Intelligent Transportation Systems (ITS) Guidelines

THE PORT AUTHORITY OF NY & NJ

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1 Introduction

1.1 Purpose of these Guidelines

The Port Authority of New York and New Jersey (PA) ITS Design Guidelines provide planning and design guidance for procurement and construction of Intelligent Transportation Systems (ITS) field devices.

The purpose of these Guidelines is to ensure the proper and consistent deployment of ITS to support PA transportation operations. These Guidelines shall not replace professional design analyses nor are the Guidelines intended to limit innovative design where equal performance in value, safety, and maintenance economy can be demonstrated. The design team shall be responsible for producing designs that comply with the Guidelines in addition to all applicable codes, ordinances, statutes, rules, regulations, and laws. Any conflict between the Guidelines and an applicable code, ordinance, statute, rule, regulation, and/or law shall be addressed with the respective functional chief. The use and inclusion of the Guidelines, specifications, or example drawing details as part of the Contract Documents does not alleviate design professionals from their responsibilities or legal liability for any Contract Documents they create. It is also recognized that the Guidelines are not universally applicable to every project. There may be instances where a guideline may not be appropriate. If the design professional believes that a deviation from the Guidelines is warranted, such a deviation shall be submitted in writing for approval to the respective functional chief.

1.2 Intended Audience

These Guidelines are directed at individuals and organizations involved in the planning, design and deployment of ITS devices. This may include PA staff, design consultants, system integrators, contractors and equipment vendors.

1.3 Supporting Resources and References

Table 1-1 lists references that serve as ancillary resources to these Guidelines. Unless specifically noted in the Guidelines, the latest edition of each reference shall be used. The table is not an exhaustive list of supporting documentation; other resources and references may be identified during the project development process. Also, all local requirements and specifications should be taken into consideration.

1.4 Living Document

Given the rapidly changing ITS landscape, it is imperative that these Guidelines be a “living document.” It should continue to be reviewed and updated periodically to reflect changes in technology, agency priorities and policies, and regional transportation needs.

Table 1-1: References

Reference	Description
Association of State Highway and Transportation Officials (AASHTO): A Policy on Geometric Design of Highways and Streets	Commonly referred to as the "Green Book," this document contains the current design research and practices for highway and street geometric design.
Federal Highway Administration: Manual on Uniform Traffic Control Devices (MUTCD)	This manual provides guidance on the basic principles of traffic signals, signs and road markings and defines the standard used nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic.
Federal Highway Administration: HRT-06-108, Traffic Detector Handbook	This handbook provides a comprehensive reference document to aid the practicing traffic engineer, planner, or technician in selecting, designing, installing, and maintaining traffic sensors for signalized intersections and freeways.
Institute of Electrical and Electronics Engineers (IEEE) Standard 829-1998, Standard for Software Test Documentation.	A set of basic software test documents is described. This standard specifies the form and content of individual test documents. It does not specify the required set of test documents.
National Fire Protection Association (NFPA) 502– Standard for Road Tunnels, Bridges, and Other Limited Access Highways	This standard provides fire protection and fire life safety requirements for limited access highways, road tunnels, bridges, elevated highways, depressed highways, and roads that are located beneath air-right structures.
The National Transportation Communications for ITS Protocol (NTCIP) Guide	The NTCIP Guide is a document created to assist in understanding, specifying and using the National Transportation Communications for ITS Protocol (NTCIP) family of communications standards. This family of standards defines open, consensus-based communications protocols and profiles for remote control of roadside devices and information sharing between centers.
PA CCTV Policy Statements	This document provides a series of policy statements on the use of Closed Circuit Television (CCTV) at PA Facilities. This document is required reading for PA consultants when planning or designing CCTV devices.
PA Construction Specifications	The PA Construction Specifications are intended for use with the General Conditions of the contract. Contractors shall comply with every requirement of the PA Construction Specification relevant to the type of work forming any part of the contract, and adopt whichever permissible option or alternative is best suited to the needs of the construction work being undertaken.
PA Standards and Guidelines for Port Authority Technology	This document provides standards and guidelines for the deployment of technology, such as computer hardware, software and communications devices for the PA.
PA Highway Design Manual (HDM)	This manual provides the guidelines for the design of roads and intersections.
PA ITS Specifications	The ITS specifications should be used by PA and their consultants for all ITS projects.
PA ITS Strategic Plan	The purpose of the ITS Strategic Plan is to identify the direction for ITS planning, development, and deployment for the next 15 years.
PA Standards for Intelligent Transportation Systems	These standard drawings and details are applied to standardize the design of infrastructure elements that support ITS. These documents should be used by PA and their consultants for all ITS projects.
PA TSD-Agency CCTV Standards	This document governs the design, implementation and operational management of all Port Authority (CCTV) systems.
Sanwal, K. and Walrand, J. Vehicles as Probes	This article is produced by the California PATH Program, Institute of Transportation Studies, University of California at Berkeley and is a seminal paper on utilizing RFID equipment to use vehicles as probes.
USDOT Systems Engineering for Intelligent Transportation Systems	This document provides an overview of Systems Engineering for ITS for Transportation Professionals

2. Systems Engineering Process

These Guidelines are intended to be part of a systems engineering (SE) process that serves as the framework for the development and deployment of ITS projects. ITS projects are diverse and consist of a variety of hardware, software, and communications technologies. The technology and required integration of components distinguish ITS implementations from most other types of capital projects undertaken by the PA. By their very nature, ITS projects present a project management challenge: Satisfy the needs of the agency and complete the project on time and within budget.

To reduce the risks inherent to ITS projects, the PA has, in conformance with USDOT policy, adopted the use of systems engineering for ITS projects.[1] Furthermore, the PA has developed a customized Systems Engineering 'V' Model as shown in Figure 2-1 below.

