233 Intelligent Transportation Systems (ITS)

233.1 General

Intelligent Transportation Systems (ITS) criteria provided in this chapter applies to the placement and installation of ITS devices and systems along Florida's roadways including Limited Access (LA) facilities, arterials, and express lanes.

The design and layout of ITS facilities should complement the basic highway design and comply with current versions of the following:

- ***Standard Specifications***
- ***Standard Plans***
- ***Turnpike Design Handbook (TDH)***
- ***FDOT Express Lanes Manual (FELM)***
- ***Traffic Engineering Manual (TEM)***
- ***Structures Manual***
- ***Highway Beautification Policy***
- ***Manual on Uniform Traffic Studies (MUTS)***
- ***AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals***
- ***Manual on Uniform Traffic Control Devices (MUTCD)***
- ***Intelligent Transportation System Integration Guide Book***
- ***National Electric Code (NEC)***
- ***National Fire Protection Association (NFPA)***
- ***Title 23 Code of Federal Regulation (CFR), Part 940***
- ***Title 47 CFR, Part 90***
- ***Title 47 CFR, Part 95L***

Additional information related to the design of ITS facilities is found in the following locations of the ***FDM***:

- ***FDM 215*** – lateral offset requirements for poles, sign structures, field cabinets, and communication hubs for deployments. Deployment refers to existing and new ITS facilities and infrastructure.

- ***FDM 221*** – utility coordination
- ***FDM 261*** – structural support requirements
- ***FDM 328*** – ITS Plans content and requirements

Refer to ***Chapter 5*** of the ***FELM*** for information on the Turnpike Toll Collection System interfaces with the District ITS and Pricing System.

The Statewide Systems Engineering Management Plan and various systems engineering templates (e.g., Concept of Operations) are found on the following web site:

http://www.fdot.gov/traffic/ITS/Projects_Deploy/SEMP.shtm

233.1.1 Railroad-Highway Grade Crossing Near or Within Project Limits

Federal-aid projects with a railroad-highway grade crossing near or within the project limits should refer to ***FDM 220.2.4***.

233.1.2 Attachments to Barriers

Refer to ***FDM 215*** for information regarding proposed attachments to bridge traffic railings, concrete median barrier walls, concrete shoulder barrier walls or the evaluation of existing attachments.

233.1.3 ITS Device Approval and Compatibility

ITS devices are traffic control devices that follow approval requirements discussed in ***FDM 232.1.3***.

Incorporate features and functions that allow interoperability with other ITS deployments throughout the region and state including existing Transportation Management Center (TMC) hardware and software. Examples of design characteristics that promote interoperability include:

- Systems and products based on open architectures and standards.
- Systems and products that are scalable and nonproprietary.
- Compatibility with the Department's SunGuide® Software directly or via support of one or more of its related Interface Control Documents (ICD).
- Compatibility with the local agency central system software, as applicable.

- Systems on the Department's Approved Products List (***APL***), Innovative Products List (***IPL***), or proprietary products. Refer to ***FDM 110.4.1*** for more information on proprietary products.
- Compatibility with existing or legacy systems and networks.
- Develop technical special provisions (TSPs) or modified special provisions (MSPs) in accordance with the Department's ***Special Provision Handbook***.

233.2 ITS Design Criteria

ITS devices and systems gather, analyze, and distribute real-time information to improve the safety, efficiency, mobility, security, and integration of transportation systems. Various ITS technologies have strengths and limitations for collecting, analyzing, and disseminating information. Select ITS devices for the appropriate application.

Many ITS devices require specific placement and configuration requirements for the equipment to perform properly. Consider the following for the design of these devices:

(1) Life cycle expectancy for continued operations and maintenance.

(2) Value engineering for installation and maintenance of the design.

(3) Environmental impacts.

(4) Technologies for commercial vehicle operations.

(5) Technologies for connected vehicles.

(6) Accommodations for future expansion.

(7) Utility and landscaping impacts.

233.2.1 Title 23 CFR, Part 940

ITS projects must comply with the requirements specified in the ***Guidelines for the Implementation of Part 940 in Florida*** (Topic No. 750-040-003). This is to ensure compliance with ***Code of Federal Regulations (CFR) Chapter 23 Part 940 Section 940.11*** and Department requirements.

233.2.2 Maintenance Considerations

Consider the following for maintenance access:

- Provide a minimum 4-foot clear area around the ITS pole for maintenance of the camera lowering device.
- Avoid ITS equipment near areas susceptible to vegetation overgrowth, swales, or wetlands.
- Avoid installing equipment in medians.
- Provide a leveling platform and railing system (handrail) to protect from any drop-off hazards and/or slopes steeper than 1:2.
- Place ITS equipment behind existing or proposed guardrails, as required in ***FDM 215.2.4***.
- Provide space to pull over on the shoulder to access the equipment.

233.3 ITS Power Design

ITS systems typically operate on 120 volts alternating current (AC) from the commercial utility service provider. Some systems operate using a low voltage (60 volts or less) direct current (DC) power source, facilitating battery and solar power options. Consider the following for power designs:

- Existing and future loads.
- Expected power consumption duty cycle.
- The time during which the system must operate.

