DULLES CORRIDOR RAPID TRANSIT PROJECT
TECHNOLOGY IMPLEMENTATION PLAN

Dulles Corridor Task Force

Technology Task Group &
Virginia Department of Rail and Public Transportation

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December 30, 1999

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Executive Summary

The Dulles Corridor Technology Task Group represents the full range of stakeholders in the Dulles Corridor's transportation system. The group's aim is to assess how advanced technology can help minimize congestion, improve mobility, enhance safety and protect the environment.

This report presents the findings and recommendations of the Group, including an implementation plan that suggests Intelligent Transportation Systems (ITS) technology concepts for the Dulles Corridor Rapid Transit Project.

PROJECT DESCRIPTION

Population and job growth along the Dulles Corridor is continuing to exceed expectations. With an increased presence of information technology firms making Northern Virginia home, growth is expected to continue at a rapid pace. Dulles International Airport is also experiencing continued high growth in passenger traffic. With this in mind transportation agencies in this region have embarked on a multi-modal transit program that includes express bus and Bus Rapid Transit (BRT) services as interim steps leading to the ultimate implementation of rail in the Dulles Corridor.

Providing oversight and direction to this effort is the Dulles Corridor Task Force. Chaired by Commonwealth Transportation Board member, J. Kenneth Klinge, the Task Force is made up of executives from stakeholder transportation and planning agencies in the Dulles Corridor. The Task Force has subcommittees to recommend funding, service delivery, technology and management of the project. The Technology Task Group developed recommendations for the application of advanced technology in the Dulles Corridor project.

> The goal of the Dulles Corridor Task Force - Technology Task Group is to apply technology where there is a payoff. Recommended technologies must make a real difference in the Dulles Corridor through increased ridership, reduced travel times, greater reliability, reduced cost and greater security and safety.

Representation on the Dulles Corridor Task Force - Technology Task Group includes:

- Northern Virginia Transportation Commission
- VA Department of Rail and Public Transportation
- Virginia Department of Transportation
- Washington Metropolitan Area Transit Authority
- Washington Airports Task Force
- Fairfax County
- Loudoun County
- Dulles Area Transportation Association
- Metropolitan Washington Airports Authority

To provide rapid transit service in the Corridor, the Dulles Corridor Task Force developed an implementation program, which consists of the following four phases:

- **Phase I: Express Bus** – Starting in 1999, provides express bus service and new bus routes within Fairfax County serving Herndon/Monroe and Wiehle Avenue to Tysons Corner and the West Falls Church Metro station.
- **Phase II: Enhanced Express Bus** – Starting in 2001, provides additional bus routes and buses serving eastern Loudoun County and the City of Fairfax to Tysons Corner and the West Falls Church Metro station.
- **Phase III: Bus Rapid Transit** – Starting in 2003, provides new BRT routes and buses serving eastern Loudoun County, Dulles Airport, Reston/Herndon, Tysons Corner, and the West Falls Church Metro station.
- **Phase IV: Rail** – Starting in 2006, provides rail from Metrorail's Orange line East Falls Church station through Tysons Corner. Starting in 2010, extents rail from Tysons Corner to Reston/Herndon, Dulles Airport, and Routes 606 and 772 in Loudoun County. Although Phase IV is proposed in two parts, it is the intention of the Task Force to complete rail all the way to the vicinity of Route 772 in Loudoun County without delay.

RECOMMENDATIONS

The recommended concepts are summarized in four concept packages: **Traveler Information, Electronic Payment, Safety and Security,** and **Operations**. A description, capital cost estimate, annual operating cost estimate, benefits and recommended phase of implementation (according to the project's four-phase program) are provided for each concept. Cost estimates are provided 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.

Traveler Information Package

The traveler information package includes technology concepts to improve information provided to transit travelers. Information on parking availability, bus/train arrival and departure information and in-vehicle next-stop information is proposed. It is expected that increases in customer convenience will occur, saving passengers time, relieving stress and uncertainty, while helping travelers make smart travel decisions. The outcome of this effort will make the transit services in the corridor more user friendly and build customer loyalty and confidence.

Transit Vehicle Tracking

Description: Global Positioning System (GPS) equipment installed on buses to pinpoint their location.

Total Capital Cost Estimate: $3.9 million

Annual Operations & Maintenance Cost Estimate: $2.0 million

Benefits: Provides more efficient and on-time operations, basis for transit traveler information (in-vehicle and wayside) and emergency response systems

Implementation Phase: Phases II, III, & IV

Parking Facility Information

Description: Dynamic (variable) message signs located at and near parking facilities showing real-time parking availability

Total Capital Cost Estimate: $2.2 million

Annual Operations & Maintenance Cost Estimate: $915K

Benefits: Convenience, saves customers time, relieves stress/uncertainty

Implementation Phase: Phases II, III, & IV

Wayside/In-station Traveler Information

Description: Next bus/train arrival and departure information

Total Capital Cost Estimate: $442K

Annual Operations & Maintenance Cost Estimate: $178K

Benefits: Convenience, saves customers time, relieves stress/uncertainty

Implementation Phase: Phases III & IV

In-Vehicle Traveler Information

Description: Next stop information

Total Capital Cost Estimate: $2.2 million

Annual Operations & Maintenance Cost Estimate: $879K

Benefits: Convenience, relieves stress/uncertainty, complies with Americans with Disabilities Act, and improves operational service

Implementation Phase: Phases III & IV

Electronic Payment Package

The electronic payment package includes ITS concepts which will make fare payment for transportation and parking more convenient for patrons as well as creating operational efficiencies for agencies. An increase in customer convenience will occur by providing one account for all electronic fare payment transactions for transportation and parking services in the corridor. This will allow for cost savings to customers and agencies. It will also save customers time by providing fast and easy access in and out of the transportation systems that require payment.

Electronic Fare Payment

Description: Pay transit fare with WMATA's SmarTrip card or other electronic media

Total Capital Cost Estimate: $7.3 million

Annual Operations & Maintenance Cost Estimate: $4.2 million

Benefits: Convenience, fast access in/out of the system, efficient collection for agency

Implementation Phase: Phases III & IV

Parking Facility Payment
Description: Pay parking fee with WMATA SmarTrip card, VDOT Smart Tag transponder or other electronic media
Total Capital Cost Estimate: $4.2 million
Annual Operations & Maintenance Cost Estimate: $2.6 million
Benefits: Convenience, fast access in/out of the system, efficient collection for agency
Implementation Phase: Phase III

In July 1999, the Federal Transit Administration (FTA) issued a Request for Proposal (RFP) for a regional demonstration of a coordinated electronic toll collection and electronic fare payment system. In response to the RFP, WMATA, on behalf of the metropolitan Washington region, submitted a proposal on October 25 ,1999 for a universal electronic payment system in the region, incorporating the electronic collection of tolls, transit fares, and parking fees into one system. The Dulles portion of the proposal combines the Dulles Toll Road toll collection, transit fare and parking fees, and Dulles Airport parking fees. The goal is to provide customers with one account for all transactions.

The test transactions will be done through one clearinghouse. The anticipated benefits include faster access through systems for the user and cost savings for the agencies through increased usage of electronic fare payment and operation of one clearinghouse as opposed to three. FTA will award $2.3 million in January 2000 to one proposer. Five proposals are being considered by FTA. If the WMATA proposal is selected, the test demonstration will be conducted within 24 months of the notice to proceed. The test demonstration could provide a starting point from which to implement a universal electronic payment system in the Corridor.

Security/Safety Package

The security/safety package includes technology concepts that will enhance the perceptions of patrons about security through surveillance technology. The use of video cameras is proposed in each of these concept applications. It is expected that by implementing security technology, it will relieve customer stress and uncertainty about using transit. It will also allow for cost savings by deterring vandalism and other criminal activity.

<u>On-board Transit Security</u>

Description: Two static video cameras and recorders per bus

Total Capital Cost Estimate: $921K

Annual Operations & Maintenance Cost Estimate: $368K

Benefits: Enhances customer safety, provides cost savings through reduced crime

Implementation Phase: Phase III

<u>Transit Facility Security</u>

Description: Video cameras at each station

Total Capital Cost Estimate: $281K

Annual Operations & Maintenance Cost Estimate:$112K

Benefits: Enhances customer safety, provides cost savings through reduced crime

Implementation Phase: Phases III & IV

<u>Parking Facility Security</u>

Description: Video cameras at each lot

Total Capital Cost Estimate: $407K

Annual Operations & Maintenance Cost Estimate: $163K

Benefits: Enhances customer safety, provides cost savings through reduced crime

Implementation Phase: Phase III

Operations Package

The operations package will allow agencies to better manage assets and operation of equipment. Included are technology concepts to improve bus docking and vehicle maintenance. Also included are concepts to automate lane access control and emergency response. A traffic signal priority study is proposed along the corridor for a limited number of signals adjacent to the Dulles Toll Road.

These concepts will improve travel times by reducing dwell times at stations and traffic signal delays. Implementation of this technology will improve equipment reliability, reduce the number of delays due to equipment failure and will improve response time to emergencies or incidents.

Bus Rapid Transit (BRT) Station Lane Access Control

Description: Transponder gate access to median stations

Total Capital Cost Estimate: $1.1 million

Annual Operations & Maintenance Cost Estimate: $434K

Benefits: Enhances safety, allows only buses to enter/exit BRT median stations

Implementation Phase: Phase III

BRT Precision Docking System

Description: Docking at BRT median stations to provide for easy passenger access/egress to/from BRT buses

Total Capital Cost Estimate: $1.7 million

Annual Operations & Maintenance Cost Estimate: $690K

Benefits: Safety, efficiency, saves time, easier boarding/alighting for disabled passengers

Implementation Phase: Phase III

Transit Vehicle Monitoring/Maintenance

Description: Sensors on vehicles connected to a central control facility and maintenance schedule software

Total Capital Cost Estimate: $428K

Annual Operations & Maintenance Cost Estimate: $171K

Benefits: Equipment reliability, safety, and efficiency

Implementation Phase: Phase III

<u>Traffic Signal Priority Study</u>

Description: Study implementing traffic signal priority at multiple locations along the Dulles Corridor to enhance bus service

Total Capital Cost Estimate: $218K

Annual Operations & Maintenance Cost Estimate: $47K

Benefits: Enhances operations for schedule adherence

Implementation Phase: Phase II

<u>Emergency Response</u>

Description: Coordinated response to emergencies using global positioning satellites

Total Capital Cost Estimate: $1.2 million

Annual Operations & Maintenance Cost Estimate: $588K

Benefits: Faster response times, saves time

Implementation Phase: Phase III

PROCESS

The process used to derive the recommendations was methodical and straightforward. Starting with a comprehensive set of Market Package concepts defined by the USDOT National ITS Architecture, the study team pared down the list of concepts based on approved evaluation criteria, logic checks with existing or planned programs, and costs. The process included:

- Using the National Architecture to identify relevant market packages to ensure a comprehensive approach.
- Developing a list of applicable ITS concepts (50 concepts identified).
- Identifying existing or planned applications in the region that would affect ITS applications along the Dulles Corridor.
- Applying evaluation criteria listed below to the preliminary list of technology concepts to identify those concepts with the greatest potential return on investment:

- Consistency with the Technology Task Group policy statement
- Technical feasibility
- Customer benefits
- Operator benefits
- Compatibility and integration with existing/planned systems
- Cost effectiveness
- Community/agency impacts

➢ Organizing technology concepts into four categories for further review using capital and operations cost, and service delivery variables in order to focus on those to be implemented as part of the Dulles plan.