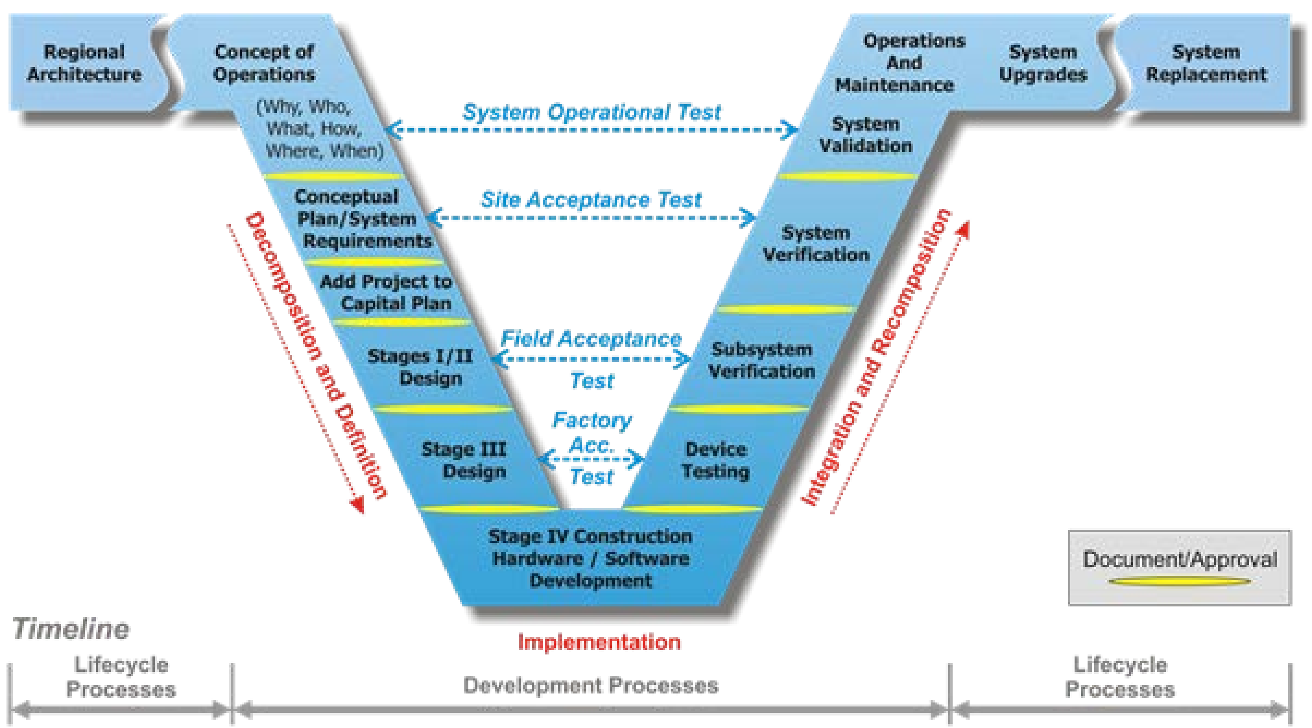


Figure 2-1: PA Systems Engineering "Vee" Diagram, PA ITS Strategic Plan, June 2012

These Guidelines assume that the Concept of Operations and System Requirements have been prepared for the ITS project under consideration and that the designer has reviewed these documents. Before undertaking an ITS project, the designer should:

- Consult the Regional ITS Architecture, discussed in Section 2.1 ITS Architecture
- Consult an existing Concept of Operations or develop a new one, as discussed in Section 2.2 Concept of Operations (ConOps)
- Consult PA Specifications for requirements, as discussed in Section 2.3 Requirements

[1] "Systems Engineering for Intelligent Transportation Systems," USDOT, January 2007.

The Guidelines will assist the designer in developing the next step in the "Vee" diagram, i.e., development of the Stage I/II Design. After the Stage I/II Design is completed and approved, the next step would be the preparation of a Stage III Design in accordance with applicable PA standards, specifications and typical details.

2.1 ITS Architecture

An ITS Architecture defines the technical and institutional integration planned for ITS deployments in a region. It is a tool to support ITS planning in the region, serving as a guide for how different ITS related projects fit together into an overall plan for the deployment of ITS. The PA is covered by two architectures. The New York City Sub-Regional ITS Architecture (NYCSRA) covers PA projects located within New York City. The architecture is located at http://www.consystec.com/nycsraupdate/web/. Portions of the architecture relevant to PA can be identified by selecting one of the menu selections on the top under "Stakeholders", such as "Inventory by Stakeholder" or "Services by Stakeholder". Directions for using the website can be found under the Resources tab, under "How to Use Web Site".

The North Jersey Transportation Planning Authority (NJTPA) Regional ITS Architecture covers PA projects in the northern New Jersey area. It is located at http://consystec.com/newjersey/njtpa/web/_regionhome.htm. Similar to the NYCSRA, portions of the architecture relevant to PA can be identified by selecting one of the tabs on the left hand side of the screen that identify portions of the architecture according to stakeholder, such as "Inventory by Stakeholder" or "Market Packages by Stakeholder". Directions for using the website can be found on the home page near the top by clicking on "How to Use this Web Site". Note that an updated process for the New Jersey ITS Architecture was initiated by NJTPA in 2013 and is ongoing as of early 2014.

2.2 Concept of Operations (ConOps)

A Concept of Operations (ConOps) is a document, written from a systems user point of view, that clearly defines the situation or problem, scope, user needs and operational context for the project. The ConOps, therefore, should be developed with participation from all users that benefit from or are impacted by the system. The PANYNJ Project Initiation Request Form (PIRF) or Project Definition Statement (PDS) typically contain most of the elements of a ConOps. A copy of the PIRF can be found in Appendix C.

The purpose of the ConOps is to clearly convey a high-level view of the system to be developed that each stakeholder (user) can understand. This step of the process identifies the user needs that must be addressed by the project – that is, each transportation problem or operational need that the project or system is to address. It documents a clear definition of the stakeholders' needs and constraints that will support system requirements development in the next step.

Developing the ConOps is a foundation step that frames the overall system and sets the technical course for the project. A good ConOps answers "who, what, where, when, why and how" questions about the project from the viewpoint of each stakeholder:

- **Who.** Who are the stakeholders involved with the system?
- **What.** What are the elements and the high-level capabilities of the system?
- **Where.** What is the geographic and physical extent of the system?
- **When.** What is the sequence of activities that will be performed?
- **Why.** What does the PA lack that the system will provide?
- **How.** What resources are needed to develop, operate and maintain the system?

The ConOps should define needs by prompting stakeholders to think about the behavior of the system and how it will interact with users and other systems. Some important techniques that can be used to develop ConOps include, but are not limited to, interviews, workshops and surveys.

The following criteria should be used as the basis for documenting transportation problems and operational needs:

- **Uniquely Identifiable.** Each need must be uniquely identified (i.e., each need shall be assigned a unique number and title).
- **Major Desired Capability (MDC).** Each need shall express a major desired capability in the system, regardless of whether the capability exists in the current system or situation or is a gap.
- **Solution-Free.** Each need shall be solution-free, thus giving designers flexibility and latitude to produce the best feasible solution within the PA guidelines and specifications.
- **Capture Rationale.** Each need shall capture the rationale or intent as to why the capability is needed in the system.

The list of user needs that is generated should be prioritized by the stakeholders. Once stakeholders start to compare and rank the user needs, they may discover that some of their "needs" are really "wants" or "nice-to-haves".

2.3 Requirements

One definition of a requirement is a condition or capability needed by a user to solve a problem or achieve an objective. Requirements are the basis of specifications that are used for testing, and play a cross-cutting role in governing the expectations of a system across the entire system life cycle.

The purpose of this step of the SE process is to identify the system requirements that will completely fulfill the user needs to be addressed by the project. One of the most important attributes of a successful project is a clear statement of requirements that meet the stakeholders' needs. When considering the implementation of a project, it is a good practice to understand the requirements of the devices and/or systems being implemented. Knowing these requirements early in the project life-cycle can alleviate potential problems during subsequent phases. Successful projects rely on the understanding of functional, design and testing requirements before any procurement, development or implementation.

It is important to involve stakeholders in the development of requirements. Stakeholders may not have experience in writing requirements, but they are the experts concerning their own job functions. The system requirements ultimately are the primary formal communication from the system stakeholders to the contractor. The project will be successful only if the requirements adequately represent stakeholders' needs and are written so they will be interpreted correctly by the contractor.

Every project should have a documented set of requirements that are approved and will become baseline design requirements. Each requirement should be derived based on the user needs identified in the ConOps; some requirements may satisfy more than one user need, but the full set of requirements that will be created will fully satisfy all the user needs identified in the ConOps. Each developed requirement should be documented and uniquely numbered to support traceability throughout the project.

PA ITS Devices Specifications include requirements for ITS Devices that may be used for PA projects. However, it is important to first develop a ConOps, and then match requirements to the User Needs derived from the ConOps. Functions should be defined in a manner reflective of the nature of the operation, such as being manual, automated or semi-automated. The following criteria should be used when documenting and writing requirements:

- Is it a "well-formed" requirement? Some of the attributes of "well-formed" requirements are:
    - **Necessary.** Is the requirement an essential part of the system?
    - **Clear.** Can the requirement be interpreted one and only one way?
    - **Complete.** Is the function fully defined without needing further clarification?
    - **Consistent.** Does the requirement contradict or duplicate another requirement?
    - **Achievable.** Is the requirement technically feasible at a reasonable cost and in a reasonable time?
    - **Verifiable.** Can one unambiguously determine if the requirement has been met?
    - **Concise.** Is the requirement described succinctly and without superfluous text?
    - **Technology independent.** Is the requirement statement technology independent?
- Is the requirement mapped to one or more user needs? This will also address whether the requirement is in fact needed.
- Does the requirement satisfy the intent and all important items of the need?