233.3.1 Power Source Design and Placement

Power service availability is an essential element to ITS design. The power service location is the demarcation point between the Department and the commercial utility service provider. In many cases, the power service is a new power service pole located immediately inside the R/W.

Identify the location of power service and design the power service cable routing from the power service to the field device cabinet. Include the device stations and offsets for proposed power service locations in the plans.

Power service locations are typically located within a half-mile of the ITS devices served. Consult with the commercial utility service provider to select optimal power service locations for power service routing greater than a half-mile.

Identify underground and above-ground obstacles (e.g., buried utilities, structure foundations, retaining walls, guardrail) between proposed ITS devices and the power services. These obstacles may affect the location of proposed ITS devices, the choice of power service points, or the routing for the power service conductors.

233.3.2 Local Backup and Alternative Power Sources

Provide Uninterruptible Power Supply (UPS) to prevent failure of normal operations for mission critical systems. Mission critical systems are systems that are critical to the daily operation of the Transportation Management Center (TMC) (e.g., master hubs, certain local hubs, detectors, cameras, signs, tolling systems) as defined by the District ITS/Transportation Systems Management & Operations (TSM&O) Engineer.

Solar or wind power sources may be an option for some ITS applications. Consider the geographical and topographic features that affect sunlight or wind exposure, size of site, and protection from maintenance operations (e.g., mowing).

An electrical distribution system may be necessary in rural areas where commercial electric service is not readily available. Design the electrical distribution system in accordance with ***NEC*** requirements. Consider voltage and amperage needs of the equipment along the distribution system. Different combinations of voltage, conductor size, step-up, step-down, and isolation transformers may be used to design a system that is cost effective to construct and maintain. Coordinate with the District ITS/TSM&O Engineer to determine additional electrical capacity needs.

Modification for Non-Conventional Projects:
Delete the last sentence above and see RFP for requirements.

233.3.3 Application for Electric Service

Proposed service points for new power service installations require approval by the commercial utility service provider. This approval should be coordinated with the Department and the commercial utility service provider early in the design process.

The approval of proposed service points for new power service installations include the following steps:

1. Determine the following:
    a. Availability of service at any location.
    b. Commercial utility service provider's standard type of service for the load to be served.
    c. Designated point of delivery (prior to confirmation with the commercial utility service).
2. Request that the proposed service points be verified and approved by the commercial utility service provider.
3. (Optional) Hold a coordination meeting in the field with the commercial utility service provider representative.
4. (Optional) Designer to obtain a written agreement with the commercial utility service provider for agreed upon service locations.

In most locations, the secondary distribution system provides service(s) at standard voltages.

Modification for Non-Conventional Projects:
Delete ***FDM 233.3.3*** and see RFP for requirements.

233.3.4 Power Design Requirements

Key design steps for an ITS device deployment electric power system are:

1. Determine the total power requirement based on anticipated peak equipment loads determined in accordance with ***FDM 233.3.5***.
2. Select a suitable power source based on availability.
3. Determine transformer requirements (step-down, step-up, or isolation), where applicable. The need for transformers may be based on voltage and power loss calculations.
4. Balance the device electrical loads to achieve a uniform and efficient power distribution design.
5. Separate power service meter to be provided for ITS infrastructure

Locate a power disconnect switch within a convenient distance from the device service enclosure. For example, the power to operate a Dynamic Message Sign (DMS) may be fed from a nearby DMS service enclosure, and a power disconnect switch is typically installed outside of the service enclosure.

233.3.5 Power Load Requirements

The total power requirement for any deployed device or deployment site is the sum of the power requirements of the following:

- Heating Ventilation and Air Conditioning (HVAC).
- Cabinet components (lights, fans, UPS).
- Devices not powered through the UPS.
- Convenience outlets.
- Future device loads.

Assume all equipment is in continuous operation.

233.3.6 Voltage Drop

Perform voltage drop calculations for ITS devices with the following considerations:

- Ability of the ITS device to operate above or below the nominal voltage.
- Distance from the power source to the ITS device.

Voltage drop mitigation strategies may include use of larger power conductors or higher service voltage.

Meet ***NEC*** code for ITS equipment electrical designs, including voltage drop calculations, load requirements, electrical device sizing (e.g., switches, isolators, bus bars, surge protective devices), and grounding.

233.3.7 Installation of Power Cable

Install power cables in separate conduits and pull boxes from communications cables. Design for the maximum duct fill ratio in accordance with ***NEC, Chapter 9***.

233.3.8 Grounding and Lightning Protection

Include provisions for grounding and lightning protection. Examples of techniques for grounding and lightning protection include the following:

- Proper bonding and installation of grounding rods and grounding conductors.
- Air terminals.
- Surge Protective Devices (SPDs).

***Standard Plans*, Index 700-090** contains additional information on grounding and lightning protection for DMS signs.

Existing geological and other physical characteristics (e.g., rock formations, underground utilities, gravel deposits, soil types, and resistivity, groundwater) affect the design or layout of grounding systems. Include in the plans relevant subsurface data at the proposed installation locations (e.g., soil resistivity measurements).

Place the grounding arrays such that grounding paths from the down cable to the primary electrode are as straight as possible. Provide details in the plans related to grounding and cable routing for each device.