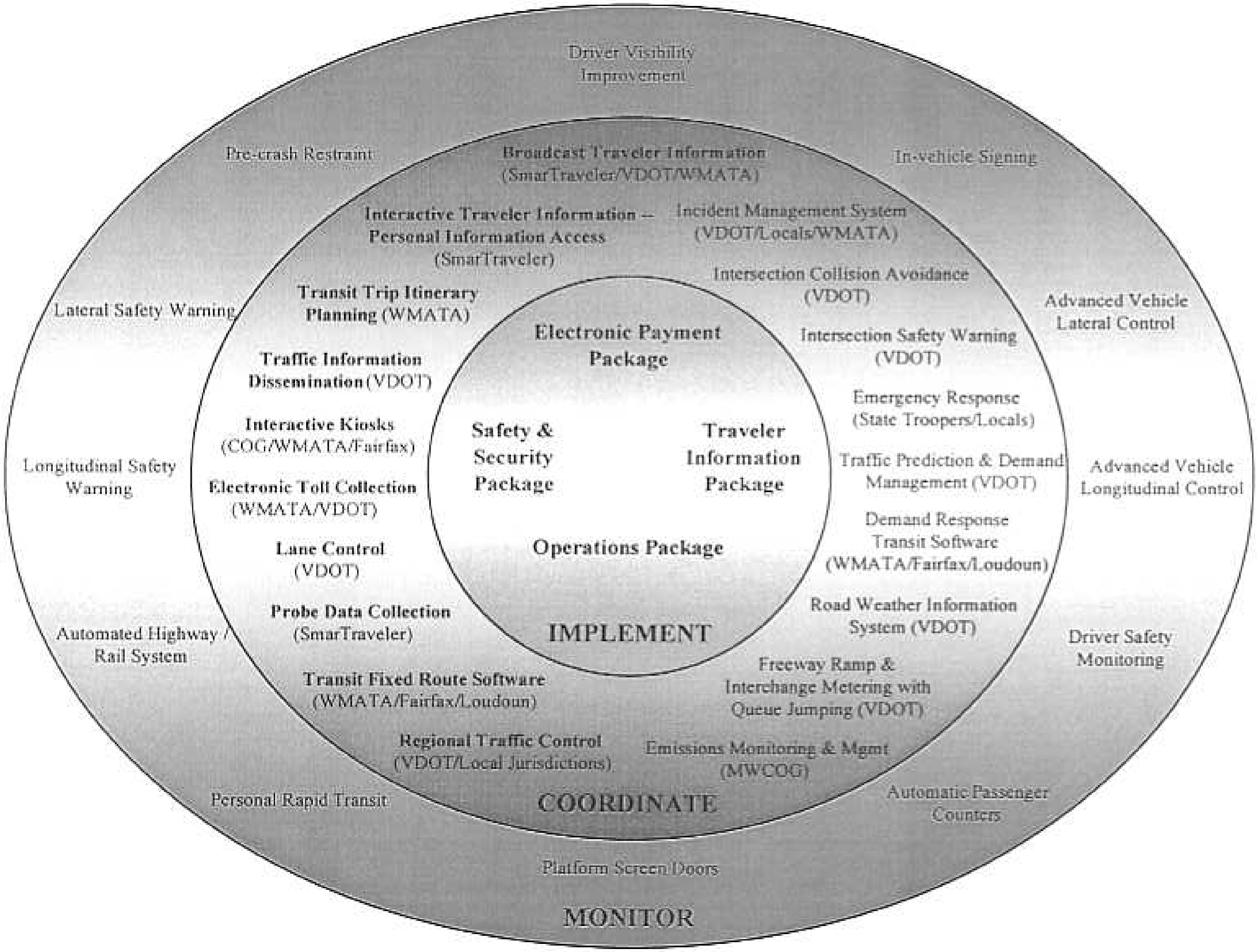
➢ Developing detailed capital and operating cost estimates for each phase of implementation.

➢ Coordinating recommended technologies with the Service Delivery Task Group.

➢ Providing recommendations to the Dulles Corridor Task Force.

Conducting the study in this comprehensive manner gave the study team a picture of the Dulles Corridor implementation recommendations in the context of regional efforts to implement ITS. Technology concepts were categorized into three areas. Concepts are either to be *implemented* as part of the Dulles project, *coordinated* as part of the Dulles project, or *monitored* along with the Dulles project. The following graphic, Exhibit 1, displays these concepts. There are 12 concepts that are proposed to be monitored. There are 19 concepts with which the Dulles project will need to coordinate. Of the 19 concepts, 10 concepts are existing (in bold) and 9 are proposed. There are 14 concepts that the Dulles project will implement, which are grouped into the four packages shown in the diagram.

Exhibit 1. Dulles Corridor ITS Concepts



ISSUES & NEXT STEPS

Several implementation issues were identified during the course of the project. These issues, and recommended actions to address these issues, are provided below.

- It is recognized that coordination is needed across transportation agencies and represented levels of government in order for effective integration of technology to occur. Therefore the Technology Task Group will be working to enhance understanding about the technology recommendation.
- The Technology Task Group recognizes that rapid changes in technology may cause obsolescence within a short period and new technologies not imagined today may be available within the next few years. The Group will monitor evolving technologies for potential adaptation to Corridor transit systems, including feeder transit service. The Group will also monitor the development of standards in ITS in order to maximize the return on investments and ease integration.
- With the approval of the Dulles Corridor Task Force, the Technology Task Group will work with the Service Delivery Task Group during the preliminary engineering/NEPA process on a system planning effort to define system requirements for the proposed technology concepts in conjunction with regional and statewide architecture efforts. Work will also commence in parallel with the Funding Task Group to identify and secure appropriate funding sources.
- Because little quantitative information is available on the pay-off from investments in advanced technology, follow-up should occur after implementation of these recommended investments to measure their performance.
- As can be seen from the detailed description that follows, not all advanced technology investments are isolated, stand-alone systems. Many are suited for implementation as part of larger, standard transportation investments. Accordingly, implementing agencies should routinely consider ITS as part of their standard projects and set aside portions of those project budgets for monitoring, coordinating and implementing future technologies.
- The cost estimates will be refined and the cost effectiveness of concepts will be measured as the project proceeds towards implementation.

Background

The Dulles Corridor is located in Northern Virginia. The corridor has become one of the most recognized places in the country for technology and Internet-based companies to locate. The corridor runs approximately 30 miles from West Falls Church to Leesburg, with major activity centers along the way including Tysons Corner, Reston/Herndon, Dulles International Airport and eastern Loudoun County.

The importance of this corridor to the economic vitality to the region and the Commonwealth is significant. Growth along the corridor has increased beyond the pace of transportation improvements, and in all likelihood will continue. The communities of Tysons Corner, Reston/Herndon, and Dulles have long discussed rapid transit opportunities to serve their communities in light of this growth.

In 1997, the Dulles Corridor Transportation Study was completed and resulted in a Preferred Alternative adopted by the Commonwealth Transportation Board (CTB) that called for:

> *"... A seamless rail extension from the East Falls Church Metro station to the vicinity of Route 772 in Loudoun County."*

The CTB further called for developing a funding plan and near-term implementation of enhanced express bus services.

Following the completion of the study, an $86 million earmark was secured by Congressman Frank Wolf and Senator John Warner in TEA-21 for BRT and preliminary engineering for rail. To date, $42 million of the earmark has been appropriated.

On July 6, 1998, Virginia Secretary of Transportation Shirley J. Ybarra established the Dulles Corridor Task Force, chaired by J. Kenneth Klinge of the Commonwealth Transportation Board. The Task Force includes the chief executives of Fairfax and Loudoun counties, City of Falls Church, Town of Herndon, several advisors appointed by the Chairman, and the heads of six public agencies:

- Virginia Department of Rail and Public Transportation (DRPT)
- Washington Metropolitan Area Transit Authority (WMATA)
- Metropolitan Washington Airports Authority (MWAA)
- Northern Virginia Transportation Commission (NVTC)
- Northern Virginia Planning District Commission (NVPDC)
- Virginia Department of Transportation (VDOT) Northern Virginia District

The mission of the Task Force is:

> *Undertake the phased implementation of rail service in the Dulles Corridor, as a single project, beginning with dedicated express bus service as a step to designing and implementing a bus rapid transit system. On a parallel basis, this*

task force will facilitate the engineering, environmental and financial actions necessary to begin rail operations.

In July 1999, the Task Force conducted a study of the potential application of a BRT system in the Dulles Corridor as a supplement to the 1996 Dulles Corridor Transportation study. The supplemental study analyzed the application of BRT in a phased approach to eventual rail service. Efforts are now underway to secure funding and move the project into the preliminary engineering and the National Environmental Policy Act (NEPA) process. The project has four phases as follows:

- **Phase I: Express Bus** – Starting in 1999, provides express bus service and new bus routes within Fairfax County serving Herndon/Monroe and Wiehle Avenue to Tysons Corner and the West Falls Church Metro station.
- **Phase II: Enhanced Express Bus** – Starting in 2001, provides additional bus routes and buses serving eastern Loudoun County and the City of Fairfax to Tysons Corner and the West Falls Church Metro station.
- **Phase III: Bus Rapid Transit** – Starting in 2003, provides new BRT routes and buses serving eastern Loudoun County, Dulles Airport, Reston/Herndon, Tysons Corner, and the West Falls Church Metro station.
- **Phase IV: Rail** – Starting in 2006, provides rail from Metrorail's Orange line East Falls Church station through Tysons Corner. Starting in 2010, extents rail from Tysons Corner to Reston/Herndon, Dulles Airport, and Routes 606 and 772 in Loudoun County. Although Phase IV is proposed in two parts, it is the intention of the Task Force to complete rail all the way to the vicinity of Route 772 in Loudoun County without delay.

The Task Force oversees the identified four-phased implementation plan, and is developing a funding strategy and coordinating technical issues through a number of subcommittees. One of these subcommittees is the Dulles Corridor Technology Task Group, chaired by Richard Taube, Executive Director of the Northern Virginia Transportation Commission. Their mission is to define and recommend a plan for the use of technology to enhance transportation systems along the Dulles Corridor. This group has adopted seven policy statements with regard to their mission as follows:

1. The overall goal is the creation of a new 21st Century transportation environment in the Dulles Corridor by the year 2010. A building-block approach should be adopted for the application of current and evolving technologies.
2. Technology should be applied where there is a pay-off for the customer or the operator.
3. Risk should be held commensurate with the time scale and potential pay-off.
4. Dulles Corridor systems should have a high degree of compatibility and integration with all modes of connecting systems.
5. The objective and time scale for each technological application should be clearly defined and linked to a system of "payment by results," with contractors.

6. It should be recognized that even "proven" technologies would require some development to adapt them to specifics of the Dulles Corridor system.

7. The Dulles Corridor Task Force should not be deterred by long term evolution requirements if the potential gain to the traveler and taxpayer is substantial.

The operator of the new service is yet undefined. WMATA is the largest and most comprehensive transit provider in the region and may operate the service. In addition to WMATA, Fairfax County and Loudoun County currently operate transit service along the corridor. As part of Virginia's Public Private Partnership Act, two private proposals to operate the Dulles service have been submitted and are currently under review.

Process

A straightforward process was used to derive viable, comprehensive and integrated ITS concepts. The process used a step by step approach to pare down concepts. Approved evaluation criteria, costs, and other coordinated efforts were used to select concepts. The process was very effective in keeping the Technology Task Group informed and involved. The process was comprehensive and based upon the USDOT National ITS Architecture, Version 2.0.

The USDOT National ITS Architecture is a framework for the integration of ITS into the transportation system. In basic form the "Architecture" provides comprehensive information about ITS. A comprehensive list of ITS concepts, applicable to the Dulles Corridor, was developed from the National ITS Architecture market packages. Market packages provide an accessible, deployment oriented perspective defining specific technology application concepts.

USDOT has presented Interim Guidance on consistency with the National ITS Architecture and Standards. The Transportation Equity Act for the 21st Century (TEA-21) requires that ITS projects receiving federal-aid funding from the Highway Trust Fund including the Mass Transit Account conform to the National Architecture and Standards. By approaching this project from the National Architecture Market Package perspective, the approach taken for this project is in conformance with the Architecture.

To gain a greater level of specificity for this project some of the concepts were broken out in further detail from their associated market package or were tailored to this project. For example, the concepts of wayside/in-station traveler information (e.g., variable message signs at transit stops), automated public address system, in-vehicle traveler information (automated next-stop annunciation), and on-board electronic destination signs were broken out in greater detail from the market package, Transit Traveler Information. Other concepts, such as transit vehicle tracking and broadcast traveler information, remained at the level of detail as defined in the National ITS Architecture market packages. Some of the concepts, such as platform screen doors and precision docking, are unique and are not contained within an existing market package.

Each market package was reviewed for application to this project. Existing or planned ITS applications in this region were reviewed and documented as to their effect on the Dulles project. Market package applications then became ITS concepts. These project concepts were evaluated against weighted criteria and ranked. They were then screened further using a logic and expert panel check. As a result of the prioritization process, the list of concepts was essentially broken into the following three groups:

- Implement: Those recommended for implementation as a part of the Dulles Corridor Rapid Transit project with the greatest potential for payoff.
- Coordinate: Those already proposed or implemented by candidate transit operators in the Corridor. Those that are functions of a traffic agency or other agency.
- Monitor: Those that could be implemented beyond the time period of the project.

After the concepts were prioritized, the top-rated ITS concepts were grouped into the areas of electronic payment, safety and security, traveler information, and operations. For each group, detailed capital and operating costs estimates for each phase of implementation were developed. The cost information was coupled with the phases of the service delivery plan. The Technology Task Group coordinated efforts with the Service Delivery Task Group in development and review of the detailed implementation plan. The combined implementation plan for technology application to the Dulles project was presented to the Dulles Corridor Task Force and recommended for approval.

Coordination Concepts

Some ITS concepts should be deployed in the Dulles Corridor by an agency or organization other than the Corridor's designated transit operator. These ITS concepts are often intermodal in nature, and require coordination with the designated transit operator. In general, the coordination ITS concepts did not rate as high a priority as those recommended for implementation by this project. However, the concepts are applicable to the Corridor and provide many benefits.