2.4 Design

The design step in the SE process consists of two distinct parts:

- **High Level Design.** Also known as Preliminary Design, this step corresponds to Stages 1 and 2 in the PA Project Development Process.
- **Detailed Design.** This corresponds to Stage 3 in the PA Project Development Process.

One of the important activities of high level design is to develop and evaluate alternative designs. To do this, the system is partitioned into subsystems, and the subsystems are partitioned into smaller assemblies in turn. The partitioning process continues until system components – the elemental hardware and software configuration items - are identified. The partitioning is driven by many factors, including consideration of existing physical and institutional boundaries, ease of development, ease of integration and ease of upgrading. One of the most important objectives is to keep the interfaces as simple and as consistent as possible. Existing systems or systems that have been planned for implementation should be compatible and interoperable, so procurement by sole source should be investigated if applicable.

Each component is then specified in detail, requirements are analyzed and derived, and all requirements are allocated to the system components. For ITS devices, the specification and requirements includes the definition of interfaces between system components, which may include identification of standards that will be used. The definitions of system components (also known as subsystems) and interfaces define a project architecture, which can be developed as a subset of the regional ITS architecture. If the project architecture, as envisioned, differs from the representation in the regional ITS architecture, then a revised project architecture should be created that accurately reflects the project. If there are alternative approaches to implementing the project, alternative architectures should be developed and evaluated to select a desired approach.

There are times when an informal high-level design is all that is required. If the ITS project being developed is a standalone system or a system that is in a single "box" that will be developed by a single group, then the project may not require a formal high-level design because the project will be dealing with few external or internal interface issues. The size, complexity and risks of the project, particularly the number of components and interfaces, should be considered to determine whether a formal high-level design is warranted. The higher the complexity and the greater the risks, the more likely a formal high-level design is needed.

Detailed design involves the specification of hardware and software in sufficient detail to procure or develop the products. For "off-the-shelf" equipment, procurement specifications are prepared. For products requiring development, detailed "build to" design specifications are created for each hardware and software component to be developed. In the case of standards-based interfaces, the detailed customization of the standard is defined for use in procurement. For software to be developed, a simple user interface prototype is developed as a quick way to help users visualize the software. Several iterations are then created based on user feedback. Any necessary requirements and high-level design changes are identified, evaluated and incorporated as appropriate.

As shown in Figure 2-1, there are important decision points that occur at the conclusions of High Level Design and Detailed Design. These usually take the form of design reviews where the PA and the project team review the design and approve moving to the next step in the development process (See the future Project Gate Review Process). In parallel with the development process, the project team must obtain any approvals required to deploy the project (such as environmental approvals).

2.5 Testing

After development and installation of the system, the next step of the SE process involves testing. From a PA perspective, the primary purpose of testing is to verify that the requirements stated in the PA specifications are delivered by the contractor. From a technical perspective, testing is performed for verification and validation:

- Testing verifies that the requirements (hardware, software and device communications interface) identified in PA specifications are fulfilled; that is, the system was built correctly.
- Testing also validates that the system satisfies user needs; that is, the correct system was built.

The right side of the "Vee" model in Figure 2 1 is about verification and validation. A complete ITS device testing program consists of many phases of testing taking place in a methodical sequence. Overall, a testing program that leads to a complete system should cover all requirements, including design, electrical, mechanical, operational and communications. Each phase may be described in a separate test plan covering a set of test items: one for hardware and environmental requirements (e.g., structural, mechanical, electrical or environmental), one for software-related requirements (e.g., functional, operational) and one for communications requirements (e.g., communications interfaces).

For PA ITS projects, the following specific testing requirements may apply:

- Factory Acceptance Tests
- Field Tests
- Operational Tests
- Burn-In Test

Refer to the PA General ITS specifications for specific requirements for each of the above phases of testing.

Test documentation is an important element of a testing program and specifies the extent of testing required for the ITS device. For example, a custom-designed ITS device with new hardware and software is likely to require more stringent testing than an unmodified device with extensive field deployments. Documentation includes:

- **Test Plan.** Describes the scope, approach, resources and schedule of testing activities.
- **Test Design.** References the test cases applicable to a particular test plan associated with the test design. The test design also references the features (requirements) to be tested.
- **Test Cases and Procedures.** Describes the inputs, outputs, expected results and procedures used to verify one or more requirements.
- **Test Reports.** Documents the test plan execution.

For additional information about developing test documentation, refer to *IEEE Standard 829-1998, Standard for Software Test Documentation.*

Test documentation may be developed by the contractor, supplier, PA, a test laboratory, or a consultant. It can also be based on test documentation used by another Agency as part of their qualified products program. Testing verifies that an ITS device complies with PA specifications.

3. CCTV Cameras

3.1 System Purpose & Design Flow

In an ITS environment, the primary function of the Closed Circuit Television (CCTV) camera is to provide surveillance of the transportation system and enhance situational awareness. CCTV cameras enable operations staff to perform a number of valuable monitoring, detection, verification and response activities.

Some typical CCTV camera uses include:

- Detecting and verifying incidents along roads and within tunnels
- Monitoring traffic conditions
- Monitoring incident response and clearance
- Verifying message displays on dynamic message signs
- Assisting emergency responders
- Monitoring environmental conditions (visibility distance, wet pavements, etc.)

To maximize the effectiveness of a CCTV camera and to support driver safety, the camera type, location and supporting structure must all be carefully considered when designing and deploying any new camera. First, the operational requirements of the camera must be considered. This will determine the camera type and the general camera location necessary to achieve those requirements. The mounting structure characteristics are then determined based on the camera type and location. The design process is illustrated in Figure 3-1.

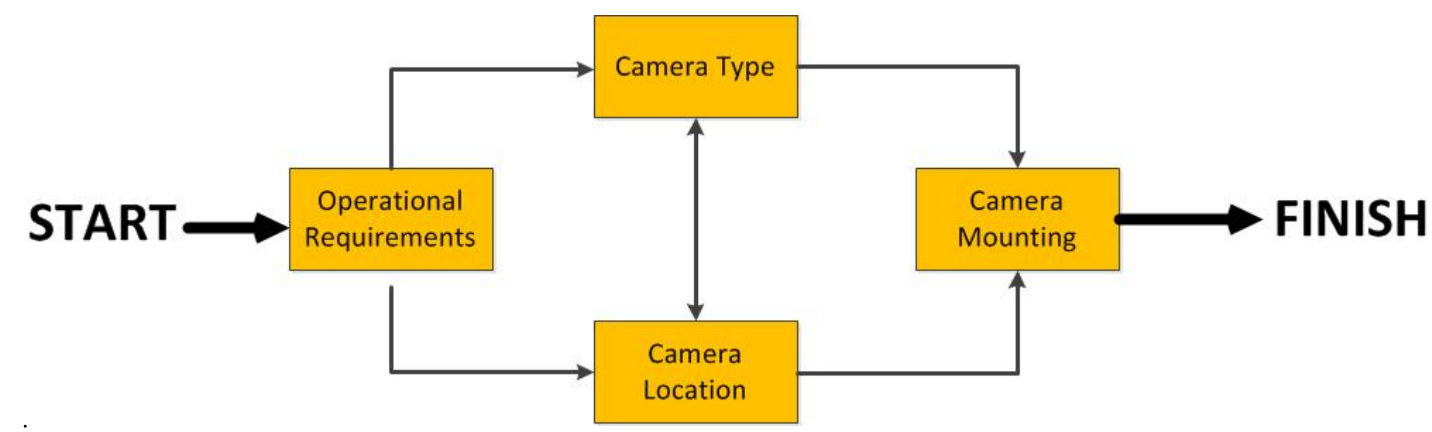


Figure 3-1: CCTV Design Flow Chart

There are several industry and agency standards and requirements related to CCTV. Table 3-1 highlights some of the more important ones:

Table 3-1: CCTV Standards

Criteria	Relevant Standard
Camera Type	PA ITS Specifications – Closed Circuit Television Camera
Communications and Software	National Transportation Communications for ITS Protocol (NTCIP)
Structure/Foundations	PA Construction Specifications. Soil testing and structural calculations are required for all foundations installed in accordance with PA Geotech procedures and must be signed by a structural engineer and reviewed by PA Structures and PA Geotech.
Enclosure	PA ITS Specifications – General Specification for ITS
Design, Implementation and Operational	PA TSD-CCTV Standards PA CCTV Policy Statements

3.2 Design Considerations

Table 3-2 provides an overview of the design considerations in this chapter. It is intended to be a high-level guide to assist designers through the criteria associated with CCTV system design. Each section of the Table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for a CCTV system.

The criteria and guidelines in this chapter should be followed when designing new CCTV systems and when adding components to an existing CCTV system. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer. The goal of this process is to provide practitioners with guidance as well as providing consistency with respect to PA camera installations.

For a design checklist, see Section 13.1, Appendix A - CCTV Design Checklist. The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set, however, it must be submitted as backup for review by PA ITS.

Table 3-2: CCTV Design Considerations and Chapter Outline

Detection Purpose
• Is this deployment consistent with the needs outlined in the Concept of Operations? • Is this deployment consistent with the regional ITS architecture?
Location/Placement Guidelines
• Has the camera location been chosen / designed with consideration to maximizing visibility? • Has the site for the camera been chosen that considers the available utilities and the costs or constraints associated with connection to those utilities? • Has the site been chosen with consideration to protecting the camera structure and ensuring that it will last without undue maintenance necessary to the structure and the surrounding site? • Has the site been chosen that makes the best use of the operational needs of a CCTV camera system (e.g. Incident Management)? • Has the site been chosen that satisfies safety requirements for personnel performing maintenance on the system? • Has the site been chosen so that it will minimize maintenance costs and facilitate maintenance (e.g., is there sufficient shoulder to park a bucket truck without the need for a full lane closure and significant traffic control activities)?
CCTV Type
• Is the camera type (barrel vs. dome; pan & tilt vs. fixed) appropriate for the desired location and application? • Is the camera frame rate and resolution appropriate for the desired location and application?
Camera Mount
• Have PA standards been followed in the design of the mount / structure?
Control Cabinet Enclosure
• Is an enclosure required at this location? • Are there special requirements for the enclosure dictated by the location, e.g. tunnel or bridge? • Is the enclosure located within 150 feet of the camera? • Is the enclosure mounted on the camera pole or on an existing structure (where possible)? • Do the location and orientation provide adequate protection for the enclosure? • Is a camera lowering system needed? • Has a maintainer's pad been provided at the enclosure's main door? • Does the enclosure conform to the PA's specifications? • Can the maintainer safely park a vehicle and safely access the enclosure? • Are the Enclosure and Electrical/Electronic components above the flood elevation?

Power Requirements
• Have the power requirements for the camera and all of the system components been determined?
Power Availability
• Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the camera site? • Have Step-Up/Step-Down requirement calculations been performed? • Have the metering options been determined?
Power Conditioning
• Have the UPS and power back-up options been determined and accounted for?
Communications
• Have the communication requirements for the camera been determined? • Has an appropriate communication infrastructure been located and confirmed within a reasonable proximity to the site? • If there are multiple communications options, have the pros/cons been studied? • Has the chosen communications option been reviewed with the PA? • If using public communications infrastructure, has service been coordinated with the PA?
Environmental
• Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

3.3 Location/Placement Guidelines

The selection of CCTV camera locations is based on the operational and maintenance requirements, desired coverage and local topography. Camera locations should provide a clear line of sight with minimal obstructions. The considerations outlined in Table 3-3 should be taken into account when selecting the site and placement of the camera.

Table 3-3: Camera Site Selection and Placement Considerations

Camera Site Selection and Placement Considerations	
Visibility	• Cameras in low light conditions, such as tunnels, should be located so that the main view is away from bright light • Near horizontal curves, install on the outside of the curve • Near vertical curves, install at the crest • At the intersection of two major routes or at an interchange, place cameras so that secondary roads and ramps can also be monitored • The blind spot created by the pole should be oriented at a location non-critical to viewing

Camera Site Selection and Placement Considerations	
Utility Availability	• Consider proximity to power and communications • If fiber optic communication is available, try to place the camera on the same side of the road to eliminate lateral crossings (this is secondary to visibility requirements)
Safety and Device Protection	• Protect mounting structure with barrier inside the clear zone, but consider lateral deflection and maintenance vehicle access • Medians are not the preferred location, but wide medians may be considered if suitable roadside locations are not available • To reduce site erosion, reduce construction costs and provide longer device structure life, avoid locating the structure on sections that have a fill slope of greater than one vertical to three horizontal (1V:3H)
Operational Considerations	• Provide for full coverage of the road network on all minor and major arterials and expressways • Provide for full coverage within all tunnels, in compliance with NFPA 502 • If possible, position cameras to view nearby Dynamic Message Signs (DMS) for message verification • It is preferable to have all cameras on one side of the road to facilitate the operators' orientation of the image • Large interchanges of two major expressways may require more than one camera to obtain all desired views of roads and ramps • If possible, avoid mounting onto bridge structures due to the potential of vibration affecting the image • Provide means to install stops on pan mechanism as a means to protect privacy of nearby residences
Maintenance Considerations	• The camera should be located such that a maintenance vehicle can park in the immediate vicinity, without necessitating a lane closure or blocking traffic • A concrete maintainer pad in front of the enclosure opening should be provided per PA ITS details • The CCTV cabinet door should be mounted away from traffic so that the maintainer is facing traffic when working in the cabinet. This is important to the safety of the maintainer and will increase the life of the filter.

3.3.1. *Camera Coverage*

For full camera coverage of a road, CCTV cameras are placed such that an operator can view and monitor the entire corridor with no breaks in coverage. To provide full and continuous coverage of a road, cameras should be placed no more than 1 mile apart, depending on the curvature and grade changes of the road. Full CCTV camera coverage within tunnels is also required, in accordance with the requirements of NFPA 502.

When possible, a camera-equipped van or bucket truck should be used to validate camera locations prior to installation.

3.4 Camera Type

Most of the desired CCTV camera features are standard with commonly available commercial products. A camera must be selected that meets PA ITS Specifications for:

- Closed Circuit Television Camera
- Video Encoder/Decoder

The following features related to camera type must be considered as part of the design process:

- Dome vs. Barrel (fixed) mount
- Analog vs. IP

Note that barrel mount cameras should only be used on a case-by-case basis for very specific applications (such as within tunnels).

3.4.1. *Pan & Tilt vs. Fixed*

Using a pan/tilt (P/T) platform, CCTV system operators can change camera position about the 360-degree azimuth axis and adjust camera elevation up or down within a 90 degree range. Together with a zoom lens, the P/T allows operators to view a scene in any direction from the camera, within the lens field-of-view and distance ranges. The speed of the pan/tilt mechanism determines the rate of camera coverage, while the horizontal and vertical camera ranges of motion determine the coverage area.

Dome-enclosed systems provide much higher P/T speeds. Dome systems also have much more range than external units, having the ability to look straight down. It should be noted that dome cameras are "horizon limited" and cannot effectively look up at the sky or up a nearby steep hill. However, unless the camera is to be placed in very hilly terrain, this is not a major drawback for road traffic monitoring.