Determine grounding and SPD placement and overall system design based on project-specific needs and the following:

- Follow ***NFPA 780 (Standard for the Installation of Lightning Protection Systems)***, ***Underwriters Laboratories*** (***UL***) ***UL-1449***, and the ***NEC***.
- Place SPD equipment so that grounding connections are as short and straight as possible.
- Avoid bending conductor routes.
- Provide physical separation between low-voltage and high-voltage signal paths.
- Avoid routing unprotected wires or grounding wires parallel or adjacent to the protected wiring.

233.3.9 Emergency Generator Power Systems (Generators)

Generators provide temporary power when commercial AC power is interrupted. Their use is associated with mission critical ITS applications (as described in ***FDM 233.3.2***).

Permanent generators are required for applications that cannot tolerate a short duration outage. Supplement with a UPS or battery system to provide continuous power service during the start-up cycle of the generator.

Include a connection and proper receptacles to accommodate a portable generator for applications that can tolerate a short duration outage of a few hours.

233.3.9.1 Generator Design Requirements

Sizing a generator depends on design load (including future device loading) and power factor. Consider run time requirements and future load expansion in the generator design. Identify and design specific critical load circuits to be powered by the generator when commercial power fails.

Use Liquefied Petroleum Gas (LPG) as the fuel type for permanent generator designs. The preferred storage technique for LPG is in-ground (buried) tank. Meet the minimum requirements in ***NFPA 58 (Liquefied Petroleum Gas Code)*** for generator designs.

Install a manual transfer switch for all generator installations.

Include an automatic transfer switch for permanent generator installations. The automatic transfer switch must provide emergency power in less than 15 seconds and permit full manual override control for testing and maintenance.

A remote monitor and control appliance is typically installed and connected to a network management system to monitor the status of a permanent generator, and allow remote operations and testing capabilities. Coordinate with the District ITS/TSM&O Engineer to determine if remote monitoring is required.

Modification for Non-Conventional Projects:
Delete the last sentence above and see RFP for requirements.

233.3.10 DC Power Plant (48 Volt)

DC power plants protect ITS devices from potential disruptions, such as high-switching voltages, transients, lightning strikes, harmonic distortion, and interference from other equipment.

Include DC power plants where ITS applications require isolation from the AC power grid utility service provider. Connect the DC power plant to the facility grounding system.

233.3.10.1 Battery Types

Use Valve Regulated Lead-Acid (VRLA) batteries for mission critical ITS applications (as described in ***FDM 233.3.2***).

Consider a large form factor lithium battery (e.g., Lithium Iron Phosphate) if a site has a unique battery size limitation.

Provide proper ventilation for specified battery system.

Do not use flooded type lead-acid batteries.

233.3.10.2 Battery Sizing

Size battery systems to support all the following:

- Present design load plus load expansion safety margin (typically 25%).
- Anticipated future load expansion.
- Minimum run time requirements of the DC power plant load.

Evaluate the present design load for the maximum instantaneous DC current requirements and the average DC current requirements.

Size VRLA battery systems such that the battery cells do not discharge below 50% of their rated capacity.

233.3.10.3 Battery Interconnects

Provide a circuit breaker disconnect and a low voltage disconnect for battery systems.

233.3.10.4 Battery Charging Systems

Match the battery charging system to the battery type and size to avoid unnecessary damage to battery cells. Battery charging systems may include multiple rectifiers for load sharing and redundancy.

233.3.10.5 Battery Monitoring System

Provide a battery monitoring system to monitor the condition of each battery or cell. Specify a monitoring system that identifies a thermal runaway event in the battery system and provides information to the charging system. This allows the charging system to lower the rectifier float voltage to limit the current or shutdown the battery system. Connect the battery monitoring system to the network to permit remote reporting.

233.3.10.6 DC Power Plant Load Distribution

Equip DC power load circuits with circuit breaker panels or fuses. Circuit breakers and fuses may be inherent to the DC power plant or part of a stand-alone fused alarm panel to distribute the DC power to load circuits. The panels may be networked to permit remote monitoring.

233.3.10.7 DC Power Plant Wiring

Specify stranded insulated wire with sufficient gauge to carry the required current in the DC power plant. Specify red insulation for source wiring (e.g., -48 VDC) and black insulation for the return (0 V).

233.3.10.8 Battery Installation

Large DC power plants and battery systems installed on flooring, may require a structural analysis to determine the load bearing capacity. Coordinate with the FDOT Project Manager to determine if structural analysis is required.

Modification for Non-Conventional Projects:
Delete the last sentence above and see RFP for requirements.

Design for the weight of large DC power plants and batteries to be evenly distributed to minimize surface or floor load.

233.4 ITS Support Infrastructure

ITS support infrastructure includes:

- Conduits infrastructure.
- Pull, slice, and junction boxes.
- Utility designation (e.g., power, communications).
- Fiber optic network cables and connections.
- Poles and structures.
- Camera lowering devices.

233.4.1 Conduit Infrastructure

Plans must specify the conduit color, inner duct type, size, and quantity of the conduit system.

