not have initiated without knowing the real-time schedule of the bus or train.

Implementation Phasing and Layout

The wayside/in-station traveler information system central software and server should be implemented in Phase III. Simultaneously, signs (display monitors or DMS signs) should be deployed at the following stops:

- West Falls Church
- West Park
- Wiehle Avenue
- Reston Parkway
- Herndon/Monroe
- Dulles Airport

- Route 606
- Route 772

It is recommended that the system be expanded in Phase IV to include the Tysons stop. For the cost estimate, it was assumed that two DMS signs (or display monitors) would be deployed per stop (one for each direction of travel). Initially, the system could provide static schedule information. Eventually, the system should be linked to the transit vehicle tracking system to provide real-time arrival/departure information.

In-vehicle Traveler Information

An in-vehicle traveler information system provides visual and audio announcements inside the transit vehicle automatically. Typically, announcements include next stop, major cross street, transfer point, and landmark information. Additional information, such as public service announcements and advertisements, may be provided at other times. An in-vehicle traveler information system also meets ADA requirements. An AVL system or beacons are typically used to trigger announcements. Because a transit vehicle tracking system has been recommended for implementation, it is recommended that the in-vehicle traveler information system be linked to the transit vehicle tracking system for triggering of announcements. The system can also be coupled with the vehicle's speaker system. Major components of the system include the following:

- DMS sign(s)
- Enunciator
- Announcement data
- Central recording station

The enunciator is the mechanism that provides the audible announcements and is the system's computer. Audible announcements are recorded at the central recording station. Announcement data include the locations at which announcements are to be made and the announcement content.

In-vehicle traveler information systems improve customer convenience, and relieve stress and uncertainty. It makes transit easier for the transit novice, visually impaired, and hearing impaired to use, and assists passengers in identifying stops during periods of poor visibility. In-vehicle information systems also improve operational performance, and allow transit drivers to concentrate on driving.

Implementation Phasing and Layout

It is recommended that 116 forty-foot buses and 23 articulated buses be equipped with an in-vehicle traveler information system in Phase III. This is the total number of buses recommended in the Dulles Corridor Transportation Study for Phase III (54 forty-foot local, 17 forty-foot non-BRT express, 45 forty-foot BRT express, and 23 articulated BRT express buses total). The central recording station should be operational during Phase III as well.

It is recommended that 98 rail cars be equipped with the in-vehicle traveler information system in Phase IV. This is the total number of rail cars recommended in the Dulles Corridor Transportation Study for this Phase.

For the cost estimate, the following assumptions were made:

- One DMS sign in each of the 40-foot buses
- Two DMS signs in each of the articulated buses and rail cars

Cost Estimates

Exhibit 3 presents cost estimates for the traveler information package implementation concepts based on the recommended implementation phasing. The capital cost value is the estimated cost to implement the specified system, or a portion of the system, during the phase. The capital cost includes hardware, firmware, software, installation, and integration costs. It does not include communications costs. The annual O&M value is the estimated maximum cost to operate and maintain the specified system, as it exists, per year during the specified phase. Details of the cost estimates, along with assumptions, are presented in the Appendix.

Exhibit 3. Traveler Information Package Cost Estimates (in dollars)

ITS Concept	Phase II (2001-2003)		Phase III (2003-2006, 2010)		Phase IV (2006-)		
	Capital	Annual O&M	Capital	Annual O&M	Capital	Annual O&M	Total Capital Cost
Transit Vehicle Tracking	3,561,000	1,780,500	338,000	1,949,500	0	1,949,500	3,899,000
Parking Facility Information	1,183,750	473,500	1,058,400	914,500	0	914,500	2,242,150
Wayside/In-station Traveler Information	0	0	406,250	162,500	36,000	177,500	442,250
In-vehicle Traveler Information	0	0	1,216,250	486,500	940,800	878,500	2,157,050
						Grand Total	8,740,450

Implementation Phasing Summary

Exhibit 4 summarizes the recommended implementation phasing of the traveler information package concepts. The bars represent the phase in which the specified system, or a portion of the system, should be implemented. Implementation includes equipment procurement, installation, integration, and acceptance testing.