Barrel (fixed) mount cameras should only be considered for installations that focus on only one view. P/T cameras are the preferred camera type for most instances.

3.4.2. *Analog vs. IP*

The PA ITS Specifications currently contain two camera types, one that transmits video in IP format only and one that is a dual IP/Analog camera. New CCTV camera deployments should be of the IP type. The dual IP/Analog cameras should only be used when there is a need for compatibility with legacy infrastructure that contains some analog devices or cannot accommodate IP.

3.5 Selection of Camera Mounting Type

The overriding factor in determining a CCTV camera location is the site's fitness for performing the operational role for which it is designed (see Section 0 Location/Placement Guidelines). If all other factors are equal, there may be more than one option for designing the type of camera mount. The three possible choices are:

- Pole-mounted
- On an existing sign or structure (e.g. bridges or sign structures)
- Inside a tunnel, on a wall or mounted on the wall of an underpass

The prevalent structure for CCTV cameras is a stand-alone pole. The minimum pole height should be 40 feet, and pole heights of 50 feet or 60 feet may be warranted at some locations depending on topography, obstructions, bridges, interchange geometry, etc. The designer should ensure that the PA has equipment available to service the higher poles. If mounting on a bridge or sign structure, the designer should determine whether a camera can sustain the vibration experienced on that structure and whether the image would be usable. Design standards for a CCTV pole can be found in PA ITS details.

3.5.1. *Camera Lowering Device*

Camera-lowering systems should be used for all pole-mounted CCTV installations with poles 40 or more feet high. A camera lowering device provides easier access to the camera, in many cases eliminating the need to use a bucket truck or similar vehicle for maintenance, and reduces the need for lane closures. Camera lowering devices are typically not used for fixed CCTV cameras mounted on tunnel walls or traffic signal mast arms. During the design process, consideration should be given to using a camera lowering device for fixed CCTV cameras wherever practical.

A cabinet for a pole mounted camera should not be on the same side as the hand hole for a camera lowering winch and should not be under the camera to be lowered.

Design standards for a CCTV Camera Lowering Device can be found in PA ITS Specifications.

3.6 CCTV Cameras in Tunnels

CCTV camera systems for use in tunnels must comply with all requirements of National Fire Protection Association (NFPA) 502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways. Refer to the NFPA 502 standard for requirements.

3.7 ITS Enclosure Placement

The ITS enclosure and its associated components must be included in the design process. Design criteria for a suitable ITS enclosure location include the following:

- When possible, the enclosure for the CCTV controller should be pole-mounted on the camera pole or existing structures to minimize cost.
- In locations where the pole is difficult to access, the enclosure may be ground-mounted at a more convenient location with easier access, such as adjacent to a frontage or access road.
    - Place the enclosure at the safest possible location, generally along the right shoulder.
    - Locate a ground-mounted enclosure at a minimum distance from the barrier, based on the design and type of barrier used. See PA standard drawings for appropriate minimums.
    - Orient the enclosure so that the maintainer is facing the road while performing maintenance at the cabinet location.
    - The enclosure should be at a level where the maintainer does not need a stepladder to perform maintenance at the cabinet location.
    - The enclosure should be located less than 100 feet from the camera. If it is farther, then equalizing amplifiers for video should be provided. If the camera is IP, the absolute maximum distance is 300 feet based on restrictions of the communications cable.

- A level concrete pad should be provided at the front of the enclosure for the maintenance worker to stand on while accessing the enclosure.
- Where possible, there should be adequate and safe parking conditions in the vicinity of the enclosure for a maintenance vehicle. Where this is not possible, locate the enclosure where it is accessible by on-foot maintenance personnel.
- See PA and manufacturer specifications to determine the maximum distance between the enclosure and the field device it services.
- Consider elevating the critical electronic components above the flood elevation.

In some cases, co-located ITS devices may share the same enclosure, which will influence enclosure size requirements.

Design standards for the ITS enclosure can be found in PA ITS Specifications.

4. Dynamic Message Signs

Dynamic Message Sign (DMS) is the PA's preferred term for the electronic signing utilized for providing information. The term DMS is interchangeable with both Changeable Message Sign (CMS) and Variable Message Sign (VMS). The term DMS is often used within the context of the National ITS Architecture and NTCIP requirements; CMS is used in the MUTCD and other Federal Highway Administration documents; and VMS is used in many of the PA's available documents and existing systems.

4.1 System Purpose & Design Flow

The primary function of Dynamic Message Signs (DMS) is to provide information to the traveling public. The nature of this information is varied, but the goal is to disseminate road condition information to travelers so that they can make informed decisions regarding their intended route and/or destination. Evacuation scenarios shall be incorporated into every PA ITS implementation program.

Some typical DMS uses include notifying travelers of:

- Full Road Closure
- Tunnel Closure
- Lane Closure (Incident, Maintenance / Construction, Events, etc.)
- Weather / Road Conditions
- Variable Speed Limits
- Special Events
- Travel Times
- Future Road Work
- Scheduled Safety Messages (e.g., Public Service Announcements)
- Evacuation related messages

To maximize the effectiveness of a DMS and to support driver safety, the sign type, location and supporting structure must all be carefully considered when designing and deploying any new sign. First, the purpose and operational requirements of the sign must be considered. This will determine the DMS type and the general sign location. The support structure characteristics are then determined based on the sign type and location. Figure 4-1 illustrates the design process.

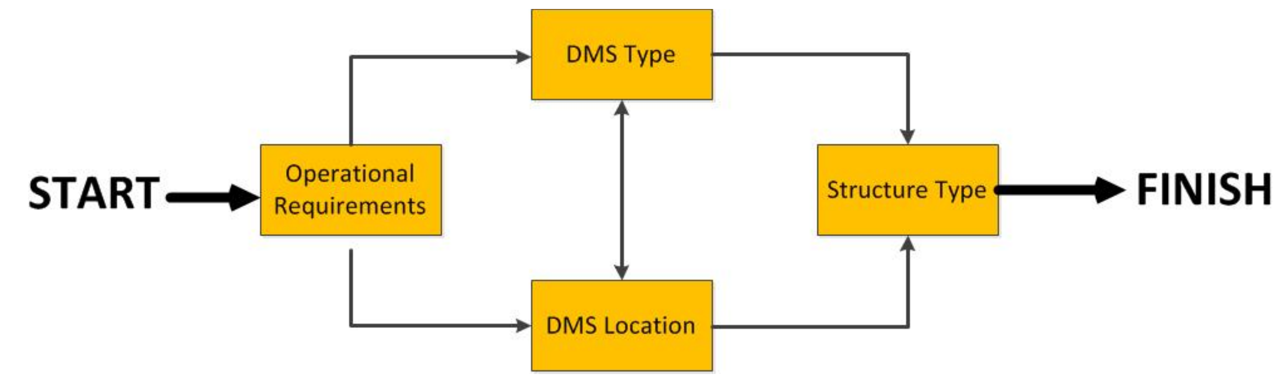


Figure 4-1: DMS Design Flow Chart

Table 4-1: DMS Standards

Criteria	Relevant Standard
Sign Type	PA ITS Specifications – Dynamic Message Signs
Communications and Software	National Transportation Communications for ITS Protocol (NTCIP)
Structure	PA Civil and Structural Standards and ITS details
Enclosure	PA ITS Specifications
Placement and Sign Legend	FHWA Manual on Uniform Traffic Control Devices

4.2 Design Considerations

Table 4-2 provides an overview of the design considerations contained in this chapter. It is intended to be a high-level guide to assist designers through the criteria associated with DMS design. Each section of the table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for a DMS.