The importance of the coordination concepts is that many of them are currently employed in the Washington, DC region, and thus the foundation of an ITS infrastructure has already been laid in the Dulles Corridor. In other words, it is not necessary to start from scratch in developing an ITS system in the Corridor. The existing ITS elements in the region provide a platform upon which to build and expand ITS in the Corridor. This provides a cost efficient approach in creating an ITS system in the Corridor. It is important to note that unreasonable delay must be avoided in achieving coordination for the deployment of technologies which are critical path items for the overall Dulles Corridor project.

In addition to the operational ITS concepts, other concepts beneficial to the Corridor were identified and are recommended for deployment. These concepts, along with the operational concepts, comprise the coordination concepts, implementation concepts, and monitor concepts which are presented in the remainder of the document.

PRIMARY COORDINATION CONCEPTS

The ITS concepts that have the greatest potential for coordination in the Dulles Corridor are discussed below. These concepts are currently employed in the region, and are shown in bold in the middle ring of Exhibit 1.

Broadcast Traveler Information

This concept provides non-interactive traveler information over the telephone, television, and radio. Information includes travel advisories and reports, general transit information, video footage, and public service announcements. The information is broadcast or transmitted to customers; customers are not provided a list of options from which to respond.

Bus and rail service status in the Corridor could be provided to an information service provider (ISP), like SmarTraveler, which in turn could broadcast the information along with other transportation information to travelers. Currently, SmarTraveler provides information in this fashion in the Washington, DC area. VDOT and WMATA also broadcast information about their respective systems to travelers in the region.

Interactive Traveler information – Personal Information Access

This concept provides tailored information, such as travel advisories, traffic conditions, transit services, traveler services, ride share/match, parking information, and fare/pricing information, in response to a traveler's request. Information is obtained via personal devices such as touch tone telephones, pagers, and personal computers connected to the Internet. The concept includes interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on the traveler's submitted profile.

Parking and transit information in the Dulles Corridor can be provided to an information service provider, such as SmarTraveler, which in turn provides the information to travelers. SmarTraveler currently provides a variety of transportation information interactively via its telephone service and Internet web site. Other interactive traveler information systems or programs in the area include VRE's Train Information Provider (TRIP) and the City of Fairfax's Travel Demand Management (TDM) Information.

Transit Trip Itinerary Planning

This concept consists of software that generates a transit trip itinerary (route, schedule, and fare information) based on user-specified trip parameters such as trip origin/destination and travel time, and criteria such as fastest route, lowest fare, least number of transfers, and least walking distance. Integration of multiple transit systems is an option. Delivery mechanisms include the Internet and telephone.

WMATA currently has itinerary planning software that its customer service agents use to develop itineraries for customers requesting information over the telephone. WMATA also provides this service on its Internet web site. It would be logical for WMATA to expand its itinerary planning system to include transit service in the Dulles Corridor. It is beneficial to travelers to be able to access one source for regional itinerary information, rather than having to contact multiple transit operators for trips that require transfers between different transit systems.

Traffic Information Dissemination

Traffic information dissemination is the provision of transportation information (congestion, incidents, etc.) to motorists using roadway equipment such as dynamic message signs (DMS) (a.k.a. variable message signs (VMS)) and highway advisory radio (HAR).

VDOT, the District of Columbia, and Maryland State Highway Administration (MdSHA) currently provide travelers information in this fashion. VDOT could implement DMS signs and HAR in the Dulles Corridor to alert drivers of major incidents. The designated transit operator could coordinate with VDOT and provide VDOT information for transit-related announcements over the HAR system and DMS signs. For example, VDOT DMS signs could suggest that drivers board a bus or train at the next park-and-ride lot to avoid an approaching traffic jam.

Interactive Kiosks

Interactive kiosks provide tailored transportation information in response to a traveler's request. The type of information includes travel advisories, traffic conditions, transit services, traveler services, ride share/match, parking information, and fares/pricing. Kiosks may link to an Internet web site or centrally controlled traveler information database.

Fairfax County, Arlington County, WMATA, and the Metropolitan Washington Council of Governments (MWCOG) currently have or are planning to implement kiosk systems. As stated previously, it is more beneficial and convenient for travelers to be able to access one source for regional transportation information. Therefore, it is recommended that the Dulles Corridor designated transit operator coordinate with WMATA and MWCOG to deploy kiosks in the Dulles Corridor and to provide transit information to these kiosk systems.

Electronic Toll Collection

This technology collects tolls electronically using in-vehicle transponders and readers mounted at tollbooths. It also detects and processes violators automatically using high-speed cameras.

VDOT currently collects tolls electronically on the Dulles Toll Road, and WMATA collects fares electronically on its transit system and in its parking facilities. In addition, MWCOG is conducting a regional electronic payment study and the Federal Transit Administration (FTA) has issued a request for proposals (RFP) for an integrated electronic payment study. It is recommended that the designated transit operator, VDOT, WMATA, and any other agency in the region considering to implement electronic payment, coordinate with one another to develop a universal electronic payment system. This coordination can extend to the I-95 Corridor Coalition's program to implement a universal electronic payment system for tolls along the eastern seaboard. Such a system would increase convenience to travelers by providing one account for all electronic payment transactions in the Corridor. It also saves travelers time by processing transactions quicker and reduces agency costs.

Transit Fixed-Route Software

Transit fixed-route software assists transit properties in planning and operating transit fixed-route services. It performs automatic driver assignment, vehicle monitoring, and routing and scheduling functions. Examples include run-cutting software and computer programs that assist transit planners in developing transit routes and schedules.

WMATA, Fairfax County, and Loudoun County currently use transit fixed-route software for transit planning. It is recommended that one or more of these existing systems be expanded to include transit service in the Dulles Corridor.

Probe Data Collection

Probe data collection uses vehicles as a means of collecting traffic data (e.g., vehicle speeds). This approach is an alternative to the "traffic network data collection" concept. Most probe data collection systems use electronic toll collection technology to collect traffic data. Another method uses wide-area wireless communications between vehicles and an ISP.

Through the Road Reporter program, drivers in the Washington, DC area can register with SmarTraveler and become "probes" by reporting traffic incidents and congestion. The Corridor's designated transit operator could participate in this program and have bus drivers report incidents. As an alternative, the designated operator could coordinate with VDOT and equip its buses with a Smart Tag transponder. Transponder readers could be deployed along certain roadways in the Corridor to measure vehicle speeds in the Corridor. VDOT is not currently practicing probe data collection, and implementation of probe data collection in the Corridor would require a VDOT policy decision.

Lane Control

This concept controls use of surface street and freeway lanes via electronic signage. Examples include dynamic lane closure and HOV signs.

VDOT currently uses lane control signs on I-66 outside the Beltway for peak period HOV and shoulder usage. VDOT could deploy lane control signage in the Dulles Corridor to reserve lane usage for buses during peak periods (the system could operate on a fixed-time basis). Lane designation and control strategies should be coordinated with the Metropolitan Washington Airports Authority and VDOT.

Regional Traffic Control

Regional traffic control provides coordinated, interjurisdictional control of traffic signals (e.g., coordinated traffic signal control on arterial roadways that cross jurisdictional boundaries).

Agencies involved in traffic control and management would provide this function. In the Dulles Corridor, this includes VDOT and local jurisdictions. Transit service in the Corridor can benefit from the regional traffic control strategy through decreased route run times. Coordinated signals increase throughput and decrease the number of unnecessary stops at red lights. The designated transit operator should coordinate closely with VDOT and the local jurisdictions to help identify arterials for regional control of traffic signals.

OTHER COORDINATION CONCEPTS

The following ITS concepts also require coordination for their implementation and should be implemented by an agency or organization other than the designated transit operator. These concepts have less opportunity for coordination (than those discussed previously) and are less applicable to transit service in the Dulles Corridor. They are the remaining (non-bold) concepts shown in the middle ring of Exhibit 1. A brief description and an example of each of these concepts is provided below.

- **Incident Management System** — Detects, verifies, and implements response to incidents. Provides electronic communication among transit agencies, traffic agencies, and emergency management service providers for coordinated response and management of incidents. Example: Using the VDOT traffic management center to manage incidents (incident detection, verification, response, and recovery) in the Dulles Corridor.
- **Intersection Collision Avoidance** — Determines probability of collision and provides warnings to vehicles. Example: A system that prevents perpendicular collisions at intersections.
- **Intersection Safety Warning** — Provides the vehicle operator with a warning of potential hazards at an intersection. Example: A system that warns drivers of potential perpendicular collisions at intersections.
- **Emergency Response** — Provides automatic location of emergency vehicles and computerized dispatching to assist dispatchers in deploying appropriate resources to an emergency quickly and efficiently. Example: The VDOT ALERT initiative.
- **Traffic Prediction and Demand Management** — The collection, storage, and processing of transportation data for historical evaluation, real-time assessment, and forecast of the roadway network performance. Example: Use of travel demand models to monitor and predict travel patterns in a region or corridor. Information produced by the models would be used to manage traffic flow (via traffic control devices such as traffic signals, ramp meters, and lane control signs) and to implement demand management policies.
- **Demand Response Transit Software** — Computer software that assists dispatchers in allocating transit fleet resources to demand response service requests (e.g., taxi, airport shuttle, and paratransit dial-a-ride service). Performs driver assignment, vehicle monitoring, and routing and scheduling of transit vehicles. Provides data processing and information display to assist dispatchers in making optimal use of the transit fleet. Example: Computer programs that assist the transit dispatcher in scheduling and routing transit vehicles for personalized, demand response service. Customer requests are typically made over the telephone.
- **Road Weather Information System** — Collects and analyzes road and weather conditions on or near the roadway. Collected road weather information is monitored to detect and forecast weather-related hazards such as icy road/bridge conditions, dense fog, and approaching severe weather fronts. Information is used to deploy road maintenance resources, and issue location specific warnings and general travel advisories. Example: Monitoring weather conditions on/near the Dulles Airport Access Road from a central traffic management center using weather sensors in/near the roadway.
- **Freeway Ramp and Interchange Metering with Queue Jumping** — Controls the number and timing of vehicles entering a freeway. Helps to reduce or eliminate a surge of vehicles entering the freeway system. High-occupancy vehicles (including transit vehicles) are typically allowed to bypass the metered queue of vehicles. Example: Ramp metering on I-66 and I-395.
- **Emissions Monitoring and Management** — Monitors individual vehicle emissions and general air quality within a corridor or area. Information is used to manage emissions and to implement

environmentally sensitive TDM programs, policies, and regulations. Example: Sensors that monitor exhaust levels of vehicles traveling on the Dulles Toll Road. TDM policies are put into action when emissions levels in the Corridor exceed a certain level. Warnings or citations are given to drivers for vehicles that violate exhaust standards.

IMPLEMENTATION PHASING

The phase of the Dulles Corridor Rapid Transit Project in which each of the coordination concepts is recommended for coordinated implementation or expansion is presented in the following table. The concepts may be implemented over a period consisting of more than one phase. The information in the table, therefore, represents the phase in which the initial implementation or expansion takes place. The implementation phasing is provided as a general guide and is based on potential opportunities for coordination with other agencies, implementation coordination with other ITS concepts (e.g., the implementation concepts), and technology maturity. The primary coordination concepts are in bold.

Phase III has two time period end points (2006 and 2010) because BRT will run between West Falls Church and Loudoun County until 2006, and between Tysons Corner and Loudoun County until 2010. Rail will replace BRT between East Falls Church and Tysons Corner starting in 2006, and between Tysons Corner and Loudoun County starting in 2010. Although rail construction is proposed in two parts (in Phase IV), it is the intention of the Task Force to complete rail all the way to the vicinity of Route 772 in Loudoun County without delay. Exhibit 2 provides a summary of the coordinated concepts with respect to the implementation phasing.

Exhibit 2. Implementation Phasing for Coordination Concepts

COORDINATION CONCEPT	PHASE 1 EXPRESS BUS (1999-2001)	PHASE II ENHANCED EXPRESS BUS (2001–2003)	PHASE III BRT (2003-2006, 2010)	PHASE IV RAIL (2006-)
Broadcast Traveler Information	✓			
Interactive Traveler Information – Personal Information Access	✓			
Transit Trip Itinerary Planning	✓			
Traffic Information Dissemination		✓		
Interactive Kiosks		✓		
Electronic Toll Collection			✓	
Transit Fixed-Route Software	✓			
Probe Data Collection		✓		
Lane Control		✓		
Regional Traffic Control			✓	
Incident Management System	✓			
Intersection Collision Avoidance				✓
Intersection Safety Warning			✓	
Emergency Response			✓	
Traffic Prediction & Demand Management				✓
Demand Response Transit Software			✓	
Road Weather Information System			✓	
Freeway Ramp & Interchange Metering with Queue Jumping		✓		
Emissions Monitoring & Management			✓	

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		■	

Monitor Concepts

Some ITS concepts are applicable to the Dulles Corridor but are technologically immature. However, these technologies are expected to become more reliable and proven over time. A few other concepts are technologically mature but ranked lower than the implementation concepts during the prioritization process (i.e., APCs and platform screen doors). However, their deployment would still be beneficial for the Corridor and their ranking may improve in the future, depending on needs.