Exhibit 4. Implementation Phasing for Traveler Information Package Concepts

ITS CONCEPT	PHASE II (2001-2003)	PHASE III (2003-2006, 2010)	PHASE IV (2006-)
Transit Vehicle Tracking (buses only)	█	█	
Parking Facility Information	█	█	
Wayside/In-station Traveler Information		█	█
In-vehicle Traveler Information		█	█

ELECTRONIC PAYMENT CONCEPTS

The electronic payment concepts recommended for implementation in the Corridor allow travelers to pay transit fares and parking fees by electronic means (i.e., magnetic stripe card, smart card, and transponder). The concepts can be integrated into one system, and customers can be issued one account. The electronic payment concepts increase customer convenience (e.g., exact change not required, simplification though a single account), allow for cost savings to customers and transportation agencies, and save customers' time. The "electronic toll collection" coordination concept can be tied together with the electronic fare payment and parking facility electronic payment concepts to provide an integrated electronic payment system in the Corridor.

The traveler information implementation concepts are discussed below. It is recommended that electronic fare payment and parking facility payment (and hopefully electronic toll collection) be integrated into one system. However, in case they are not, component and cost information provided below is based on autonomous and separate systems. For example, separate systems would each have a central computer (hardware, software, and database) and clearinghouse. An integrated system would only need one set of central equipment, and typically, these components and their costs would not be duplicated.

Electronic Fare Payment (EFP)

This concept provides an electronic means of collecting and processing fares. Customers use a smart card instead of tokens or cash to pay for transit rides. The electronic fare payment system may be linked to the transit vehicle tracking system for distance-based fare collection. The MWCOG, WMATA, and FTA electronic payment studies should be considered in development of this concept. Major components of the system include the following:

- Bus farebox with card reader
- Turnstiles with card reader
- Ticket vending machines with card reader
- Central hardware
- Central software and database
- Clearinghouse

The central hardware, software/database, and clearinghouse components perform the financial processing and transaction functions of the electronic payment system.

Electronic fare payment improves customer convenience, increases boarding throughput and thus reduces travel time, and increases fare collection efficiency for transit operators. It also relieves drivers of some of the fare collection tasks, which makes their job easier.

Implementation Phasing and Layout

It is recommended that electronic fare collection be implemented at the following BRT stations in Phase III:

- West Park
- Wiehle Avenue
- Reston Parkway
- Herndon/Monroe
- Route 606

Each of these stations would be equipped with EFP turnstiles and ticket vending machines. The central computer system and clearinghouse would also be developed in Phase III.

In addition, it is recommended that 116 forty-foot buses and 23 articulated buses be equipped with EFP fareboxes in Phase III. This is the total number of buses recommended in the Dulles Corridor Transportation Study for Phase III (54 forty-foot local, 17 forty-foot non-BRT express, 45 forty-foot BRT express, and 23 articulated BRT express buses total). Although fare collection will take place at the BRT station and not on the bus, the BRT buses will need to be furnished with EFP fareboxes because they will also stop at locations that are not stations.

It is recommended that the electronic fare payment system be expanded in Phase IV and that the following rail stations be equipped with electronic fare payment capabilities:

- Tysons
- Dulles Airport
- Route 772

For the cost estimate, the following assumptions were made:

- Three EFP vending machines per station
- Six EFP turnstiles per station

Parking Facility Electronic Payment

This concept collects parking fees electronically and detects and processes violators. Payment may be made using a credit/debit card, smart card, or vehicle-mounted transponder. The MWCOG, WMATA, and FTA electronic payment studies should be considered in development of this concept. Major components of the system include the following:

- Transponder reader assembly
- Smart card reader
- Camera (for violation enforcement)
- Central hardware
- Central software and database
- Clearinghouse

The central hardware, software/database, and clearinghouse components perform the financial processing and transaction functions of the electronic payment system. The camera takes pictures of violators' license plates. For example, if someone drives through an unattended, automated booth without paying, the camera would take an image of the violator's license place. The violator would receive a warning or a citation in the mail. The camera could be replaced with a gate, but that would decrease vehicle throughput.