The criteria and guidelines in this chapter should be followed when designing new DMS and when adding components to an existing DMS system. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer. The goal of this process is to provide practitioners with guidance as well as providing PA consistency with respect to PA DMS installations. Existing systems or systems that have been planned for implementation should be compatible and interoperable, so procurement by sole source should be investigated if applicable.

For a design checklist, see Section 13.2, Appendix A - DMS Design Checklist

The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set; however, it must be submitted as backup for review by PA ITS.

Table 4-2: DMS Design Considerations and Chapter Outline

Deployment Purpose
• Is this deployment consistent with the needs outlined in the Concept of Operations? • Is this deployment consistent with the regional ITS architecture?
Longitudinal Placement
• Is the DMS visible and unobstructed? • Is the DMS placed sufficiently in advance of any interchanges that would be used for diversions? • Is the DMS properly spaced away from existing guide signs?
Lateral Placement
• Is the DMS structure protected by a barrier and/or located outside of the road clear zone? • Has the lateral offset of the DMS been accounted for when calculating the length of the Reading and Decision Zone?
Vertical Placement
• Is the approaching segment of road relatively flat (between 0% and 4 % vertical grade)?
Sign Matrix Type
• Has a sign matrix type been chosen that is consistent with the visibility and message requirements of the road? • Will the height of displayed characters meet road type and speed requirements? • Is the sign matrix type and size suitable for the operational messages desired to be displayed at the specific location? • Is the sign matrix type suitable for displaying graphic images, if there is a stated desire or need for it?
Sign Viewing Angle
• Is the sign viewing angle appropriate for the road alignment and the DMS structure?
Sign Access
• Are there any traffic, environmental or safety factors that warrant a specific type of sign access (front, rear, walk-in)?
Structure
• Have visibility, road speed / volume, right-of-way and maintenance / cost issues all been considered when selecting the sign structure type? • Is there sufficient vertical clearance for the sign and the structure?
Control Cabinet Enclosure
• Is the enclosure located within a reasonable distance of the sign? • Is the enclosure mounted on an existing structure (where possible)? • Is the sign face visible from the enclosure location? • Do the location and orientation provide adequate protection for the enclosure? • Has a maintainer's pad been provided at the enclosure's main door? • Does the enclosure conform to the PA's specifications? • Can the maintainer safely park a vehicle and safely access the enclosure? • Are the Enclosure and Electrical/Electronic components above the flood elevation?
Power Requirements
• Have the power requirements for the DMS and all of the system components been determined?
Power Availability
• Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the DMS site? • Have Step-Up/Step-Down requirement calculations been performed? • Have the metering options been determined?
Power Conditioning
• Have the UPS and power back-up requirements been determined and accounted for?
Communications
• Have the communication requirements for the DMS been determined? • Has an appropriate communications source been located and confirmed within a reasonable proximity to the site? • If there are multiple communications options, have the pros / cons been studied? • Has the chosen communications option been reviewed with the PA? • If using public communications infrastructure, has service been coordinated with the PA?
Environmental
• Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

4.3 Location/Placement Guidelines

The site characteristics in the vicinity of the planned DMS must be investigated. These characteristics dictate the amount of information that can be displayed. Relevant characteristics include:

- Operating speed of the road (speed limit or prevailing speed)
- Presence and characteristics of any vertical curves affecting sight distance
- Presence of horizontal curves and obstructions such as trees or bridge abutments that constrain sight distance to the DMS
- Location of the DMS relative to the position of the sun (for daytime conditions)
- Presence and number of static guide signs in the vicinity and the information displayed on those signs
- Presence and number of traffic signals in the vicinity

Figure 4-2: Full Color DMS

4.3.1. Longitudinal Placement

The main considerations related to longitudinal placement of a DMS are to minimize obstructions of and by the DMS, provide for the maximum visibility of the DMS message and allow the driver sufficient time to read, process and react to the message.

The approach to a sign can be divided into 3 "zones" (see Figure 4-3)

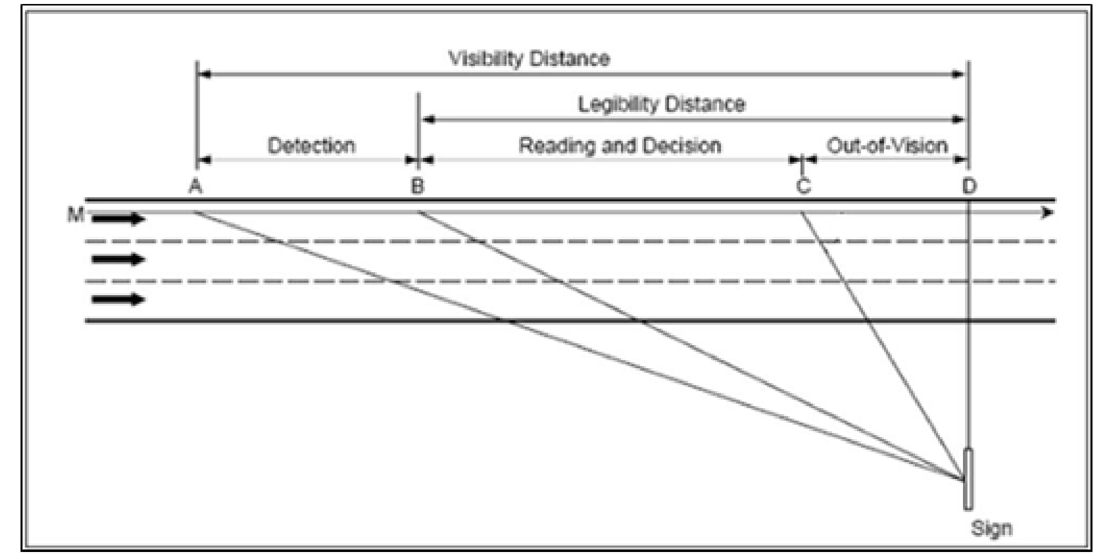


Figure 4-3: DMS Lateral and Longitudinal Visibility

- **Detection Zone.** At expressway or freeway speeds (between 50 and 75 mph), the DMS should be visible to the approaching driver from approximately 1,000 to 2,000 feet away. The visibility distance should be increased if the DMS is placed at an offset from the traveling lane.

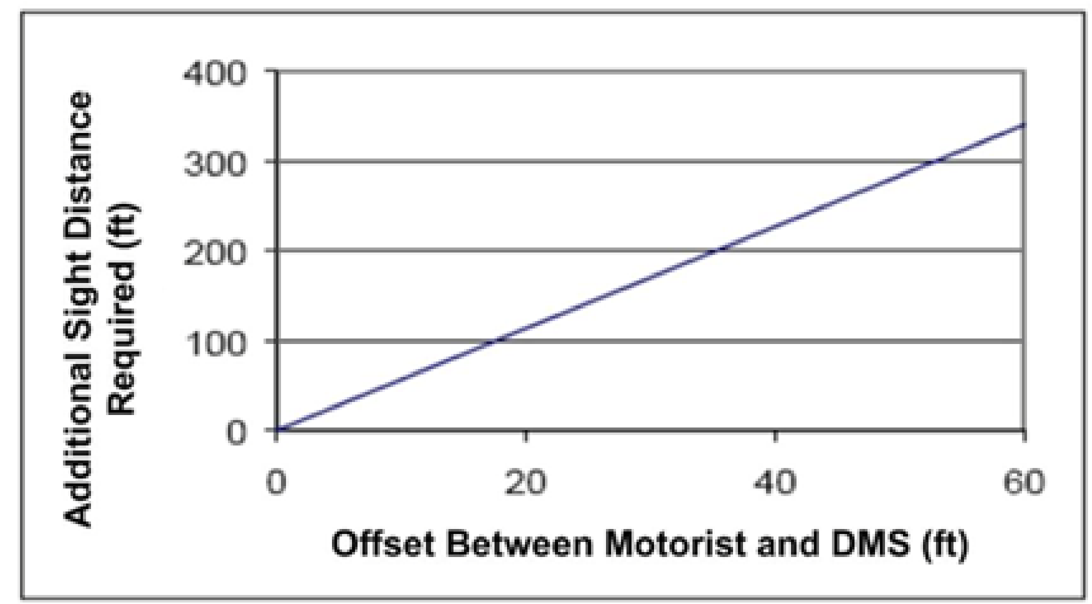


Figure 4-4: Lateral Offset vs. Required Sight Distance

- **Reading and Decision Zone.** Message panels on a limited access highway-deployed DMS typically provide room for 3 lines of 12-21 characters each.
  - For deployment on roads with operating speeds of 50 mph or less, the reading and decision zone should be a minimum of 800 feet.
  - For deployment on roads with operating speeds of 55 mph or more, the reading and decision zone should be a minimum of 1,000 feet.