These concepts should be monitored over time and should be implemented if it is determined that they are reliable and address the needs of and goals for the Corridor. The monitor concepts are shown in the outer ring of Exhibit 1. A brief description of each concept is provided below.

- **Driver Visibility Improvement** – Enhances driver visibility using an enhanced vision system. For example, infrared vision can be used to improve visibility for a bus driver when he/she is driving in dust, rain, snowstorms, and fog. This technology increases safety. However, the Dulles Corridor rarely experiences severe weather that inhibits driving visibility.
- **In-vehicle Signing** – Provides travel advisory, warning/regulatory, and other driver information through in-vehicle devices. An example includes roadway warnings, such as sharp curves or reduced speeds ahead, provided visually and/or audibly to the bus driver via a heads-up display. The information can help transit drivers operate transit vehicles safely and efficiently. However, information must be very accurate and should not be announced frequently or it will not be useful and viewed as an annoyance.
- **Longitudinal Safety Warning** – Warns driver of a potential rear-end collision. Uses collision sensors on the front and rear of the vehicle to detect impending longitudinal collisions. An example of this concept is a system that warns a bus driver that he/she is following a vehicle too closely. This technology improves safety and decreases costs from accidents.
- **Lateral Safety Warning** – Warns driver of a potential side collision. Uses collision sensors on the sides of the vehicle to detect impending lateral collisions. An example of this concept is a system that warns a bus driver that he/she is about to sideswipe a vehicle in an adjacent lane (in the driver's blind spot) during a lane change. Like longitudinal safety warning, this technology improves safety and decreases costs from accidents.
- **Advanced Vehicle Longitudinal Control** – This concept is one step more advanced than longitudinal safety warning. Rather than warning the driver, it automates speed and headway control functions using collision sensors and vehicle dynamics processing to control the throttle and brakes. For example, this system prevents a bus driver from committing a rear-end collision by taking control of the vehicle. This system needs to be very reliable. Some drivers may not like relinquishing control of the vehicle.
- **Advanced Vehicle Lateral Control** – This concept is one step more advanced than lateral safety warning. Rather than warning the driver, it automates the steering control function using collision sensors, vehicle dynamics, and other sensors to measure the lane position and lateral deviations, and to control steering. For example, this system prevents a bus driver from committing a lateral collision by taking control of the vehicle. Like advanced vehicle longitudinal control, this system needs to be very reliable, and some drivers may not like relinquishing control of the vehicle.

- **Driver Safety Monitoring** – Determines a driver's condition and performance, and warns the driver of potential dangers. For example, the system monitors the physiological conditions of the driver and warns the driver that he/she is too sleepy to operate the vehicle. It warns the driver that he/she is weaving or driving too aggressively. This technology improves safety, but may not be supported by transit drivers. They may view the system as being too restrictive and an infringement on their privacy.
- **Automatic Passenger Counters** – Automatically counts the number of people boarding and alighting a transit vehicle to determine passenger loading. Data are used for planning and analysis purposes, in determining real-time loads (to dispatch additional vehicles during periods of heavy ridership), and sometimes in determining traffic signal priority requests. The system is often linked to an AVL system to mark the location of passenger data. Data may be downloaded to the control center manually or automatically (via vehicle communications system). Technologies include treadle mats and horizontal or vertical infrared beams. This system greatly decreases the time and cost to gather passenger data. However, the accuracy of data is debatable.
- **Platform Screen Doors** – Provides a safety barrier between a platform edge and transitway (prevents passengers from falling from the platform onto the transitway). When the transit vehicle arrives at a stop, the transit vehicle doors line up with the platform screen doors, through which passengers board and alight the transit vehicle. The doors close shortly before the vehicle departs from the station platform. The system may have integral precision docking, or may interface to a pre-existing precision docking system. Platform screen doors improve safety, and conserve energy for enclosed stations (heating and cooling). The system may be applied to rail and BRT stations.
- **Personal Rapid Transit** – Provides direct origin to destination transportation service, on demand, via a fixed-guideway network. Vehicles, which travel on the fixed guideway, are fully automated and accommodate a small group of people (typically one to six passengers). Personal rapid transit increases passenger comfort, convenience, and security, increases service performance, and reduces operating costs. It may be implemented incrementally. Like most of the monitor concepts, personal rapid transit systems have not been widely implemented. A personal rapid transit system could serve as a feeder/distributor system in the Tysons Corner area, the Reston/Herndon area, and the Route 28 Corridor, and serve as a link to the I-66 Corridor.
- **Automated Highway/Rail System** – Automates driving functions (enables "hands-off" operation of a vehicle). For example, this concept provides fully automated operation of private vehicles on freeways and fully automated operation of trains. This technology eliminates incidents due to driver error. It also greatly increases capacity. However, technological and societal issues exist. The technology is immature and travelers may not support a system that takes over full control of a vehicle. The system is likely to be opposed by transit drivers. Advanced vehicle longitudinal and lateral controls are prerequisite technologies.
- **Pre-crash Restraint** – Determines the probability of a collision and, if determined that a collision is within a certain degree of certainty, deploys a pre-crash restraint mechanism to protect the driver and passengers against the collision. A simple example is vehicle air bags. Pre-crash restraint improves safety and saves lives. However, a more sophisticated system than vehicle air bags is currently unavailable.

Technology is developing at a rapid pace these days. For ITS, what may currently be the state of the art may be obsolete in five to ten years. Also, what is not reliable or proven today may be commonplace in the next decade. The market is a major driving force for this. A technology that can provide greater benefits at a reasonable price will tend to be more popular. Take AVL for example. Several technologies can be used to provide AVL and have been around for a while (e.g., ground-based radio, signpost and odometer, dead reckoning). Each has its advantages and disadvantages. However, GPS became the preferred technology after it was fully developed because it was less expensive and provided greater flexibility. Because of some weaknesses (urban canyon effects), however, it is often coupled with another AVL technology (e.g., dead reckoning).

Developing technologies tend to be costly. Research and development costs are recouped during the initial years of implementation. Over time, the cost tends to go down as the market for the technology increases and its use becomes widespread. In addition, cutting edge technologies may be more costly to operate and maintain than proven technologies. New technologies may need tweaking or may need to be repaired more frequently than technologies that have been fully developed.

It is for these reasons that the above ITS concepts should be monitored during the life of the project and beyond. They have great potential and can provide significant benefits, and their cost will more than likely come down as they become mainstreamed.

Funding

Since the implementation of ITS concepts are driven by allocated funds and/or available resources, it is essential to capture funding resources as early as possible during the planning stages. This information helps in identifying those concepts that generate potential early winners for deployment along the corridor. Currently there is great interest in the Dulles Corridor by the Federal Transit Administration, the Commonwealth of Virginia, the Northern Virginia Transportation Coordinating Council, regional transit operators and private companies. Funding of the identified technology concepts will most likely involve each of these stakeholders to some extent. The following are potential sources of funding for capital.

- Special ITS earmarks
- Title I funding – CMAQ, STP, NHS
- State 6-year TIP
- Public/private partnerships

Funding issues related to the establishment of an adequate, dependable, and long-term O&M funding source for ITS continues to be a major challenge facing local and regional agencies. The question is how to provide the additional funds required for operation and maintenance after the initial project capital expenditures have been exhausted and the system is operational. In recent years, public agency funding sources have been squeezed to the point where they have very little supplemental funding available for the O&M costs associated with the deployment of ITS.

The recently approved Transportation Equity Act for the 21st Century (TEA-21) retains O&M funding eligibility originally set forth in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and amended in the National Highway System Act of 1995 as follows:

- The Surface Transportation Program (STP) program can be used to fund the "capital and operational costs for traffic management and control." Eligible operating costs include operational and maintenance system staffing, and the tools required to make a system respond to control strategies effectively. No time limit is set for the use of operational support funding. STP funds are also renewable on a yearly basis, which provides for flexibility in requesting funds for operational activities.
- The National Highway System (NHS) program can be used to fund ongoing operating costs for traffic monitoring, management and control facilities. The term "operating costs for monitoring, management, and control" includes labor costs, administrative costs, costs of utilities and rent, and other costs associated with the continuous operation of ITS. Similar to STP funds, no time limit is set for the use of operational support funding.
- The Congestion Mitigation and Air Quality (CMAQ) fund can be used to fund both capital and operational costs, only if an air quality benefit can be determined. CMAQ funding for operations is, however, limited to a three-year time frame. After this, the improvement is considered part of the "base" transportation network.

The pending Northern Virginia 2020 Transportation Plan recognizes the need to provide sufficient operations and maintenance funding and has included these costs in its funding projections. It also advocates integration of technology funding in its high priority transportation projects.

Issues & Next Steps

Several implementation issues were identified during the course of the project. These issues, and recommended actions to address these issues, are provided below.

- It is recognized that coordination is needed across transportation agencies and represented levels of government in order for effective integration of technology to occur. Therefore the Technology Task Group will be working to enhance understanding about the technology recommendation.
- The Technology Task Group recognizes that rapid changes in technology may cause obsolescence within a short period and new technologies not imagined today may be available within the next few years. The Group will monitor evolving technologies for potential adaptation to Corridor transit systems, including feeder transit service. The Group will also monitor the development of standards in ITS in order to maximize the return on investments and ease integration.
- With the approval of the Dulles Corridor Task Force, the Technology Task Group will work with the Service Delivery Task Group during the preliminary engineering/NEPA process on a system planning effort to define system requirements for the proposed technology concepts in conjunction with regional and statewide architecture efforts. Work will also commence in parallel with the Funding Task Group to identify and secure appropriate funding sources.
- Because little quantitative information is available on the pay-off from investments in advanced technology, follow-up should occur after implementation of these recommended investments to measure their performance.
- Not all advanced technology investments are isolated, stand-alone systems. Many are suited for implementation as part of larger, standard transportation investments. Accordingly, implementing agencies should routinely consider ITS as part of their standard projects and set aside portions of those project budgets for monitoring, coordinating and implementing future technologies.
- The cost estimates will be refined and the cost effectiveness of concepts will be measured as the project proceeds towards implementation.

APPENDIX

1. Dulles Corridor Technology Task Group Policy Statement
2. Dulles Corridor Rapid Transit Technology Concepts Description
3. Dulles Corridor Rapid Transit Technology Concepts Evaluation Matrix
4. Dulles Corridor Rapid Transit Technology Implementation Concepts Phasing
5. Dulles Corridor Rapid Transit Technology Implementation Concepts Costs

Dulles Corridor Technology Task Group Policy Statement

C:dctftech

Dulles Corridor Task Force

Technology Application Criteria and Policy

Technologies derived from the aerospace industry can be used to make transit systems more attractive for the user, increase their on-time performance, improve their efficiency and build towards a whole new 21st century urban transportation environment. Some of these technologies are commonplace in other cities while others are developmental or evolutionary. *These technologies are generically referred to as Intelligent Transportation Systems (ITS) enhancements to conventional highway and transit systems, Personal Rapid Transit (PRT) of which the first is running in prototype form, and longer term Automatic Highway Systems (AHS) which were first demonstrated in 1997.*

The DCIIS plan, for which the Dulles Corridor federal appropriation was obtained, is a phased multi-modal concept, which envisioned the extensive use of appropriate new technologies to attract a high level of transit use from a relatively wealthy suburban area.

The near term technologies are summarized in attachment 1, the far term concepts in attachment 2 and the technology section of the DCIIS plan is attachment 3. The technology choice is broad. The purpose of this note is to define in lay terms the criteria which should be applied to the application of technology in the Dulles Corridor. The Corridor is defined as the actual transportation corridor plus its "trafficshed".

1. ***The overall goal is the creation of a whole new 21st Century transportion environment in the Dulles Corridor by the year 2010. A building-block approach should be adopted for the application of current and evolving technologies.***
   Background:
   - The National Capital Region faces a 70% increase in highway demand and a 20% increase in highway capacity based on conventional systems. The Dulles Corridor trafficshed is projected to gain *about 25% of the new jobs and households projected for the entire region by 2020.*
   - Effective transportation will not be achieved simply by extrapolating the conventional highway and transit systems that have resulted in the region's current congested system.
   - New ideas and technologies are evolving and their application involves various degrees of risk.
   - The DCTF should not be deterred by long term evolution requirements if the potential gain to the traveler and taxpayer is substantial.

2. ***Technology should be applied where there is a pay-off for the customer or the operator.***
   - Examples include technologies which:
     a) heighten the system's appeal to users
     b) reduces trip time and increase on-time performance

c) increase system productivity.

3. ***Risk should be held commensurate with the time scale and potential pay-off.***
Governments for good reason traditionally are not risk-takers.