Like the electronic fare payment concept, parking facility electronic payment improves customer convenience, increases throughput and thus reduces queues and waiting time, and increases fee collection efficiency for parking operators.

Implementation Phasing and Layout

It is recommended that parking facility electronic payment be implemented at the following parking facilities in Phase III:

- West Park
- Wiehle Avenue
- Reston
- Herndon/Monroe
- Route 606
- Route 772

Each of these facilities would be equipped with transponder readers, card readers, and cameras. The central computer system and clearinghouse would also be developed in Phase III.

For the cost estimate, the following assumptions were made:

- Two transponder readers per facility
- Two card readers per facility
- One camera per facility

Cost Estimates

Exhibit 5 presents cost estimates for the electronic payment package implementation concepts based on the recommended implementation phasing. The costs represent two separate and autonomous systems (i.e., each concept contains a central computer system and clearinghouse). The cost of an integrated system would be less than the total of the two systems.

The capital cost value is the estimated cost to implement the specified system, or a portion of the system, during the phase. The capital cost includes hardware, firmware, software, installation, and integration costs. It does not include communications costs. The annual O&M value is the estimated maximum cost to operate and maintain the specified system, as it exists, per year during the specified phase. Details of the cost estimates, along with assumptions, are presented in the Appendix.

Exhibit 5. Electronic Payment Package Cost Estimates (in dollars)

ITS Concept	Phase II (2001-2003)		Phase III (2003-2006, 2010)		Phase IV (2006-)		
	Capital	Annual O&M	Capital	Annual O&M	Capital	Annual O&M	Total Capital Cost
Electronic Fare Payment	0	0	6,840,000	3,920,000	450,000	4,145,000	7,290,000
Parking Facility Electronic Payment	0	0	4,167,000	2,583,500	0	2,583,500	4,167,000
						Grand Total	11,457,000

Implementation Phasing Summary

Exhibit 6 summarizes the recommended implementation phasing for the electronic payment package concepts. The bars represent the phase in which the specified system, or a portion of the system, should be implemented. Implementation includes equipment procurement, installation, integration, and acceptance testing.

Exhibit 6. Implementation Phasing for Electronic Payment Package Concepts

ITS CONCEPT	PHASE II (2001-2003)	PHASE III (2003-2006, 2010)	PHASE IV (2006-)
Electronic Fare Payment			
Parking Facility Electronic Payment			

SAFETY & SECURITY CONCEPTS

The safety and security concepts provide surveillance in transit vehicles, in transit stations, at transit stops, and in parking facilities. Surveillance components consist of video, silent alarms, and two-way intercoms. The safety and security package deters vandalism and other criminal activities. This creates a safer environment for transit patrons and reduces maintenance costs due to vandalism.

The safety and security concepts are discussed below. For efficiency purposes, it is recommended that the monitoring and control functions of the transit facility security and parking facility concepts be integrated into one central system. In case they are not, however, the two concepts are presented as separate, autonomous systems each having their own central monitoring and control facility. If the two concepts were integrated, only one central video switcher and controller would be needed and the cost for that component should not be duplicated.