- o Individual characters of 12" in height can be seen from approximately 650 feet away under normal conditions.
- o Individual characters of 18" in height can be seen from approximately 1,100 feet away under normal conditions.

Drivers need approximately one second per word to read and comprehend a message. For a 10-word message, drivers traveling at approximately 65 mph would require approximately 10 seconds to read and comprehend the message. The character height, cone of vision and lateral placement must all be considered when determining the placement of the sign to meet the sight distance requirements.

- **Out-of-Vision Zone.** Once the driver gets close to the sign, they will not be able to read the message. The distance to this zone is determined by the viewing angle of the sign, the structure that the sign is placed on and the lateral placement of the sign.

4.3.2. Lateral Placement

Standards regarding lateral placement of signs must be followed when designing DMS. PA design details provide information on the setback distances and vertical clearances. The DMS structure must be placed far enough behind a barrier or outside the clear zone to comply with the minimum clearances. Refer to the design details of the particular barrier present at the site or planned to be installed. Setbacks vary by facility. Check with PA ITS Engineering.

Depending on the horizontal offset of the DMS from each travel lane, additional sight distance will be required for drivers to clearly view and react to the sign.

Table 4-4 illustrates the approximate additional visibility distance that must be considered when determining sign placement. For roads with a speed limit of 60 mph or greater, the center of the DMS should be no more than 30 feet laterally from the driver's forward line of vision.

Table 4-3: DMS Longitudinal Placement Guidance

Criteria	Guidance
Visibility	• Location of the DMS must provide a viewing distance to drivers of at least 800 feet, and optimally 1,000-2,000 feet, depending on the prevailing speed • On expressways or freeways, the DMS should be placed at least 800 to 1,000 feet from a static directional sign, depending on the speed of the expressway or freeway • DMS should be located on straight sections of road if possible • If the DMS must be located on a curve, it should be angled towards the road
Reaction Time	• Two DMS in sequence should be no less than 1,000 feet apart, and optimally at least ½ mile apart • DMS should be a minimum of 1,000 feet away from a lane merge or expansion • DMS should be located 1 to 3 miles in advance (no closer than 1 mile) of an alternate route or major decision point • DMS should not be placed near a signalized intersection
Cost	• DMS should be located as close to existing communications and power as possible to minimize costs • DMS should not be located on a fill slope of greater than one vertical to three horizontal (1V:3H) to reduce site erosion, reduce construction costs and provide longer device structure life

Table 4-4: DMS Sight Distance Based on Speed Limit and Road Type

Legibility Distance Requirements	Expressway or Freeway	Limited Access Arterial	Major Arterial
Less than 45 mph	N/A	650 feet	650 feet
45 mph to 55 mph	850 feet	850 feet	850 feet
Greater than 55 mph	1000 feet or more	1000 feet or more	N/A

4.3.3. Vertical Placement

A road's vertical alignment impacts the visibility of the DMS. If there are a limited number of potential locations available, a slight upward grade is preferable to a downward grade. Where possible, DMS should be located on road segments that are as level as possible (grade of 1% or less). Signs may be placed on segments with a maximum 4% grade. This requirement may be waived if the sign is placed on an upward grade immediately following a similar downward grade. In these situations, expanded cones of vision should be considered to compensate for the reduced visibility distance caused by the grade.

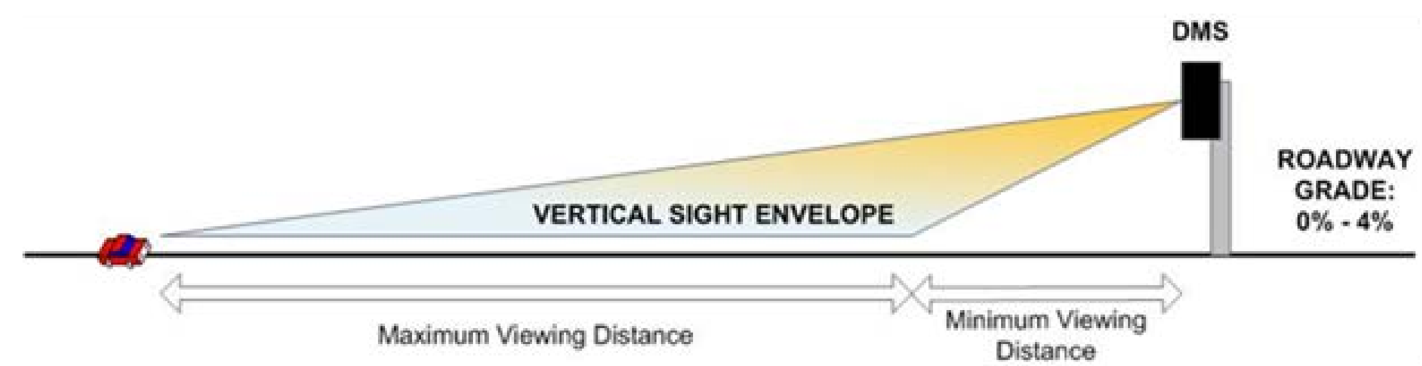


Figure 4-5: DMS Vertical Sight Envelope

4.5 **Selection of Sign Type**

The selection of the sign type, the configuration of the display, and the technology employed all have direct or indirect impacts on the visibility of the message that will be displayed on the DMS.

4.5.1. Matrix Characteristics

DMS display characters and symbols in a matrix format, generally in one of the following three patterns[2]:

- **Character Matrix.** A type of DMS that uses character matrices with a fixed amount of blank space (no pixels present) between matrices to achieve the inter-character spacing. There is also blank space (no pixels present) between lines of characters to achieve the inter-line spacing.
- **Line Matrix.** A type of DMS that has no hardware-defined blank spaces (no pixels) between characters. The entire line contains columns of pixels with a constant horizontal pitch across the entire line.
- **Full Matrix.** A type of DMS with the entire display area containing pixels with the same horizontal pitch and the same vertical pitch, without fixed lines or spaces between characters.

Full matrix DMS displays are important as the use of graphics and symbols becomes more accepted and used. In this format, the entire display consists of a continuous matrix of pixels, shown in Figure 4-6. Full matrix signs may be provided in monochrome or full color. The use of a full color display allows the DMS to display a warning, regulatory or guide message that simulates the appearance and color of a static sign panel.