- The risks should be well understood for each application.
- The promise should not be oversold to the public.
- For higher risk applications the basic system should be able to function at some level if the application falls behind schedule or fails to meet its full promise.
- Phase 2 can accept less risk than later phases due to its short time scale.
- Visible short-term success is desirable.

4. ***Dulles Corridor Systems should have a high degree of compatibility and integration with all modes of connecting systems.***
    - A high degree of seamless use is important if commuters are to be attracted to use the Dulles Corridor system.
    - Compatibility extends to the provision of real time information for the user and to the coordination of scheduling, operation and control between connecting elements.
    - "Seamless use" should be extended when practical, from transit fare cards to include a single electronic card to pay fares, parking at transit stations and highway tolls.
    - "Compatibility" should be considered with respect to coordination and control of all transportation features in the Dulles Corridor and its trafficshed including toll roads, future "Hot Lanes", traffic management systems and other future road based or fixed guideway systems.
    - However, application to the Dulles Corridor project should not be unreasonably delayed by compatibility considerations.

5. ***The objective and time scale for each technological application should be clearly defined and linked to a system of "payment by results," with contractors.***
    - Technology advances rapidly. The perfect can be the enemy of the good. Proposals to add the latest advance should be measured against the objective and time scale.
    - Whenever practical the design concept or "system architecture", should have the flexibility to accept up grades.

6. ***It should be recognized that even "proven" technologies would require some development to adapt them to the specifics of the Dulles Corridor system.***
    - If the technology already is working well in Metro or another connecting system, extension of that technology to the Dulles Corridor would be the lowest risk option providing it does not involve future technological or other limitations.
    - **Definitions**:
      Level 1: If the technology is in use elsewhere it's available "off the shelf" which implies no risk. But while proven units may be available those units

will have to be integrated into an operating system specific to the Dulles Corridor project.
Level 2: If the technology is available but not supported by user experience, the development and integration required for the Dulles Corridor will require more time and risk.
Level 3: If the technology has been demonstrated but has yet to be engineered for production, the time scale performance and probably cost, will be uncertain.

7. ***The DCTF should not be deterred by long term evolution requirements if the potential gain to the traveler and taxpayer is substantial.***
    - In Phase 2, the first phase to be technologically enhanced, the time scale is short and applications should be limited to level 1 risk.
    - Phase 3, the BRT, has a longer lead time with which to accept risk.
    - For Phase 4 the DCTF should consider the potential identified in the DCIIS, of the new concepts under development that offer a whole new level of transportation capability.

Recommendation: The DCTF as the current managing entity, should appoint a technology manager now and use a subcontractor to *create* its "system architecture" *before the end of June.*

Dulles Corridor Rapid Transit Technology Concepts Description

Dulles Corridor Rapid Transit ITS Concepts -- REVISED 8/16/99

Preliminary Candidate Technologies	Description / Functional Performance	Technology/ Technique	Technology Status	Prerequisite System	Current Regional Applications	Benefits	Issues	Dulles Phase
Public Transportation Systems								
1. Transit Vehicle Tracking (AVL)	Provides real-time location information for schedule adherence, dispatch, and traveler information. Optional features include silent alarm for alerting dispatchers of emergencies, and vehicle engine probes to alert dispatchers of potential engine problems	- GPS (GPS receiver) - Dead Reckoning (odometer, compass) - Signpost and Odometer (radio beacons, reader, odometer) - Ground-based Radio	Existing	None	- PRTC - Montgomery County - VDOT Snow Plow Pilot - WMATA Columbia Pike	- Security, safety - Enhanced operations - Better customer information	Prerequisite for many other technologies.	Phase 2 +
2. Transit Fixed-Route Software	Computer software that assists transit properties in planning and operating transit fixed-route services. Performs automatic driver assignment, vehicle monitoring, and routing and scheduling	hardware, software	Existing	May use schedule performance data from transit vehicle tracking system for route and schedule planning	- PRTC (FlexRoute) - Montgomery County	- Improves operating efficiency - Better customer satisfaction		Phase 2 +
3. Demand Response Transit Software (ParaTransit)	Computer software that assists dispatchers in allocating transit fleet resources to demand response service requests. Performs driver assignment, vehicle monitoring, and routing and scheduling of transit vehicles. Provides data processing and information display to assist dispatchers in making optimal use of the transit fleet. Area of application includes Tyson's Corner.	hardware, software	Existing	May use real-time transit vehicle tracking data for dynamic routing and scheduling of transit fleet	- PRTC (FlexRoute)	- Improves operating efficiency - Enhanced trip scheduling - Better customer satisfaction		Phase 2 +
4. Automatic Passenger Counters (APC)	Automatically counts the number of people boarding and alighting a transit vehicle to determine passenger loading. Data are used for planning and analysis purposes, in determining real-time loads (to dispatch additional vehicles during periods of heavy ridership), and sometimes in determining traffic signal priority requests. Data may be downloaded to the control center manually or automatically (via vehicle communications system)	- Treadle Mats - Infrared Beams - Video Imaging - EFP systems are sometimes used as a means of automatically counting passengers, for rail systems	Existing	APCs are often coupled with the transit vehicle tracking system	- None	- Improves planning and route scheduling/dispatching - Enhances operations		Phase 2 +
5. Electronic Fare Payment (EFP)	Provides an electronic means of collecting and processing fares. Customers use a smart card instead of tokens or cash to pay for transit rides.	- Magnetic Stripe Card - Credit Card - Contact Smart Card - Proximity Smart Card	Existing	May be coupled with transit vehicle tracking system for flex fare system (distance-based fare collection); can use the same payment media and systems as parking facility electronic payment and electronic toll collection systems	- WMATA SmarTrip - ITS Task Force Electronic Payment Study	- Improves operating efficiency - Reduces lost transactions - Better customer satisfaction	Compatibility with electronic toll collection (Smart Tag) and other systems	Phase 3 +
6. Parking Facility Electronic Payment	Collects parking fees electronically, determines parking space availability, and detects and processes violators.	- Vehicle/Roadside Short Range Communications (tag, reader) - Electronic Card	Existing	Can use the same payment media and systems as transit electronic fare payment and electronic toll collection systems	- WMATA SmarTrip (Metrorail) - DC Parking Meter Payments - Arlington Parking Meter Payments	- Provides customer service - Enhances operations	Compatibility with electronic toll collection (Smart Tag) and other systems.	Phase 3 +
7. On-board Transit Security	Provides remote visual monitoring/recording of the passenger safety environment on board the transit vehicle. Allows drivers and passengers to request assistance in case of an emergency. Direct link to authorities	Surveillance, communications, systems	Existing	Transit Vehicle Tracking	- Montgomery County	- Enhances safety - Better customer satisfaction	privacy, monitoring	Phase 2 +
8. Transit Facility Security	Provides remote visual monitoring/recording of the passenger safety environment in stations, parking lots, and at transit stops. Allows passenger to request assistance in case of an emergency. Direct link to authorities.	- Surveillance, communications, systems - Solar-powered bus stops	Existing	None	- Metrorail Stations and Parking Lots	- Enhances safety - Better customer satisfaction	privacy, monitoring	Phase 3 +
9. Parking Facility Security	Provides remote visual monitoring/recording of the safety environment for persons in parking lots. Allows person to request assistance in case of an emergency.	Surveillance, communications, systems	Existing	None	- VDOT I-95 Park & Ride Lots Security and Surveillance (planned)	- Improves safety - Provides customer service - Enhances operations	privacy, monitoring	Phase 2 +
10. Transit Vehicle Mechanical Safety Monitoring and Maintenance	Automatically monitors the condition of transit vehicle engine components and provides warnings if failures occur. Manages the maintenance records of transit vehicles.	Sensors, systems	Existing	May be coupled with transit vehicle tracking system for real time engine component monitoring at transit management center	- WMATA Columbia Pike and Falls Church electric bus	- Improves operations - Improves vehicle maintenance		Phase 2 +

Preliminary Candidate Technologies	Description / Functional Performance	Technology/ Technique	Technology Status	Prerequisite System	Current Regional Applications	Benefits	Issues	Dulles Phase
11. Multi-modal Coordination	Establishes two-way communications between multiple transit and traffic agencies, or transit mode operators, to improve operations and service coordination. Includes timed transfers of transit vehicles.	hardware, software	Existing	Transit Vehicle Tracking	- Metrobus/Metrorail - SmarTraveler Agency Server - IEN	- Improves Regional Communication and Coordination - Improves Operations		Phase 2 +
12. On-board Electronic Destination Signs	The external display of bus route / rail line information on transit vehicles. Information includes route/line destination and/or bus route number / rail line, indicating the bus route / rail line and direction the vehicle is traveling. Electronic displays are typically mounted on the front and side(s) of the transit vehicle.	- Dot Matrix Sign - LED Sign - LCD Sign	Existing	May be coupled with transit vehicle tracking system to change displayed information automatically at end of route/line	- Metrobus/Metrorail - Montgomery County	- Better customer service -Enhanced operations	Information must be very accurate	Phase 2 +
13. In-vehicle Traveler Information	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.	- AVL-triggered Announcements - Beacon-triggered Announcements - LED Dynamic Message Sign - LCD Dynamic Message Sign - Dot Matrix Dynamic Message Sign	Developing	Transit vehicle tracking for AVL-triggered announcements	- None	- Better customer service -Enhanced operations	Information must be very accurate; technology status	Phase 3 +
14. Automated Public Address System	Automatically routes messages to designated stations. Messages may be pre-recorded or voice synthesized. System may be operated manually (live voice messages). May be coupled with visual in-station traveler information system.	hardware, software	Existing	PA infrastructure	- VRE Trip	- Better customer service -Enhanced operations	ADA - visual signs also needed	Phase 3 +
15. Wayside/In-station Traveler Information	Provides real-time arrival/departure information at bus stops and terminals, and train stations and platforms.	- LED Dynamic Message Sign - LCD Dynamic Message Sign - Dot Matrix Dynamic Message Sign - CRT Display Monitor - Solar-powered bus stops	Existing	Transit Vehicle Tracking	- VRE Trip	- Better customer service -Enhanced operations	Technology status; information must be very accurate; ADA; vandalism, maintenance	Phase 3 +
16. Parking Facility Information	Dynamic messages signs that provide parking availability information and parking lot navigational guidance.	Hardware, software	Developing	Parking Facility Electronic Payment	- VDOT I-95 Park & Ride Lots Parking Guidance Info.	- Provides customer service - Enhances operations	Technology status Information must be very accurate	Phase 4 +
Traveler Information Systems								
17. Broadcast Traveler Information	Non-interactive traveler information, such as travel advisories/reports, general transit information, video footage, and public service announcements, provided over the telephone, television, and radio.	- Telephone - Television - Radio - Internet	Existing	Transit vehicle tracking and traffic network surveillance for real-time information	- SmarTraveler - VDOT - WMATA	- Better customer service -Enhanced operations	Need to coordinate with SmarTraveler. Information must be accurate	Phase 2 +
18. Interactive Kiosks	Provides tailored static information, via agency/company-owned kiosks, in response to a traveler request. Information provided includes travel advisories, traffic conditions, transit services, traveler services, ride share/match, parking information, and fare/pricing information. Kiosks may link to an Internet web site or centrally-controlled traveler information database as a means of accessing traveler information.	hardware, software, communications	Existing	Transit vehicle tracking and traffic network surveillance for real-time information	- Fairfax County Kiosk Program - Arlington County Kiosk Program - MWCOG Kiosk Program	- Better customer service -Enhanced operations	vandalism, maintenance	Phase 2 +
19. Transit Trip Itinerary Planning	Software that generates a transit trip itinerary (route, schedule, and fare information) based on user-specified trip parameters such as trip origin/destination and travel time, and criteria such as fastest route, lowest fare, least number of transfers, and least walking distance. Integration of multiple transit systems is an option. Delivery mechanisms include the Internet and traveler information telephone systems.	hardware, software	Existing	None	- WMATA's ARTS System	- Better customer service -Enhanced operations	Information must be very accurate	Phase 2 +
20. Interactive Traveler Information -- Personal Information Access	Provides tailored information, via personal devices, in response to a traveler request. Includes interactive request/response systems and information systems that "push" a tailored stream of information to the traveler based on the traveler's submitted profile. Information provided includes travel advisories, traffic conditions, transit services, traveler services, ride share/match, parking information, and fare/pricing information.	- Telephone - PC (Internet Web Site) - Pager / Personal Data Devices - Fax -E-mail	Developing	Transit vehicle tracking and traffic network surveillance for real-time information	- SmarTraveler - VRE Trip - VRE Express Link - Fairfax City TDM Info.	- Better customer service -Enhanced operations	Information must be very accurate	Phase 2 +