On-Board Transit Security

On-board transit security provides video monitoring of the passenger safety environment on board the transit vehicle. Video images may be recorded and later reviewed, or they may be transmitted in real time over the bus's communications system to a central location. A silent alarm feature allows transit drivers to request assistance from dispatching in case of an emergency. Often there is a direct link of this feature to the authorities. The on-board transit security system is usually linked to the transit vehicle tracking system. Therefore, a vehicle can be quickly located during emergencies. Rail vehicles often have an integral two-way intercom system so that passengers in distress can contact the train operator for assistance. Major components of the recommended system include the following:

- CCTV camera
- Silent alarm and microphone

For the Dulles Corridor, it is recommended that this concept be implemented on buses only. Most rail cars already come equipped with some type of passenger safety/security system. It is also recommended that video images be recorded onboard the buses as opposed to real-time video transmission. Real-time transmission often puts a strain on the bus's communication system. Signs can be posted on the bus alerting riders to video surveillance activities. This presence in itself will deter vandalism and other criminal activity.

In addition to deterring vandalism and other criminal activity, and notifying the authorities for assistance during emergencies associated with crime, the on-board transit security system is very beneficial during medical emergencies. For example, a bus driver can press the alarm if a passenger is having a heart attack. With the bus's security system and transit vehicle tracking system, emergency management services can be notified promptly and the bus's location can be pinpointed.

Implementation Phasing and Layout

It is recommended that 116 forty-foot buses and 23 articulated buses be equipped with an on-board transit security system in Phase III. This is the total number of buses recommended in the Dulles Corridor Transportation Study for Phase III (54 forty-foot local, 17 forty-foot non-BRT express, 45 forty-foot BRT express, and 23 articulated BRT express buses total). For the cost estimate, it was assumed that there would be two cameras per bus.

Transit Facility Security

Transit facility security provides remote, real-time video monitoring and recording of the passenger safety environment at transit stops and in stations. It allows passengers to request assistance via a two-way intercom system in case of an emergency. Monitoring and control typically occurs at a central location. A direct link is often provided to the authorities. Major components of the recommended system include the following:

- CCTV cameras
- Video monitors
- Central video switcher and controller

A video controller provides the pan, tilt, and zoom control capabilities of the CCTV cameras. Typically, there are less video monitors than CCTV cameras in a security system. The video switcher allows central monitoring personnel to switch to a particular camera for viewing. The two-way intercom component is not included in this particular application because most stations are built with traveler intercom systems.

Implementation Phasing and Layout

It is recommended that CCTV cameras be installed in the following transit facilities during Phase III:

- West Park
- Wiehle Avenue
- Reston Parkway
- Herndon/Monroe
- Route 606
- Route 772

A central monitoring and control facility should be implemented concurrently. Video monitoring capabilities should be provided at the Tysons transit facility in Phase IV.

For the cost estimate, the following assumptions were made:

- Six cameras per transit facility
- One video monitor per transit facility (located in a central location)

The camera cost for the Tysons station is not included in the cost estimate below. The cameras will be a part of the station construction and are included in the station construction cost.

Parking Facility Security

Parking facility security is very similar to transit facility security except that security is provided in parking facilities instead of transit facilities. Parking facility security provides remote, real-time video monitoring and recording of the safety environment in parking lots and garages. It allows patrons to request assistance via a two-way intercom system in case of an emergency. If several parking facilities are involved, monitoring and control may take place at a central location. A direct link may also be provided to the authorities. Major components of the recommended system include the following:

- CCTV cameras
- Video monitors
- Central video switcher and controller

The two-way intercom component is not included in this particular application because it is assumed that the parking facility will be built with an intercom system (except for Herndon/Monroe).

Implementation Phasing and Layout

It is recommended that CCTV cameras be installed in the following parking facilities during Phase III:

- West Park
- Wiehle Avenue
- Reston
- Route 606
- Route 772

A central monitoring and control facility should be implemented concurrently. The Herndon/Monroe parking facility currently has CCTV cameras. However, it will need to be retrofitted with a two-way intercom system in Phase III.

For the cost estimate, the following assumptions were made:

- One CCTV camera per 80 parking spaces (out of an estimated 4,700 spaces total)
- One video monitor per 35 CCTV cameras
- Two intercoms for the Herndon/Monroe parking facility

Cost Estimates

Exhibit 7 presents cost estimates for the safety and security package implementation concepts based on the recommended implementation phasing. For the transit facility security and parking facility security concepts, the costs reflect two separate monitoring and control centers (i.e., each system has a central video switcher and controller). The cost of an integrated system would be less than the total of the two systems.