Design the conduit system in accordance with the following:

- Conduit runs are to be as straight as possible.
- Joints and bends in the conduit system are to meet minimum bending radius of the fiber optic cable as defined in ***Standard Specifications***, ***Section 633***.
- Place conduit along the edge of R/W as much as possible to avoid future widening conflicts.
- Avoid placing conduits:
    - Within terrain steeper than 1:4 slope.
    - Near endangered species habitats, chronic wet areas, landscaping, drainage features, and existing or proposed roadside features (e.g., guardrail).
    - Near underground utilities and lighting conductors.
    - Behind noise walls.
- Provide maintenance access to the conduit and pull or splice boxes.
- Minimize the number of directional borings. If there are two directional bore sections, less than 100 feet apart, then consider using a continuous directional bore.
- Minimize road crossings. When road or ramp crossing is necessary, place conduit perpendicular (shortest distance) to the roadway or ramp to the greatest extent possible.

233.4.2 Pull, Splice, and Junction Boxes

Provide access points using pull, splice, or junction boxes. Minimum requirements for placement of access points are as follows:

- Provide at-grade access to fiber optic cables housed within conduit systems.
- Provide assist points to aid in fiber optic cable installation.
- Provide protection for the fiber optic cable.
- Provide space for storing cable slack/coils and splice enclosures.
- Provide space for entry, routing, and slack fiber storage for pull boxes and splice boxes. Typically, 100-foot cable slack is used per splice box and 50-foot cable slack is used per pull box.

Access points are required at the following locations:

- At every 2,500 feet in a continuous straight conduit section, if no fiber optic cable splice is required.
- At every 1,000 to 1,500 feet in urban areas (typically in context classifications C4 through C6).
- Major fiber optic cable and conduit reel junctions.
- Planned or future splice locations.
- On each side of:
  - A tunnel, river, or lake crossing.
  - An above-ground conduit installation (e.g., attachment to bridge or wall).
  - A railroad crossing.
  - A roadway crossing, except for narrow roadways, such as ramps.
- Turns in the conduit system.
- Near the base of a service pole or communication cabinet.

Splice boxes must be used for access points on fiber optic cable backbone routes or for device drop. Pull boxes can only be used for access points when the conduit system extends from the backbone to the ITS field devices.

Standard Plans*, *Index 634-002 includes information for aerial interconnect, and ***Index 635-001*** includes information for pull and splice box details.

233.4.3 Fiber Optic Cable Designating System

The fiber optic cable designating system provides visual indication of the underground fiber optic conduit or cable system. Provide appropriate fiber optic designating system per Standard Specifications 630.

233.5 Fiber Optics and Network Design

Design network facilities based on specific project needs with the following information:

- General network topology.
- Facility diagrams illustrating conduit routes.
- Network diagrams, including communication hub details.
- External network connections and demarcation points.
- Fiber block diagram to show switches, field devices, and physical network connectivity.

Include Special Provision SP0071101-Tolls in the contract documents when there are existing power or communication cables that transmit toll system information near areas where work is to be performed. Refer to the General Tolling Requirements (GTR) for specific ITS requirements related to toll facility design.

233.5.1 Fiber Optic Cable

Fiber optic cable is utilized in the Department's statewide network infrastructure to provide data and device control communications between ITS field devices, Transportation Management Centers (TMCs) and other identified stakeholder facilities.

Requirements for fiber optic cable are as follows:

- Design for single mode fiber strands.
- Define fiber optic cable trunk, drop buffer tube, and strand color requirements.

233.5.1.1 Splices, Terminations, and Connection Hardware

Plans must provide the following:

- Splice points and splice diagrams.

- Interconnect fiber strands, origination, and destination points.
- Minimum link loss budget; including line, splice, and termination losses
- Reserve loss budget for future splicing and cable deterioration. Budget for future loss to equal one-half of the total decibels of the circuit or 10 decibels, whichever is greater.
- Splice enclosures to protect all fiber splices within splice trays. Number and size of splice trays and enclosures are based on the number of fibers involved in the splicing diagram at each splice location.
- Existing fiber optic cables and the location of the nearest full splices in the existing cables, including distance in each direction.
- Termination of fiber optic cables using a Fiber Patch Panel (FPP). Terminate single-mode fiber optic cable in the FPP or use pre-terminated FPP connectors.

233.6 ITS Poles and Structures

Consider the following to locate and select ITS poles and structures:

- Existing ITS infrastructure, roadway features, device type (match existing), and environment.
- Road geometry, static signs spacing, lightning protection, underground utilities, and drainage infrastructure.
- Aesthetics, conflict avoidance, and line of sight issues.
- Soil boring information for the foundation design of the structures.
- Co-locating ITS devices to minimize the number of poles and structures.
- Pole type for each ITS device (e.g., pre-stressed concrete, steel) and structure type (e.g., cantilever, full-span, mid-span).

233.6.1 Camera Lowering Device

Provide a lowering device for pole-mounted cameras where height impedes access via maintenance truck.

Design external conduit for housing the cables, mounting box hardware at the top of the structure, and component details required for installation (e.g., air terminal, guide wire) for a lowering device to be attached to an existing pole or similar structure.

The lowering device must be oriented to prevent an operator from standing directly beneath the equipment while it is being lowered.

233.7 ITS Enclosures

ITS enclosures include ITS field cabinets, small equipment cabinets, and equipment shelters. Each of these cabinets require an analysis for design, usage, and placement.