Preliminary Candidate Technologies	Description / Functional Performance	Technology/ Technique	Technology Status	Prerequisite System	Current Regional Applications	Benefits	Issues	Dulles Phase
Traffic Management Systems								
21. Traffic Network Data Collection	Collect traffic data, such as vehicle speeds, occupancy, and volumes, via a number of devices for incident detection, roadway system management, and planning	- CCTV - Loop Detectors - Radar	Existing	Traffic Operations/Management Centers	- VDOT Smart Traffic Center - Smart Traffic Center - VDOT VA Beltway Detection - Alexandria Red Light Cameras - MdSHA TOC - Montgomery Co. ATMS - Montgomery County TOC - Chesapeake HA Routing Traffic	- Improves operations - Enhances safety - Improves Regional Mobility - Meets regional goals	Information must be very accurate; maintenance	Phase 2 & 3
22. Probe Data Collection	Uses vehicles as a means of collecting traffic data. This approach is an alternative to Traffic Network Data Collection. Most systems use electronic toll collection technology to collect traffic data. Another method uses wide-area wireless communications between vehicles and an information service provider (ISP).	- Vehicle/Roadside Short Range Communication (tag, reader) - Vehicle/ISP Wide-area Wireless Communications	Existing	Electronic Toll Collection, cellular coverage	- SmarTraveler	- Enhances traffic information - Provides data to other transportation technology systems	Information must be very accurate; maintenance	Phase 2 +
23. Traffic Signal Priority	Holds traffic signal green, or turns it green earlier than scheduled, to provide right-of-way to transit vehicle. 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	- DGPS - RF - Spread Spectrum Radio - Video - Infrared - Optical	Developing	Transit Vehicle Tracking, Multi-modal Coordination (optional)	- ITS Task Force Signal Priority Treatment Study - NOVA Signal Coordination (Preemption only) - WMATA Columbia Pike - Montgomery County - MD 210/Rt 5 - DC Georgia Avenue (planned)	- Improves schedule adherence - Enhances transit attractiveness	Highly political. No adopted standards for the region	Phase 2 +
24. Computerized Traffic Signal Control	Central control and monitoring of surface street traffic signals	hardware, software, communications	Existing	None	- VDOT Smart Signal System - Montgomery County - DC DPW - Arlington County - City of Alexandria - City of Fairfax	- Provides BRT line crossing control - Enhances operations	Highly political. No adopted standards for the region	Phase 2 & 3
25. Lane Control	Controls use of surface street and freeway lanes via electronic signage. Examples include dynamic lane closure and HOV signs.	hardware, software, communications	Existing	None	- VDOT	- Enhances operations	Limited information on signs	Phase 2 & 3
26. Freeway Ramp and Interchange Metering with Queue Jumping	Controls the number and timing of vehicles entering a freeway. Helps to reduce or eliminate a surge of vehicles entering the freeway system. High-occupancy vehicles (including transit vehicles) are allowed to bypass the metered queue of vehicles	hardware, software, communications	Existing	None	- VDOT	- Enhances operations	Capacity for preemption/queue jumping tolls	Phase 2 +
27. Lane Access Control and Reversible Lane Management	Controls the access to and direction of traffic flow in reversible lanes. Control is typically accomplished via dynamic message signs, and physical means such as ramp gates and moveable barriers. May also detect vehicles traveling the wrong way via sensory and surveillance devices. May provide control for BRT lane entry.	- Dynamic Message Sign (dot matrix) - Dynamic Physical Barriers (moveable Jersey barrier, ramp gate) - Vehicle/roadside Short Range Communications (tag, reader) - Surveillance (CCTV, loop detectors)	Existing	None	- VDOT	- Enhances operations	Safety	Phase 3 +
28. Regional Traffic Control	Provides electronic communication among traffic agencies to allow coordinated, interjurisdictional control of traffic signals.	hardware, software	Developing	Computerized Traffic Signal Control	- None	- Enhances operations	Highly political	Phase 3 +
29. Incident Management System	Detects, verifies, and implements response to incidents. Provides electronic communication among transit agencies, traffic agencies, and emergency management service providers for coordinated response and management of incidents.	hardware, software, communications	Existing	Traffic Network Data Collection	- Montgomery County ATMS - VDOT Smart Traffic Center	- Improves safety - Provides customer service - Enhances operations	Co-location (Montgomery County)	Phase 2 +
30. Traffic Prediction and Demand Management	The collection, storage, and processing of transportation data for historical evaluation, real-time assessment, and forecast of the roadway network performance.	hardware, software	Developing	transportation data collection systems	- VDOT Data Warehouse - COG Data Warehouse (planned)	- Better resource management - Enhances data organization	Technology status	Phase 3 +

Preliminary Candidate Technologies	Description / Functional Performance	Technology/ Technique	Technology Status	Prerequisite System	Current Regional Applications	Benefits	Issues	Dulles Phase
31. Electronic Toll Collection	Collect tolls electronically, and detect and process violators	- Vehicle/Roadside Short Range Communications (tag, reader)	Existing	Can use the same payment media and systems as transit electronic fare payment and parking facility electronic payment systems	- VDOT Smart Tag - MWAA AVI Study	- Provides customer service - Enhances operations	Compatibility with electronic fare collection (Smart Trip) and other systems.	Phase 2 +
32. Traffic Information Dissemination	Disseminate traffic information (congestion, incidents, etc.) to motorists using roadway equipment such as dynamic message signs (a.k.a. VMS) and highway advisory radio (HAR).	- Dot Matrix Dynamic Message Signs - HAR	Existing	None	- VDOT VMS - VDOT HAR - DC VMS - DC HAR - MdSHA VMS - MdSHA HAR	- Provides safety and delay information to travelers - Improves operations	Information must be very accurate.	Phase 2 +
33. Road Weather Information System	Collects and analyzes road and weather conditions on or near the roadway. Collected road weather information is monitored to detect and forecast weather related hazards such as icy road/bridge conditions, dense fog, and approaching severe weather fronts. Information is used to deploy road maintenance resources, and issue location specific warnings and general travel advisories.	Sensors, communications, systems	Developing	None		- Provides customer service - Enhances operations	Technology status. Information must be very accurate.	Phase 3 +
Vehicle Safety Systems								
34. Driver Safety Monitoring	Determines a driver's condition and performance, and warns the driver of potential dangers	- Lane Tracker - Infrared Camera	Immature	None	- None	- Improves safety	Technology status	Phase 4 +
35. Longitudinal Safety Warning	Warns driver of a potential rear-end collision. Uses collision sensors on the front and rear of the vehicle to detect impending longitudinal collisions.	- Radar	Developing	None	- None	- Improves safety	Technology status	Phase 3 +
36. Lateral Safety Warning	Warns driver of a potential side collision. Uses collision sensors on the sides of the vehicle to detect impending lateral collisions.	- Radar	Developing	None	- None	- Improves safety	Technology status	Phase 3 +
37. Advanced Vehicle Longitudinal Control	Automates speed and headway control functions using collision sensors and vehicle dynamics processing to control the throttle and brakes.	- Radar	Developing	Longitudinal Safety Warning System	- None	- Improves safety	Technology status	Phase 3 +
38. Advanced Vehicle Lateral Control	Automates the steering control function using collision sensors, vehicle dynamics, and other sensors to measure the lane position and lateral deviations; and to control steering.	- Roadway Magnets (disks, tape) - Video Imaging	Immature	Lateral Safety Warning System	- None	- Improves safety	Technology status	Phase 4 +
39. Intersection Safety Warning	Provides the vehicle operator with a warning of potential hazards at an intersection.		Immature		- None	-Improves Safety	Technology status	Phase 3 +
40. Intersection Collision Avoidance	Determines probability of collision and provides warnings to vehicles.		Immature		- None	-Improves Safety	Technology status	Phase 3 +
41. Driver Visibility Improvement	Enhances driver visibility using an enhanced vision system.	- Infrared cameras	Immature	None	- None	- Improves safety	Technology status	Phase 4 +
42. In-vehicle Signing	Provides travel advisory, warning/regulatory, and other driver information through in-vehicle devices. The information helps transit drivers operate transit vehicles safely and efficiently.	- Vehicle/Roadside Short Range Communications	Immature	None	- None	- Improves operations - Enhances safety	Technology status. Information must be very accurate.	Phase 4 +
43. Pre-crash Restraint	Determines the probability of a collision and, if determined that a collision is within a certain degree of certainty, deploys a pre-crash restraint mechanism to protect the driver and passengers against the collision. A vehicle air bag system is a somewhat similar concept.	Sensors, systems	Immature	Longitudinal and Lateral Safety Warning Systems	- None	- Improves safety	Technology status	Phase 4 +
44. Emergency Response	Provides automatic location of transit police vehicles and computerized dispatching to assist dispatchers in deploying appropriate resources to an emergency quickly and efficiently.	- GPS	Existing	None		- Improves safety - Better incident control and response	Technology status	Phase 2 +
45. Precision Docking Systems	Assists driver in correctly placing the transit vehicle at a stop.	Proximity sensors	Developing	None	- None	- Improves loading operation - Better customer satisfaction - Reduces damage	Technology status	Phase 3 +

Preliminary Candidate Technologies	Description / Functional Performance	Technology/ Technique	Technology Status	Prerequisite System	Current Regional Applications	Benefits	Issues	Dulles Phase
46. Automated Highway/Rail System	Automates driving functions – enables "hands-off" operation of a vehicle	Sensors, systems, communications	Immature	Advanced Vehicle Longitudinal and Lateral Control Systems		- Improves safety - Increased capacity	Technology status	Phase 4 +
47. Emissions Monitoring and Management	Monitors individual vehicle emissions and general air quality within a corridor or area. Information is used to manage emissions and to implement environmentally sensitive TDM programs, policies, and regulations.	Sensors, Communications	Developing	None	- None	- Supports regional goals	Technology status	Phase 4 +
ITS Planning								
48. ITS Planning	ITS data collected from ITS systems used for policy making, funding allocation, and planning.	hardware, software, communications	Existing	ITS data collection systems	- ITS Task Force (preemption/priority study and electronic payment study) - WMATA Electronic Payment Study - VDOT – Northern Virginia EDP - VDOT – NOVA ITS Framework - DC DPW – Washington DC EDP - I-95 Corridor Coalition - ITS Task Force Umbrella Study - ITS Task Force ITS Training - VDOT Woodrow Wilson ITS Design (planned)	- Supports regional goals - Provides for better systems/projects - Reduces technology takeover	Highly political. Coordination with multiple jurisdictions	Phase 2 +
Personal Rapid Transit								
49. Personal Rapid Transit (PRT)	Provide direct origin to destination transportation service, on demand, via a fixed-guideway network. Vehicles, that travel on the fixed guideway, are fully automated and accommodate a small group of people (typically one to six passengers).	- Hanging Suspension - Air Suspension - Linear Induction Motor	Developing	None	- None	- Reduces pollution - Increases customer comfort and convenience (e.g., privacy, minimal weight time, no transfers, etc.) - Increases service performance - Reduces operating costs - Can be implemented incrementally	Technology status	Phase 4 +
Miscellaneous								
50. Platform Screen Doors	Provides a safety barrier between the platform edge and the transitway – prevents passengers from falling from the platform onto the transitway. The system is integrated with a precision docking system. When the transit vehicle arrives at a stop, the transit vehicle doors line up with the platform screen doors, through which passengers board and alight the transit vehicle.	- Structure and Transparent Barrier - Actuated Screen Doors - Vehicle Detectors	Existing	Precision Docking System	- None	- Security, safety - Energy savings (from reduction in heating / air conditioning for enclosed stations)	Requires reconfiguration for change in vehicle types (alignment issues)	Phase 3 +

Dulles Corridor Rapid Transit Technology Concepts Evaluation Matrix

Dulles Corridor Rapid Transit Project ITS Concept Evaluation Matrix (Prioritized) -- REVISED 8/16/99

ITS Concepts	Evaluation Criteria							Total Score
	Consistency with the Tech. Task Group's Application Criteria and Policy	Technical Feasibility	Customer Benefits	Operator Benefits	Integration and Compatibility with Existing and Planned Systems	Cost Effectiveness	Community and Agency Opportunity	
Weights	5	4	5	5	2	4	3	
1. Transit Vehicle Tracking (AVL)	10	8	8	10	7	9	8	246
5. Electronic Fare Payment (EFP)	10	8	9	9	5	7	9	237
2. Transit Fixed-Route Software	8	9	8	9	8	9	7	234
7. On-board Transit Security	9	8	8	8	7	7	10	229
16. Parking Facility Information	10	7	9	8	7	7	8	229
8. Transit Facility Security	9	9	8	7	7	7	10	228
9. Parking Facility Security	9	9	8	7	7	7	10	228
11. Multi-modal Coordination	10	8	8	8	6	6	9	225
6. Parking Facility Electronic Payment	10	7	8	8	6	6	7	215
3. Demand Response Transit Software (ParaTransit)	4	8	9	9	8	9	6	212
44. Emergency Response	7	8	7	9	6	7	8	211
29. Incident Management System	5	9	7	8	8	8	8	208
31. Electronic Toll Collection	5	9	8	8	7	7	8	207
15. Wayside/In-station Traveler Information	10	7	9	5	5	6	8	206
19. Transit Trip Itinerary Planning	8	6	8	8	6	6	8	204
13. In-vehicle Traveler Information	10	5	10	5	6	6	7	202
14. Automated Public Address System	8	9	8	5	7	6	7	200
32. Traffic Information Dissemination	5	8	8	7	8	7	8	200
24. Computerized Traffic Signal Control	6	9	5	9	8	8	5	199