The capital cost value is the estimated cost to implement the specified system, or a portion of the system, during the phase. The capital cost includes hardware, firmware, software, installation, and integration costs. It does not include communications costs. The annual O&M value is the estimated maximum cost to operate and maintain the specified system, as it exists, per year during the specified phase. Details of the cost estimates, along with assumptions, are presented in the Appendix.

Exhibit 7. Safety & Security Package Cost Estimates (in dollars)

ITS Concept	Phase II (2001-2003)		Phase III (2003-2006, 2010)		Phase IV (2006-)		
	Capital	Annual O&M	Capital	Annual O&M	Capital	Annual O&M	Total Capital Cost
On-board Transit Security	0	0	920,875	368,350	0	368,350	920,875
Transit Facility Security	0	0	276,250	110,500	4,200	112,250	280,450
Parking Facility Security	0	0	406,500	163,000	0	163,000	406,500
						Grand Total	1,607,825

Implementation Phasing Summary

Exhibit 8 summarizes the recommended implementation phasing of the safety and security package concepts. The bars represent the phase in which the specified system, or a portion of the system, should be implemented. Implementation includes equipment procurement, installation, integration, and acceptance testing.

Exhibit 8. Implementation Phasing for Safety & Security Package Concepts

ITS CONCEPT	PHASE II (2001-2003)	PHASE III (2003-2006, 2010)	PHASE IV (2006-)
On-board Transit Security			
Transit Facility Security			
Parking Facility Security			

OPERATIONS CONCEPTS

The operations concepts improve the operations and maintenance functions of the transit system. They control access to and automate docking at BRT stations, monitor vehicle mechanics and manage maintenance, provide priority to buses at traffic signals, and assist in the dispatching of transit police. In short, the operation concepts improve transit travel times by reducing dwell times at stations and traffic signal delays, improve equipment reliability and reduce the number of delays due to equipment failure, and improve response time to emergencies. Each of the operations concepts is discussed below.

BRT Station Lane Access Control

This concept limits access at BRT stations to BRT buses. It prevents passenger vehicles and trucks from accidentally traveling on the entrance ramp to a BRT station (slip ramp from the Dulles Airport Access Road). A gate, located at the front of the entrance ramp, is used to control BRT station access. The gate opens as a BRT bus, equipped with a transponder, passes a transponder reader upstream from the BRT station entrance ramp. Major components of the BRT station lane access control system include the following:

- Transit vehicle transponder
- Transponder reader assembly
- Gate assembly

The primary benefit of this concept is safety because it prevents unauthorized vehicles from driving up to a BRT station. This control mechanism also reduces, or eliminates, confusion.

Implementation Phasing and Layout

It is recommended that this system be implemented in Phase III at the entrance ramps to the following BRT stations:

- West Park
- Wiehle Avenue
- Reston Parkway
- Herndon/Monroe

Concurrently, transponders should be installed on 45 forty-foot BRT buses and 23 articulated BRT buses. This is the total number of BRT buses recommended in the Dulles Corridor Transportation Study for Phase III. For the cost estimate, it was assumed that there would be two transponder reader assemblies and two gate assemblies per BRT station (one per entrance ramp for each travel direction).

BRT Precision Docking System

A precision docking system assists drivers in correctly placing a transit vehicle at a stop or station. For example, the system would automatically position a bus, or assist a bus driver in positioning a bus, at a BRT station during a stop. The system designates where the bus must stop along the length of the BRT station platform. The technology used typically includes magnetic tape or nails along the roadway (e.g., Dulles Airport Access Road and BRT station entrance ramp), vehicle sensors and actuators, and a driver display.