233.7.1 ITS Field Cabinets

Placement of ITS field cabinets is based on the safety of the motorist, visibility of roadside devices, and safety of maintenance staff. Mount the ITS field cabinets on concrete pads, structures, or poles. Do not place cabinets in flood-prone areas or wetlands. Consider including safety features such as service slabs and railings for cabinets placed on slopes steeper than 1:2. Place ground mounted DMS cabinets based on the DMS type. Cabinet mounting details are shown in ***Standard Plans*, *Indexes 641-020*** and ***649-020***.

Size the cabinet to accommodate equipment to be installed, ease of access, anticipated future equipment (e.g., connected vehicle roadside unit in-cabinet equipment), and proper ventilation. All cabinets within a project corridor should have a consistent layout for the interior by functionality. Orientate the cabinet such that the maintenance technician is facing oncoming traffic when accessing the cabinet. Show cabinet orientation and door swings in the plans.

Provide one power and one communication entry conduit for each cabinet, at minimum. Include additional conduit entries as required for the equipment to be housed. Include spare conduits in the cabinet for future expansion.

233.7.2 Small Equipment Enclosures

Small equipment enclosures include structure- or pole-mounted cabinets (e.g., National Electrical Manufacturers Association (NEMA) 3R). These may be used in lieu of ITS field cabinets in locations that require minimal equipment to be housed. Small equipment enclosures may be connected to another ITS site, which houses the Ethernet switch and other ITS components. When locating the small equipment enclosure, consider the allowable power and communication loss per ***IEEE 802.3ab*** to District network speed requirements.

233.7.3 Equipment Shelter

Co-location of master hub equipment in existing FDOT-owned microwave tower buildings may be used in-lieu of new equipment shelters. Coordinate with the District ITS/TSM&O Engineer and the State Traffic Engineering and Operations Office's ITS Communications division to determine if co-location is possible.

Modification for Non-Conventional Projects:
Delete the last sentence above and see RFP for requirements.

If co-location is not possible, provide the following information in the equipment shelter details:

1) Site layout
    - Shelter dimensions.
    - Site preparation work, clearing and grubbing, fencing, and landscape.
    - Conduit and pull box installation.
    - Details for grounding.
2) Shelter layout
    - Details for electrical and lighting.
    - HVAC systems.
    - Back-up power systems (e.g., UPS, generator, fuel tanks).
    - Security features (e.g., cameras, security alarms).
    - Remote monitoring alarms.
3) Equipment layout
    - Overhead cable trays.
    - Standard EIA/TIA 19-inch racks.
    - Demarcation punch blocks.
    - Patch panels.
    - Equipment placement within each rack.

233.8 Communication and Networking Devices

Network devices include a variety of Internet Protocol (IP)-addressable electronic equipment. This equipment is used for the collection and dissemination of video, traffic data, and other information.

Provide communication and networking devices that conform with the following:

- Network requirements and information for communication network design.
- Compatibility with existing network equipment currently in operation.
- Minimal system downtime to facilitate immediate replacement of defective or damaged units.
- Open architecture.
- Survivability and reliability.
- Redundant path and no single point of failure.

233.8.1 Managed Field Ethernet Switch (MFES) Network

Provide MFES network to avoid the following:

- Distance limitations for common Ethernet media types.
- Interference that may be induced on copper-based interconnects.
- Data size transfer limitations based on Gigabit Interface Converter (GBIC).

Provide layer 3 routing to support the District's network architecture in leap-frog configuration to provide redundancy and optimized data transfer. Ensure no more than one DMS and no more than six CCTV devices are included on any one leap-frog circuit. Ensure that adjacent CCTV devices are on separate circuits.

Provide Ethernet connection ports for each planned ITS field device, along with spare capacity for future expansion. Coordinate with District ITS/TSM&O Engineer for port preferences, and data bandwidth requirements.

Modification for Non-Conventional Projects:
Delete the last sentence above and see RFP for requirements.

233.8.2 Device Server

Include device servers when remote field devices with serial communication interfaces require connection to an Ethernet network.

Equipment that may require the use of device servers include:

(1) Vehicle detection systems.

(2) Road Weather Information System (RWIS).

(3) Low-speed data output devices.

233.8.3 Media Converter

Media converters may be used to transition between various types of interfaces.

233.8.4 Wireless Communications System

Determine the proper wireless communications system to fit the ITS application (e.g., point-to-point, point-to-multipoint). Consider reliability, security, capital and operational expenditures, licensed versus unlicensed radio bands, and regulatory requirements for the wireless communications system selection.

Wireless systems enable data communications through radio links.

Typical applications for point-to-point wireless communications system includes:

- Remote ITS field devices or intersections that can use a wireless connection to the nearest fiber drop point.
- Across rugged terrain and bodies of water.
- The use of fiber optics is temporarily unavailable during construction; this use must be approved by the District ITS/TSM&O Engineer.
- ITS device sites where it is difficult or cost prohibitive to install fiber optic cables.

Typical applications for point-to-multipoint wireless communications system includes:

- Land Mobile Radio push-to-talk.
- Highway Advisory Radio.
- Citizens Band (CB) Radio.

The ITS Communications division maintains the Federal Communications Commission (FCC) licenses associated with ITS wireless communications and manages assignment of new licenses. Districts using wireless communications systems to support an ITS application are encouraged to contact State Traffic Engineering and Operations Office's ITS Communications division.