ITS Concepts	Evaluation Criteria							Total Score
	Consistency with the Tech. Task Group's Application Criteria and Policy	Technical Feasibility	Customer Benefits	Operator Benefits	Integration and Compatibility with Existing and Planned Systems	Cost Effectiveness	Community and Agency Opportunity	
Weights	5	4	5	5	2	4	3	
49. Personal Rapid Transit (PRT)	8	6	8	7	6	6	8	199
20. Interactive Traveler Information -- Personal Information Access	6	8	8	5	7	8	8	197
26. Freeway Ramp and Interchange Metering with Queue Jumping	6	8	7	7	6	8	6	194
50. Platform Screen Doors	6	7	8	7	6	6	7	190
27. Lane Access Control and Reversible Lane Management	6	9	5	8	7	7	5	188
45. Precision Docking Systems	7	6	8	8	6	5	5	186
23. Traffic Signal Priority	7	7	7	7	6	6	5	184
17. Broadcast Traveler Information	5	8	7	6	6	7	7	183
48. ITS Planning	6	7	5	7	6	7	8	182
10. Transit Vehicle Mechanical Safety Monitoring and Maintenance	6	7	6	8	5	6	6	180
12. On-board Electronic Destination Signs	6	7	7	7	7	5	5	177
4. Automatic Passenger Counters (APC)	5	6	4	8	7	7	5	166
35. Longitudinal Safety Warning	6	6	5	7	5	6	6	166
36. Lateral Safety Warning	6	5	5	7	5	6	6	162
21. Traffic Network Data Collection	2	7	5	6	6	8	8	161
25. Lane Control	1	9	5	5	8	8	6	157
30. Traffic Prediction and Demand Management	5	5	5	5	5	7	6	151
47. Emissions Monitoring and Management	3	5	5	6	6	6	8	150

ITS Concepts	Evaluation Criteria							Total Score
	Consistency with the Tech. Task Group's Application Criteria and Policy	Technical Feasibility	Customer Benefits	Operator Benefits	Integration and Compatibility with Existing and Planned Systems	Cost Effectiveness	Community and Agency Opportunity	
Weights	5	4	5	5	2	4	3	
18. Interactive Kiosks	5	8	5	3	5	5	7	148
37. Advanced Vehicle Longitudinal Control	4	5	5	6	6	6	5	146
38. Advanced Vehicle Lateral Control	4	5	5	6	6	6	5	146
28. Regional Traffic Control	3	6	5	5	5	7	6	145
34. Driver Safety Monitoring	6	3	5	7	4	4	5	141
33. Road Weather Information System	1	8	5	5	5	6	6	139
39. Intersection Safety Warning	3	4	6	6	5	5	6	139
22. Probe Data Collection	5	5	3	5	7	5	5	134
40. Intersection Collision Avoidance	3	3	6	6	4	5	6	133
43. Pre-crash Restraint	2	4	5	5	5	6	6	128
41. Driver Visibility Improvement	2	3	6	6	5	5	5	127
46. Automated Highway/Rail System	8	2	5	5	2	2	5	125
42. In-vehicle Signing	2	4	3	5	5	4	4	104

Note: ITS concepts are rated on a scale of 0 to 10 on how they meet each of the evaluation criteria (0 = meets criterion negatively, 1 = does not meet criterion, 5 = meets criterion, 10 = completely meets criterion).

Dulles Corridor Rapid Transit Technology Implementation Concepts Phasing

Dulles Corridor Rapid Transit Project ITS Concept Phasing – REVISED 8/31/99

A list of ITS concepts applicable to the Dulles Corridor was compiled and analyzed. The most beneficial ITS concepts, with respect to the Dulles Corridor Rapid Transit project, were identified and are recommended for deployment. The phase in which these ITS concepts should become operational is provided below. Operational means that the system is fully deployed, has passed acceptance testing, and is operating on a full-time basis. The list on the left (see below) contains ITS concepts that should be implemented by the Corridor's designated transit operator as a part of the Dulles Corridor Rapid Transit project. The number of concepts in this list is limited due to fiscal constraints. The list on the right (see below) contains ITS concetps that should be implemented in the Corridor, but by an agency/organization other than the Corridor's designated transit operator. These ITS concepts deal with functions typically provided by VDOT or some other non-transit entity. ITS concepts that have already been deployed in the Dulles Corridor, or ITS concepts that are not recommended for deployment in the Dulles Corridor, are not listed. A glossary of ITS concepts with deployment examples is provided at the end of this document.

Phase I – Express Bus 1999 - 2001

Dulles Corridor Transit Agency

Other Transportation Agencies

- Interactive Traveler Information – Personal information Access (SmarTraveler)
- Broadcast Traveler Information (SmarTraveler)

Phase II – Enhanced Express Bus 2001 - 2003

Dulles Corridor Transit Agency

- Parking Facility Information
- ITS Planning

Other Transportation Agencies

- Traffic Information Dissemination (VDOT)
- Interactive Kiosks (WashCOG)

Phase III – Bus Rapid Transit 2003 - 2010

Dulles Corridor Transit Agency

- Transit Vehicle Tracking
- Electronic Fare Payment
- On-Board Transit Security
- Transit Facility Security
- Parking Facility Security
- Multi-modal coordination

Other Transportation Agencies

- Intersection Safety Warning (DAAR operator)

- Parking Facility Electronic Payment
- Wayside/In-station Traveler Information
- In-vehicle Traveler Information
- Lane Access Control
- Precision Docking Systems
- Transit Vehicle Mechanical Safety Monitoring and Maintenance

Phase IV – Rail Tysons 2006 / Beyond 2010

Dulles Corridor Transit Agency

- Emergency Response
- Platform Screen Doors

Other Transportation Agencies

- Traffic Prediction and Demand Management (VDOT, NVTC, WashCOG)
- Emissions Monitoring and Management (NVTC, WashCOG)

Beyond Phase IV or As Needed

Dulles Corridor Transit Agency

- Personal Rapid Transit (PRT)
- Traffic Signal Priority
- Automatic Passenger Counters (APC)
- Longitudinal Safety Warning
- Lateral Safety Warning
- Advanced Vehicle Longitudinal Control
- Advanced Vehicle Lateral Control
- Automated Highway/Rail System

Other Transportation Agencies

- Freeway Ramp and Interchange Metering with Queue Jumping (VDOT)
- Traffic Signal Priority (appropriate traffic agency)
- Automated Highway/Rail System (VDOT, DAAR operator)

Dulles Corridor Rapid Transit Project ITS Concept Phasing -- REVISED 8/31/99

The table below contains ITS concepts that are applicable to the Dulles Corridor. The number preceding each concept is the same as the number assigned to each concept in Technical Memorandum 1 (*Dulles Corridor Rapid Transit ITS Concepts*). The order in which the concepts appear below represent the order in which the concepts were ranked, from highest to lowest, in the evaluation exercise (the concepts were rated on how well they met certain evaluation criteria). Implementation phasing is provided below for the ITS concepts that are to be deployed by the Corridor's designated transit operator. Phasing steps include "planning," "pilot," and "operational." "Planning" is defined as the design, procurement, and installation of the ITS concept. "Pilot" is defined as the period during acceptance testing. "Operational" is defined as the ITS application being fully functional for revenue service. Implementation phasing is not provided below for ITS concepts that:

- are already implemented
- are primarily provided by a non-transit operator or other organization
- would be deployed on a specific or as-needed basis, or beyond phase 4
- are not recommended for implementation as a part of this project

Only the ITS concepts that contain phasing information in the table will be considered and recommended for implementation as a part of the Dulles Corridor Rapid Transit project. Due to fiscal constraints, the project is limited to recommending the deployment of the most applicable and beneficial ITS concepts in the Corridor. Further refinement in the selection of the recommended ITS concepts will commence with the identification of costs and relative benefits. ITS concepts not "making the cut" may be implemented by other agencies and projects, after completion of phase 4, or when funding becomes available. Refer to the "comments" column in the table for the justification and reasoning in selecting the ITS concepts recommended for implementation in this project.

ITS Concepts	Phase 1	Phase 2	Phase 3	Phase 4A	Phase 4B	Comments
1. Transit Vehicle Tracking (AVL)	Planning	Pilot	Operational	Operational	Operational	May be an enhancement/expansion of an operator's planned/existing system. Identify operator(s) in Phase 1.
5. Electronic Fare Payment (EFP)		Planning / Pilot	Operational	Operational	Operational	Coordinate with the WashCOG and WMATA electronic payment studies. Coordinate with concepts 6 and 31. Prerequisite: legacy EFP systems
2. Transit Fixed-Route Software						For bus service only. Transit agencies in the region currently have this system. Enhance/expand operator's existing system in Phase 3.
7. On-board Transit Security		Planning	Pilot / Operational	Operational	Operational	For bus service only. Application of this concept is tied to the procurement of transit vehicles; the level of functionality will be determined at the time of procurement.
16. Parking Facility Information	Planning / Pilot	Operational	Operational	Operational	Operational	Need to coordinate with VDOT for display of parking information on VDOT VMSs.
8. Transit Facility Security		Planning	Pilot / Operational	Operational	Operational	Install when BRT stations are built.
9. Parking Facility Security		Planning	Pilot / Operational	Operational	Operational	Operation of system is an issue (e.g., What agency will monitor the cameras?).
11. Multi-modal Coordination		Planning	Pilot / Operational	Operational	Operational	Need to establish coordination agreements among participating operators.

ITS Concepts	Phase 1	Phase 2	Phase 3	Phase 4A	Phase 4B	Comments
6. Parking Facility Electronic Payment		Planning / Pilot	Operational	Operational	Operational	Coordinate with concepts 5 and 31.
3. Demand Response Transit Software (ParaTransit)						Transit agencies in the region currently have this system.
44. Emergency Response		Planning	Pilot	Operational	Operational	Coordinate with concepts 7, 8, and 9.
29. Incident Management System						Is primarily a VDOT function -- coordinate with VDOT. Coordinate with concept 44.
31. Electronic Toll Collection						Is a VDOT function. Coordinate with concepts 5 and 6.
15. Wayside/In-station Traveler Information		Planning	Pilot / Operational	Operational	Operational	Provide static information initially, then provide real-time information. May want to coordinate information with concept 16. Prerequisite: AVL system for real-time information
19. Transit Trip Itinerary Planning						Expand WMATA's existing project.
13. In-vehicle Traveler Information		Planning	Pilot / Operational	Operational	Operational	Need mechanism to trigger announcements at specific locations. May use GPS receivers on board vehicle or beacons along transitway, or may integrate with AVL system.
14. Automated Public Address System						Provide function as a part of concept 15.
32. Traffic Information Dissemination						Is a VDOT function. Coordinate with and provide information to VDOT for transit-related announcements.
24. Computerized Traffic Signal Control						Is a VDOT function. A synchronized traffic signal system would improve bus service.
49. Personal Rapid Transit (PRT)						Progression of technology should be monitored. Concept may be applied in the future.
20. Interactive Traveler Information -- Personal Information Access						Information should be provided to travelers by SmarTraveler. Provide transit data to SmarTraveler.
26. Freeway Ramp and Interchange Metering with Queue Jumping						Is a VDOT function. Queue jumping would improve bus service.
50. Platform Screen Doors			Planning	Pilot / Operational	Operational	Deploy at underground airport station. Prerequisite: Precision Docking System
27. Lane Access Control and Reversible Lane Management		Planning / Pilot	Operational	Operational	Operational	Used for controlled access to BRT stations from the Dulles Airport Access Road. Need to establish what agency is responsible for deployment.
45. Precision Docking Systems		Planning / Pilot	Operational	Operational	Operational	
23. Traffic Signal Priority						May be applied on a site-specific basis (e.g., at station parking lots) if/when a need for deployment is determined.
17. Broadcast Traveler Information						Information should be provided to travelers by SmarTraveler. Provide transit data to SmarTraveler.