The precision docking concept improves docking efficiency and precision, and saves time loading passengers. Passenger queue locations can be marked on station platforms that may reduce boarding times. The concept is especially beneficial to passengers in wheelchairs because the gap between the vehicle and station platform is controlled. It is also helpful to the visually impaired because the stop location is consistent. The system may also reduce damage caused from bus collisions with station platforms during stops.

Implementation Phasing and Layout

It is recommended that the precision docking system be implemented at the following BRT stations in Phase III:

- West Park
- Wiehle Avenue
- Reston Parkway
- Herndon/Monroe

Concurrently, precision docking equipment should be installed on 45 forty-foot BRT buses and 23 articulated BRT buses. This is the total number of BRT buses recommended in the Dulles Corridor Transportation Study for Phase III.

Precision docking equipment is not necessary for rail operations because most rail systems have some mechanism for stopping longitudinally along station platforms. In addition, lateral distance is not a problem because the distance between the train and station platform is fixed.

Transit Vehicle Mechanical Safety Monitoring and Maintenance

This concept automatically monitors the condition of transit vehicle engine components, via engine sensors, and provides warnings if failures occur. The system may be linked to the transit vehicle tracking system to log the location and time of an incident, and to transmit real-time data to the transit management center or depot. For example, if the oil temperature and pressure of a bus went outside a specified range, a warning would be provided to the bus driver and/or relayed to the central transit management center and/or depot via the AVL system.

This concept also provides vehicle diagnostics and manages the maintenance records of transit vehicles. It may simply consist of a computer spreadsheet to record and monitor maintenance activity or be a sophisticated computerized diagnostic system. Engine data, stored in the vehicle's processor, may be downloaded onto the central system for analysis. Major components of the transit vehicle mechanical safety monitoring and maintenance system include the following:

- Engine sensors and on-board processor
- Driver warning interface
- Central computer hardware and maintenance scheduling software

This concept improves vehicle maintenance and thus improves operations. It increases equipment reliability, safety, and efficiency. Reliable and consistently good transit service increases customer satisfaction.

Implementation Phasing and Layout

It is recommended that transit vehicle mechanical safety monitoring and maintenance equipment be installed on 116 forty-foot buses and 23 articulated buses in Phase III. This is the total number of buses recommended in the Dulles Corridor Transportation Study for Phase III (54 forty-foot local, 17 forty-foot non-BRT express, 45 forty-foot BRT express, and 23 articulated BRT express buses total). It is recommended that the central computer hardware and maintenance scheduling software be deployed at the depot.

Traffic Signal Priority (TSP) Study

Traffic signal priority holds a traffic signal green, or turns it green earlier than scheduled, to provide right-of-way to transit vehicles. Signal priority is typically granted to transit vehicles running behind schedule. The number of passengers on board the transit vehicle may also be used as a criterion in determining whether or not to grant the transit vehicle priority. This system can be linked to the transit vehicle tracking system to determine if the vehicle is running behind schedule. It could also be linked to an APC system to determine the number of passengers onboard the vehicle. One of several technologies can be used for communications between the transit vehicle and traffic signal controller. These include, but are not limited to, radio frequency, spread spectrum radio, infrared, and optical communications. One of several control strategies can be used for TSP signal timing. These include, but are not limited to, conditional preemption, green extension/red truncation, HOV-weighted OPAC, queue jumping, and lift.

Traffic signal priority improves schedule adherence. It also reduces run times, which allows transit agencies to serve routes with fewer buses while retaining frequency (a cost savings to transit agencies), or serve routes with the same number of buses while increasing frequency. On-time buses and a reduced run time make transit more attractive to travelers. Traffic signal priority may be highly political, however, because altered signal phasing may interfere with normal traffic flow.