Specify each component in the wireless communications system including antennas, radios, transmission lines, and connectors. Provide installation details, location, and placement of the system components. Design cable management details. Consider the length between transmit and receive equipment to attain optimum communications signal.

Design line-of-sight, throughput, frequency, availability, power levels, and path calculations for the communications design plans as follows:

- Design the communication path so that two-thirds of the Fresnel Zone is clear of any obstructions (e.g., surrounding terrain, trees, signs, buildings).
- Set throughput capacity for each radio link to transmit two times more data than the maximum data throughput.
- Analyze multipath challenges over large water bodies and within urban street canyons (created by large buildings).
- Analyze spectrum interference in the vicinity.

To maximize data security and minimize communication interference, wireless communications are not recommended for express lanes.

233.9 Vehicle Detection Systems

Include the location and placement of system components and provide installation details for the cables. Design the cabling installation details.

Consider capabilities and functional limitations at each location to attain the required levels of detection accuracy as specified in ***Standard Specifications***, ***Section 660-2***.

Show detector types and locations on the plans to obtain traffic data such as speed, occupancy, and volume. Detector placement must conform to the following requirements:

- Cover all lanes in both directions (as a group or individually).
- Space one-third to one-half mile in urban areas (context classifications C4, C5 and C6).
- Space one-mile in suburban areas (context classifications C3R and C3C).

- Space one to two-mile in rural areas (context classifications C1, C2, and C2T).
- Space one-fourth to one-third mile on express lanes.
- Place at major interchanges exit and entrance ramps.
- Place at intersection to detect vehicle presence at the stop bar, when required.

233.9.1 Loop Detectors

Do not use loop detectors on concrete pavement or on corridors with large traffic volumes of heavy vehicles. Consider using them at locations with low volumes of traffic.

233.9.2 Video Vehicle Detection Systems (VVDS)

Design considerations for VVDS include:

- Upstream versus downstream view orientation.
- Shoulder coverage to detect stalled vehicles.
- Detection zone layout to cover near and far zones.
- Roadway geometry and line of sight.
- Requirement to view VVDS images from the Transportation Management Center (TMC).
- High contrast or low light conditions that might interfere with VVDS data reliability.
- Maintenance requirements and impact of high winds on detector alignment and calibration.

233.9.3 Microwave Vehicle Detection Systems (MVDS)

Design considerations for MVDS include:

- Cover all lanes in both directions of travel.
- Provide offset mounting on structures.
- Avoid aiming toward steel structures.
- Align detector perpendicular to the roadway.
- Provide access for maintenance and calibration.
- Use Power over Ethernet when connecting to an ITS Field Cabinet within 330 feet.

233.9.4 Wireless Magnetometer Detection Systems (WMDS)

Design considerations for WMDS include:

- Determine the number and spacing of sensors based on detection requirements; e.g., three magnetometers may be required for truck parking.
- Align sensors such that they are placed in the direction of traffic flow or parking space.
- Provide access for installation, maintenance, and calibration.

233.9.5 Automatic Vehicle Identification (AVI) Systems

Design considerations for AVI systems include:

(1) Follow manufacturer's requirements for AVI sensor placement, mounting height, offset, and line of sight.

(2) Follow location and spacing based on District objectives for the AVI system. Potential locations include mid-blocks, major intersections, and locations prior to or after interchanges.

233.10 Closed-Circuit Television Systems

Closed-circuit television (CCTV) systems consist of roadside cameras, communication devices, as well as camera control and video display equipment. CCTV is located at one or more remote monitoring locations that allow surveillance of roadway and traffic conditions for traffic and incident management. Cameras are also required for visual confirmation of dynamic message signs and ramp signal operation, as well as security purposes.

Design and placement considerations for CCTV cameras includes:

- Locate cameras on limited-access facilities and arterials to obtain a continuous view of roadway features including lanes, shoulders, ramps, ramp terminals, and designated emergency stopping and crash investigation sites beyond the traveled way.
- Place cameras at interchanges to view arterial traffic.
- Place cameras for DMS verification no further than 1,000 feet from the face of the DMS with a clear line of sight within the horizontal and vertical viewing cone.
- Dedicated express lane cameras for verification must be capable of pan, tilt, and zoom (PTZ) for every DMS.

- Accommodate service and maintenance access with minimal impact to traffic.
- Utilize crash data analysis to place cameras at high-crash locations.
- Place the camera at a location with minimal vegetation obstruction within half-mile on each side.
- Identify locations for vegetation removal in the plans or propose closer spacing upon approval from the District ITS/TSM&O Engineer and District Landscape Architect.

Modification for Non-Conventional Projects:
Delete the last bullet above and see RFP for requirements.

- Locate the camera outside the clear zone, or place behind existing guardrail and barrier walls. Avoid introducing new guardrail and barrier walls.
- Specify camera mounting height in the plans based on specific project needs. Consider the following in determining the mounting height:
    - Required viewing distance.
    - Roadway geometry and lane configuration.
    - Roadway functional classification (e.g., arterial, collector, limited access facility).
    - Environmental factors (e.g., glare from the horizon, headlight glare).
    - Vertical clearance.
    - Co-location with the other ITS devices.
    - Existing and anticipated vegetation.
- Consider camera life-cycle cost, including maintenance costs.
- Consider CCTV performance and bandwidth requirements, control type, use of temporary cameras, and camera housing.