ITS Concepts	Phase 1	Phase 2	Phase 3	Phase 4A	Phase 4B	Comments
48. ITS Planning		Operational	Operational	Operational	Operational	Initial application of this concept may involve minimal use of technology and transportation data collected via ITS. Additional transportation data will be used over time as data collection increases.
10. Transit Vehicle Mechanical Safety Monitoring and Maintenance		Planning	Pilot / Operational	Operational	Operational	Application of this concept is tied to the procurement of transit vehicles; the level of functionality will be determined at the time of procurement. May be coupled with AVL system.
12. On-board Electronic Destination Signs						Is standard on transit vehicles.
4. Automatic Passenger Counters (APC)						Progression of technology should be monitored. Concept may be applied in the future. As an alternative, ridership data may be collected manually.
35. Longitudinal Safety Warning						Progression of technology should be monitored. Concept may be applied in the future.
36. Lateral Safety Warning						Progression of technology should be monitored. Concept may be applied in the future.
21. Traffic Network Data Collection						Is a VDOT function.
25. Lane Control						Is a VDOT function.
30. Traffic Prediction and Demand Management						Is a VDOT and MPO function -- coordinate with VDOT and MPO.
47. Emissions Monitoring and Management						Is a MPO function -- coordinate with MPO.
18. Interactive Kiosks						Coordinate with WashCOG's kiosk program.
37. Advanced Vehicle Longitudinal Control						Progression of technology should be monitored. Concept may be applied in the future.
38. Advanced Vehicle Lateral Control						Progression of technology should be monitored. Concept may be applied in the future.
28. Regional Traffic Control						Is a VDOT function.
34. Driver Safety Monitoring						Not recommended for implementation. There is not a perceived need to apply this concept for this project.
33. Road Weather Information System						Is a VDOT function.
39. Intersection Safety Warning						Coordinate with VDOT or appropriate roadway operator. Consider implementation for island platform / right door bus, median cross-over design of BRT stations.
22. Probe Data Collection						Buses will not be traveling on Dulles Toll Road.
40. Intersection Collision Avoidance						Not recommended for implementation. Sufficient functionality is provided by concept 39.
43. Pre-crash Restraint						Not recommended for implementation. The concept is difficult to implement for multi-passenger service, such as transit.

ITS Concepts	Phase 1	Phase 2	Phase 3	Phase 4A	Phase 4B	Comments
41. Driver Visibility Improvement						Not recommended for implementation. There is not a perceived need to apply this concept in the Dulles Corridor.
46. Automated Highway/Rail System						Progression of technology should be monitored. Concept may be applied in the future.
42. In-vehicle Signing						Not recommended for implementation. There is not a perceived need to apply this concept for this project.

NOTE: Planning = the design, procurement, and installation of an ITS concept; Pilot = the period during acceptance testing; Operational = the ITS application is fully functional for revenue service

Dulles Corridor Rapid Transit Technology Implementation Concepts Costs

			Phase II (2001-2003)					Phase III (2003-2006, 2010)					Phase IV (2006-)					
				Costs ($)					Costs ($)					Costs ($)				
ITS Concept	Component	Unit Cost ($)	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Total Capital Cost ($)
Parking Facility Information	Parking Dynamic Message Sign (DMS)	15,000	6	90,000				6	90,000									
	Highway DMS	120,000	6	720,000				6	720,000									
	Vehicle Detector	2,000	6	12,000				6	12,000									
	DMS Controller	10,000	6	60,000				6	60,000									
	System Server	65,000	1	65,000	236,750	1,183,750	473,500	continued		176,400	1,058,400	914,500	continued				914,500	2,242,150
Phase II: 3 facilities including Wiehle, Herndon and 606. Phase III: 3 additional facilities including West Park, Reston, and 772 Includes two parking DMS, two highway DMS, and two detectors per site.																		
Transit Vehicle Tracking	AVL Vehicle Equipment (GPS receiver, on-board computer, mobile data terminal)	9,000	114	1,026,000				25	225,000									
	Monitoring & Dispatching System (central hardware & software)	2,500,000	1	2,500,000				continued										
	ITS Planning Computer Hardware & Software	35,000	1	35,000				continued										
	Multi-modal Coordination Computer Hardware & Software)	113,000	0	0	0	3,561,000	1,780,500	1	113,000	0	338,000	1,949,500					1,949,500	3,899,000
Phase II: 114 total buses. Phase III: 25 additional buses (139 total buses) System cost includes integration. Deployed on entire bus fleet.																		
Wayside/In-station Traveler Information	DMS or Display Monitor	15,000						16	240,000				2	30,000				
	System Server	65,000						1	65,000				continued					
	Central Software	20,000						1	20,000	81,250	406,250	162,500	continued		6,000	36,000	177,500	442,250
Phase III: 8 facilities including West Falls Church, West Park, Wiehle, Reston, Herndon, Dulles, 606 and 772. Phase IV: Additional facility at Tysons Includes two DMS per facility.																		
In-vehicle Traveler Information	DMS	1,500						162	243,000				196	294,000				
	Annunciator	5,000						139	695,000				98	490,000				
	Announcement Data	20,000						1	20,000				continued					
	Central Recording Station	15,000						1	15,000	243,250	1,216,250	486,500	continued		156,800	940,800	878,500	2,157,050
Phase III: One DMS on each of the 116 standard buses and two DMS on each of the 23 articulated buses. One annunciator on each of the 116 standard buses and 23 articulated buses. Deployed on entire bus fleet. Phase IV: Two DMS on each of the rail cars and one annunciator on each of the rail cars. Note: Announcements of major stops and transfer points are a requirement of the Americans with Disabilities Act (ADA).																		
GRAND TOTAL																		8,740,450

[1] Initial installation/integration is 25% of capital costs; additional installations/integration is 20% of capital costs

[2] Operations and maintenance is 50% of capital costs; the value is the maximum annual cost of operating and maintaining the ITS application during the phase

ELECTRONIC PAYMENT PACKAGE

			Phase II (2001-2002)					Phase III (2003-2006,2010)					Phase IV (2006-)					
				Costs ($)					Costs ($)					Costs ($)				
ITS Concept	Component	Unit Cost ($)	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Total Capital Cost ($)
Electronic Fare Payment	Bus Farebox & Card Reader	15,000						139	2,085,000				0	0				
	Turnstile w/Card Reader	10,000						30	300,000				18	180,000				
	Ticket Vending Machine with Card Reader	30,000						15	450,000				9	270,000				
	Central Hardware	5,000						1	5,000				continued					
	Central Software & Database	3,000,000						1	3,000,000				continued					
	Clearinghouse	1,000,000						1	1,000,000	0	6,840,000	3,820,000	continued		0	450,000	4,145,000	7,290,000
Parking Facility Electronic Payment	Transponder Reader Assembly	8,000						12	96,000									
	Card Reader	3,000						12	36,000									
	Camera (violation enforcement)	5,000						6	30,000									
	Central Hardware	5,000						1	5,000									
	Central Software & Database	3,000,000						1	3,000,000									
	Clearinghouse	1,000,000						1	1,000,000	0	4,167,000	2,583,500					2,583,500	4,167,000
GRAND TOTAL																		11,457,000

Electronic Fare Payment: Phase III: 139 total buses, farebox / card reader deployed on entire bus fleet; 5 BRT stations at West Park, Wiehle, Reston, Herndon, and 606; three vending machines per station and 6 turnstiles per station. Phase IV: 8 rail stations at West Park, Tysons, Wiehle, Reston, Herndon, Dulles, 606 and 772 (3 additional stations from Phase III); 6 turnstiles per station and three vending machines per station. System cost includes integration. Annual O&M cost for the clearinghouse function is $1,000,000. Central costs (hardware, software, clearinghouse) should not be duplicated for an integrated electronic fare payment / parking facility payment system.

Parking Facility Electronic Payment: Phase III: 6 parking facilities including West Park, Wiehle, Reston, Herndon, 606, and 772. Two transponder readers and two card readers per facility, and one camera per site. System cost includes integration. Annual O&M cost for the clearinghouse function is $1,000,000. Central costs (hardware, software, clearinghouse) should not be duplicated for an integrated electronic fare payment / parking facility payment system.

[1] Initial installation/integration is 25% of capital costs; additional installations/integration is 20% of capital costs

[2] Operations and maintenance is 50% of capital costs; the value is the maximum annual cost of operating and maintaining the ITS application during the phase

SECURITY/SAFETY PACKAGE

ITS Concept	Component	Unit Cost ($)	Phase II (2001-2003) Quantity	Phase II Costs ($) Capital	Phase II Costs ($) Capital Installation / Integration [1]	Phase II Costs ($) Total Capital	Phase II Costs ($) Annual O&M [2]	Phase III (2003-2006,2010) Quantity	Phase III Costs ($) Capital	Phase III Costs ($) Capital Installation / Integration [1]	Phase III Costs ($) Total Capital	Phase III Costs ($) Annual O&M [2]	Phase IV (2006-) Quantity	Phase IV Costs ($) Capital	Phase IV Costs ($) Capital Installation / Integration [1]	Phase IV Costs ($) Total Capital	Phase IV Costs ($) Annual O&M [2]	Total Capital Cost ($)
On-board Transit Security	CCTV Camera	2,500						278	695,000									
	Microphone & Silent Alarm	300						139	41,700	184,175	920,875	368,350					368,350	920,875
Phase III: 139 total buses. Two cameras per bus. Deployed on the entire bus fleet.																		
Transit Facility Security	CCTV Camera	5,000						36	180,000				0	0				
	Video Monitor	3,500						6	21,000				1	3,500				
	Central Video Switcher & Controller	20,000						1	20,000	55,250	276,250	110,500	continued		700	4,200	112,250	280,450
Phase III: 6 facilities including West Park, Wiehle, Reston, Herndon, 606, and 772; 6 cameras at each facility. One monitor per facility. Phase IV: 1 additional facility at Tysons, camera costs are included in rail station construction cost.																		
Parking Facility Security	CCTV Camera	5,000						59	295,000									
	Video Monitor	3,500						2	7,000									
	Central Video Switcher & Controller	20,000						1	20,000									
	Two-way Intercom	2,000						2	4,000	80,500	406,500	163,000					163,000	406,500
Phase III: 5 parking facilities including West Park, Wiehle, Reston, 606, and 772. Estimated 4,700 spaces (assumed 1 camera per 80 spaces). 1 monitor per 35 cameras. Intercom cost is included in the facility construction cost. The Herndon facility needs to be retrofitted with Two-way Intercom (2 intercoms for facility).																		
GRAND TOTAL																		1,607,825

[1] Initial installation/integration is 25% of capital costs; additional installations/integration is 20% of capital costs.

[2] Operations and maintenance is 50% of capital costs; the value is the maximum annual cost of operating and maintaining the ITS application during the phase.

OPERATIONS PACKAGE

			Phase II (2001-2003)					Phase III (2003-2006,2010)					Phase IV (2006-)					
				Costs ($)					Costs ($)					Costs ($)				
ITS Concept	Component	Unit Cost ($)	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Quantity	Capital	Capital Installation / Integration [1]	Total Capital	Annual O&M [2]	Total Capital Cost ($)
BRT Station Lane Access Control	Vehicle Transponder	50						68	3,400									
	Transponder Reader Assembly	8,000						8	64,000									
	Gate Assembly	100,000						8	800,000	216,850	1,084,250	433,700					N/A	1,084,250
Phase III: 68 BRT buses; deployed on BRT buses only. Four readers with gates eastbound and four readers with gates westbound. System is used to restrict BRT station access to BRT buses only.																		
Precision Docking System	Per Bus	20,000						68	1,360,000									
	Per Station	5,000						4	20,000	345,000	1,725,000	690,000					N/A	1,725,000
Phase III: Deployed on BRT buses only. Based on four stations at West Park, Wiehle, Reston and Herndon																		
Transit Vehicle Mechanical Safety Monitoring and Maintenance	Engine Sensors & On-board Processor	600						139	83,400									
	Driver Warning Interface	1,000						139	139,000									
	Computer Hardware and Maintenance Scheduling Software	120,000						1	120,000	85,600	428,000	171,200					171,200	428,000
Phase III: 139 total buses. Deployed on entire bus fleet.																		
Traffic Signal Priority Study	Traffic Signal Priority Equipment (intersection)	8,500	9	76,500														
	Transit Vehicle Priority Equipment (bus)	1,500	12	18,000														
	Report (pre-study and evaluation)	100,000	1	100,000	23,625	218,125	47,250					N/A					N/A	218,125
Phase II: Deployed at 9 intersection and on 12 buses.																		
Emergency Response	AVL Vehicle Equipment (GPS receiver, radio & mobile data terminal) Non-Bus/Rail Vehicles	7,000						25	175,000									
	Monitoring & Dispatching System (central hardware & software)	1,000,000						1	1,000,000	0	1,175,000	587,500					587,500	1,175,000
Part of the VDOT ALERT initiative. Assumes 25 non-bus/rail vehicles. System cost includes integration.																		

GRAND TOTAL 4,630,375

[1] Initial installation/integration is 25% of capital costs; additional installations/integration is 20% of capital costs

[2] Operations and maintenance is 50% of capital costs; the value is the maximum annual cost of operating and maintaining the ITS application during the phase

N/A = Not applicable