Implementation Phasing and Layout

It is recommended that a traffic signal priority study be conducted in the Dulles Corridor during Phase II. The study should be based on the findings of the on-going regional signal priority study, and it should consist of a pre-study, installation and operation of TSP at the identified intersections, and an evaluation of the system. The pre-study task should include reviewing the regional study findings and further defining the regional study scope, and determining the locations and strategies for traffic signal priority in the Corridor. For cost estimation purposes, the following suggestions are made:

- Deploy TSP at 9 intersections in the Corridor
- Implement 12 buses with TSP equipment

The cost of the analysis and report are included in the study cost estimate.

Emergency Response

The emergency response concept provides automatic location of transit police vehicles and computerized dispatching to assist dispatchers in deploying appropriate resources to an emergency quickly and efficiently. This concept may be coordinated with transit vehicle tracking / on-board transit security, transit facility security, and parking facility security. For example, a silent alarm received from the on-board transit security system, and a bus's location, determined by the transit vehicle tracking system, may be automatically provided to the transit police or other authorities. Likewise, the authorities may be directly informed of emergencies in transit stations and parking garages.

The emergency response concept included here is for the designated transit operator. The emergency response concept included in the coordination concepts ties the emergency response systems of several agencies (e.g., VDOT, Virginia State Police, and local police, fire, and emergency management services) together for inter-agency coordination of incidents.

The major components of the emergency response system are provided below. It is recommended that GPS technology be used for location referencing. It is assumed that the current radio system is used for communications.

- GPS receiver (located in police vehicle)
- Mobile data terminal (located in police vehicle)
- Monitoring & dispatching workstation and software (central hardware and software)

Emergency response provides faster response to emergencies, which reduces the impact of incidents.

Implementation Phasing and Layout

It is recommended that 25 emergency vehicles be equipped with GPS AVL in Phase III. At the same time, the central AVL/CAD system should be deployed at the transit agency's emergency management center or transit management center.

Cost Estimates

Exhibit 9 presents cost estimates for the operations package implementation concepts based on the recommended implementation phasing. The capital cost value is the estimated cost to implement the specified system during the phase. The capital cost includes hardware, firmware, software, installation, and integration costs. It does not include communications costs. The annual O&M value is the estimated maximum cost to operate and maintain the specified system per year during the specified phase. Details of the cost estimates, along with assumptions, are presented in the Appendix.

Exhibit 9. Operations Package Cost Estimates (in dollars)

ITS Concept	Phase II (2001-2003)		Phase III (2003-2006, 2010)		Phase IV (2006-)		
	Capital	Annual O&M	Capital	Annual O&M	Capital	Annual O&M	Total Capital Cost
BRT Station Lane Access Control	0	0	1,084,250	433,700	0	N/A	1,084,250
BRT Precision Docking System	0	0	1,725,000	690,000	0	N/A	1,725,000
Transit Vehicle Mechanical Safety Monitoring & Maintenance	0	0	428,000	171,200	0	171,200	428,000
Traffic Signal Priority Study	218,125	47,250	0	N/A	0	N/A	218,125
Emergency Response	0	0	1,175,000	587,500	0	587,500	1,175,000
						Grand Total	4,630,375

It should be noted that there will not be operations and maintenance costs for the BRT station lane access control during Phase IV. This is because BRT will not be operating after 2010. Likewise, the precision docking system will only be used for BRT and will not be operating after 2010. The traffic signal priority study will be conducted during Phase II. It is not known at this time whether or not TSP will become an operational system in later phases.

Implementation Phasing Summary

Exhibit 10 summarizes the recommended implementation phasing of the operations package concepts. The bars represent the phase in which the specified system should be implemented. Implementation includes equipment procurement, installation, integration, and acceptance testing.

Exhibit 10. Implementation Phasing for Operations Package Concepts

ITS CONCEPT	PHASE II (2001-2003)	PHASE III (2003-2006, 2010)	PHASE IV (2006-)
BRT Station Lane Access Control		■	
BRT Precision Docking System		■	
Transit Vehicle Mechanical Safety Monitoring & Maintenance		■	
Traffic Signal Priority Study	■		
Emergency Response		■	