Design camera housings, enclosures, lowering devices, and mounts in accordance with the ***Standard Specifications***.

Refer to ***Standard Plans**, **Index 649-020*** or ***Index 641-020*** for CCTV camera pole and foundation details. Refer to Department's ***Standard Specifications***,(Division II and III) Section 649 for Steel Pole and Section 641 for Concrete CCTV Pole.

233.11 Motorist Information Systems

Motorist Information Systems include DMS, Highway Advisory Radio (HAR), electronic display signs, and Citizens Band (CB) Radio.

233.11.1 Dynamic Message Sign (DMS)

Select the appropriate DMS type based on specific project needs. Position the DMS to be legible from the roadway based on the display characteristics of DMS technology (e.g., the vertical and horizontal viewing angles of LED displays).

Determine DMS placement based on the following requirements:

- Compatible with the message library proposed for use on the project, including text and graphics.
- Utilize DMS capable of displaying minimum character heights and line spacing per the ***MUTCD***, Section 2L.04.
- Place in advance of high crash locations and traffic bottlenecks.
- Place where sufficient space is available between the edge of travel lanes and the R/W limits, while meeting the minimum clear zone requirement.
- Place where no conflict with underground or overhead utilities exists.
- Accommodate access for service and maintenance.
- Place along key commuter or evacuation corridors.
- Place on Interstate and Freeway facilities in advance of interchanges that offer alternate routes, and meet the requirements of ***MUTCD***, Section 2L and the following:
    - Place in advance of 1-mile exit signing.
    - Provide a minimum 800-foot spacing between existing and planned overhead static and other signs, per the ***MUTCD***. Provide increased spacing when conditions allow.
    - Install walk-in DMS on support structures without static signage.
    - In advance of interchanges where interstates meet to allow for advance messaging of traffic conditions on both roadways. Consider locations that are two exits before major interchanges as well as immediately prior to the interchange.

  - o Mount embedded DMS over or under the static sign panel or use a static sign cut-out.
- Place on arterials prior to major intersections and interchanges:
  - o Approximately 1/4 to 1/2 mile in advance of major intersections or interchanges.
  - o At least 600 feet from adjacent signalized intersections.
  - o Where the DMS is continuously visible to motorists for 600 to 800 feet, depending on the design speed of the roadway.
  - o Where no existing or planned guide signs exist within the 600-foot minimum visibility distance.
  - o With minimum interference from lighting, adjacent driveways, side streets, or commercial signage.
  - o Where no historical neighborhoods exist.

233.11.1.1 Express Lanes DMS

Express lanes DMS must be full-color or full-matrix DMS and conform to the following application criteria:

Table 233.11.1 DMS Characters

<table>
<tr><th colspan="2">DMS Type</th><th>Character Size (inches)</th><th>Number of Characters Per Line</th><th>Resolution (millimeter pixel pitch)</th></tr>
<tr><td rowspan="2">Lane Status</td><td>LA Facility</td><td>18</td><td rowspan="2">18</td><td rowspan="4">20</td></tr>
<tr><td>Arterial</td><td>12</td></tr>
<tr><td rowspan="2">Toll Amount</td><td>LA Facility</td><td>18</td><td rowspan="2">7</td></tr>
<tr><td>Arterial</td><td>12</td></tr>
<tr><td colspan="5">Notes:
Lane Status DMS can accommodate a single line of characters. Toll Amount DMS can accommodate multiple lines of characters.</td></tr>
</table>

233.11.2 Highway Advisory Radio (HAR)

A highway advisory radio (HAR) system is an advisory tool that informs the public of traffic- and safety-related issues. HAR systems may be installed or upgraded with the approval from the Chief Engineer. See Engineering and Operations Memorandum 16-03.

Include the equipment necessary for the operator to record verbal messages from onsite or remote locations, and to continually broadcast live, prerecorded, or synthesized messages from roadside transmission sites. Also, include highway signs with remotely-operated flashing beacons to notify motorists of HAR broadcasts.

Refer to FCC regulations ***Title 47 CFR, Part 90.242*** for additional design requirements on travelers' information stations. Additional information on licensing issues, frequency allocation, and other specifics may be obtained by contacting the State Traffic Engineering and Operations Office's ITS Communications division.

Determine placement of a HAR installation based on specific project needs, as well as the following requirements:

- Transmission of message that can be received by motorists traveling through the broadcast zone.
- Placement on Interstate and Freeway facilities prior to interchanges that offer alternate routes.
- Placement in advance of high crash locations and traffic bottlenecks.
- Placement that accommodates access for service and maintenance.
- Placement along key commuter or evacuation corridors.
- Placement of flashing beacon signs within the HAR coverage area prior to exit signs or DMS associated with an interchange.
- Wood poles are often recommended by HAR manufacturers for antenna mounting to reduce interference that may occur with conductive poles. Install the antenna in accordance with the manufacturer's recommendations and in compliance with FCC requirements.

233.11.3 Electronic Display Signs

Place Variable Speed Limit (VSL) signs and Lane Control Signals (LCS) in accordance with:

- Locations per District requirements.
- Sign spacing per ***MUTCD*** requirements.

Modification for Non-Conventional Projects:
Delete the first bullet above and see RFP for requirements.

Specify field cabinet, support structure, power supply, and communications to support VSL and LCS installation.

233.11.4 Citizens Band (CB) Radio

The Department deploys CB radios to advise motorists (particularly commercial freight vehicles) about travel conditions and emergencies. The CB radio service operations and electronic equipment are regulated by the FCC in ***Title 47 CFR, Part 95, Subpart D***.

Operation of a remotely-located CB radio station from a facility (e.g., a Transportation Management Center (TMC) where the operator is not co-located with the CB radio) requires a written waiver of the FCC rules. Contact State Traffic Engineering and Operations Office's ITS Communications division to obtain the required FCC waiver needed to remotely operate a CB radio.

233.12 Additional ITS Devices

This section includes information on other ITS devices that are TSM&O tools.

233.12.1 Road Weather Information System (RWIS)

RWIS consists of Environmental Sensor Station that incorporates multiple or single environmental sensor(s) (e.g., wind speed sensors, visibility sensors, pavement sensors) that are attached to one pole. Location of Environmental Sensor Stations should consider the following:

- Place in locations where weather observations will be the most representative of the roadway segment of interest.
- Select locations to avoid the following:
  - o Effects of passing traffic (e.g., heat, wind, splash).
  - o Standing water.
  - o Locations where billboards, surrounding trees, or other vegetation would affect the weather measurements.

For more information on appropriate location of ESS and additional design requirements, refer to the ***FHWA's Road Weather Information System (RWIS) Environmental Sensor Station Siting Guidelines*, *Publication No. FHWA-HOP-05-026***.

Identify the appropriate communication platform for the RWIS application (e.g., copper, fiber, wireless).

Licensing for using satellite-based communications is required, and it must be coordinated by the Department with the National Oceanic and Atmospheric Administration (NOAA). Coordinate the use of satellite-based systems with the State Traffic Engineering and Operations Office's ITS Communications division.

Modification for Non-Conventional Projects:
Delete the last sentence above and see RFP for requirements.

233.12.2 Ramp Metering Signals

A ramp metering signal controls the number of vehicles entering a limited-access facility to maintain steady traffic flow. Consider the following when designing ramp metering signals:

- ***MUTCD*** signalization requirements for ramp signals (e.g., design of the signal system, number of signal heads, placement beside or over the ramp).
- Distance from the stop bar to the acceleration lane to allow vehicles starting from the signal to reach highway speeds and merge safely.
- Distance from signal stop bar to the cross-street intersection to allow adequate vehicle storage at the signal.

- Add two-lane storage upstream of stop bar from cross street to store additional vehicles and not spill over cross street, if ramp meter is proposed on a single lane ramp and traffic analysis warrants the need.
- Placement of stop bar and queue length detection.
- Placement of detectors to support local or central ramp signal control algorithm in use by the District.
- Signing to support signal operation.

233.12.3 Connected Vehicle Infrastructure

Connected Vehicle (CV) is an emerging TSM&O strategy that generally falls into three application categories:

- Vehicle-to-Infrastructure (V2I).
- Vehicle-to-Vehicle (V2V).
- Vehicle-to-Others (V2X).

The V2X components include pedestrians, bicyclists, personal mobile devices, aftermarket safety devices (ASDs), and any other Internet of Things (IoT). The common communications source uses 5.9 GHz Dedicated Short Range Communication (DSRC) or cellular communications to and from Roadside Units (RSUs) and On-board Units (OBUs).

Use the following national standards when designing CV infrastructure:

- United States Department of Transportation (USDOT) ***DSRC RSU Specifications***.
- Society of Automotive Engineers (SAE) ***DSRC Message Set Dictionary***, including Basic Safety Messages (BSMs) and Traveler Information Messages (TIMs).
- USDOT ***Mapping Tool*** or LiDAR for intersection mapping.
- USDOT Architecture Reference for Cooperative and Intelligent Transportation (***ARC-IT***).
- FCC, ***Title 47 CFR***, Parts 90 and 95L.
- USDOT Security Credential Management System (***SCMS***).
- Communications requirements for Internet Protocol version 6 (**IPv6**).

Consider the following for the RSU device placement:

- Co-location of devices with new or existing ITS or signal infrastructure.
- Availability of inside cabinet space for RSU-associated equipment.
- Antenna placement location.
- Wireless coverage.

Provide the RSU locations to the State Traffic Engineering and Operations Office's ITS Communications division and the District ITS/TSM&O Engineer to file for FCC licenses for all DSRC RSUs. FCC licenses must be granted before a station transmits on any channel.

233.13 Maintenance of ITS Devices and Communications

Coordinate with District ITS/TSM&O Engineer to determine if maintenance of ITS devices and communications during a construction project is required. Considerations for uninterrupted ITS devices and communications include the following:

- Install new ITS communications network before removing the existing network.
- Use of temporary fiber that is placed outside the limits of construction.
- Use of temporary aerial fiber or wireless communications.
- Use of other public or private communications.
- Make every effort to maintain existing ITS devices and field equipment. If ITS device locations are impacted by planned construction, include temporary ITS devices.

The maintenance of ITS devices and communications plan must be approved by the District ITS/TSM&O Engineer.

Modification for Non-Conventional Projects:
Delete ***FDM 233.13*** and see RFP for requirements.