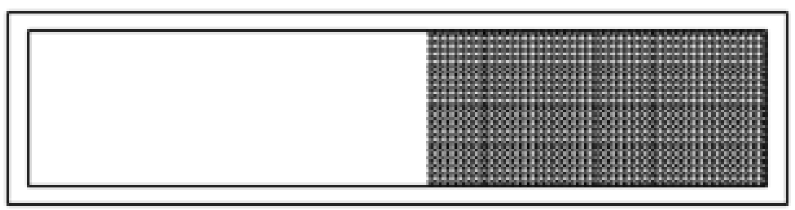


Figure 4-6: DMS Full Matrix

4.5.2. DMS Technologies

Light-Emitting Diode (LED) technology is the most commonly used in DMS. LEDs are semiconductors that emit light when current is applied. Typically, several individual LEDs are "clustered" together to create each pixel. LEDs have the added benefit of being able to display signs in full color with the appropriate LED type, and each pixel will still be lit even with the failure of one or two LEDs within the pixel. The reliability of LED lamps is very high.

Other technologies that are still specified by some agencies:

- **Drum.** A multifaceted cylinder, with associated lighting, motor/brake drive unit and position sensing switches that rotates to display one face to the motorist. Its primary advantage is that the message is still displayed even if electrical power is lost, and it can be manually operated at the sign to change messages without electrical power. Typically, two or three drums are combined in a single DMS assembly to allow the display of more complex messages than can be accommodated on a single drum. The disadvantage of drum signs is that the messages that can be displayed are limited to what has been printed or affixed on the sides of the drum.
- **Flip disk (shutter).** A two-state display technology using an electromechanically actuated disk for each pixel position. One side of the disk displays the ON state of the pixel, which is white or otherwise brightly colored, and the other side displays the pixel's OFF state, typically black and non-reflective. Similar to a drum sign, messages displayed by flip disk signs are still displayed even if electrical power is lost. The advantage compared to drum signs is that flip disk signs can display a variety of messages.

Table 4-5: DMS Display Recommendations

Criteria	Recommendation
General	• Character height should be between 12 and 18 inches. • Sign should be limited to three lines of text. • Each line of text should have a minimum of 11 characters (arterial or local road) or 21 characters (limited access roads).
On Limited Access Roads	• Character height should be 18 inches. • 21 characters per line should be provided.
All Signs	• Provide a photocell to automatically adjust the illumination intensity of the display based on ambient light conditions. Note that this does not apply to drum and flip disk type signs, which typically do not have illuminated displays.

4.5.3. Viewing Angle

Viewing angle is an important aspect when designing and placing a DMS, and depends upon the mounting location of the DMS and the curvature of the road. There are three standard viewing angles available from DMS manufacturers: 15 degrees, 30 degrees and 70 degrees (from the center axis), as summarized in Table 4-6 and Figure 4-7. For DMS located directly over the road and in residential areas where the road approaching the face of the DMS is straight (no curves), the 15 degree viewing angle may be preferred. This prevents the LED glare from disturbing residents. Conversely, a 70 degree viewing angle may be preferred to maximize visibility if the DMS is located on a curved road. Otherwise, the 30 degree viewing angle is typical and recommended for most conditions.

Table 4-6: DMS Placement

Viewing Angle	Recommendation
15 degrees	Overhead placement and on straight road sections.
30 degrees	Roadside placement and on slightly curved (horizontally or vertically) road sections.
70 degrees	Wide highways and on curved road sections where a 30 degree viewing angle would not provide sufficient visibility distance.

[2] Definitions from NTCIP 1203 version v03: National Transportation Communications for ITS Protocol: Object Definitions for Dynamic Message Signs (DMS)

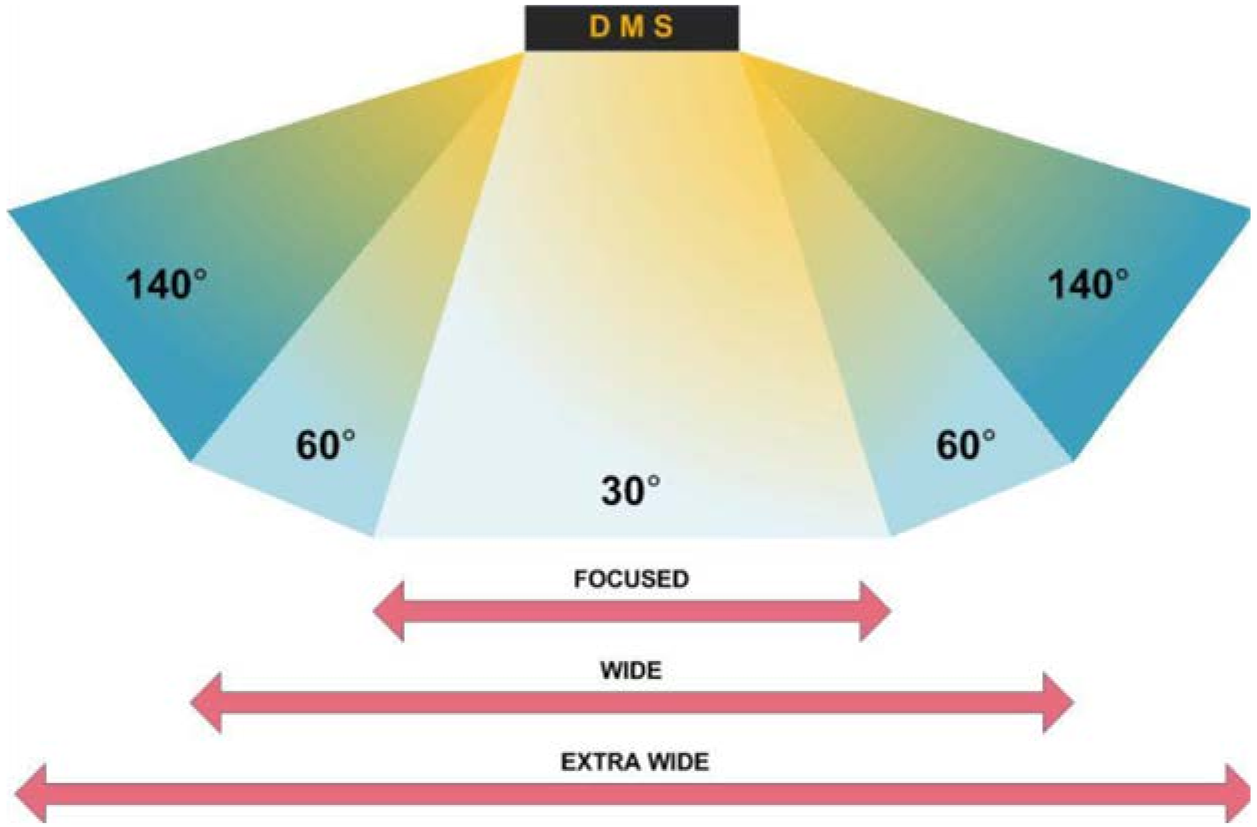


Figure 4-7: DMS Viewing Angles

4.5.4. Sign Access

Sign access can be walk-in, front-access or rear access, as shown in Figure 4-8. A brief examination of the advantages and disadvantages of each type is presented in Table4-7.

Figure 4-8: DMS Maintenance Access

Table 4-7: DMS Access Types

Access Type	Advantages	Disadvantages	Other Considerations
Rear Access	• Smaller and lighter sign allows for smaller structure	• Signs mounted overhead might require a lane closure for maintenance • Maintenance on rear access signs can be difficult	• A bucket truck is typically used to access the sign • Consider installing catwalk to avoid need for bucket truck and lane closures
Walk-In	• Provides safe environment for worker over live traffic	• Highest in installed and recurring costs	• Catwalk or platform required to access the DMS
Front Access	• Smaller and lighter sign allows for a smaller structure	• Sign mounted overhead might require a lane closure for maintenance	• A bucket truck is typically used to access the sign • Consider installing catwalk to avoid need for bucket truck and lane closures

4.6 Selection of Structure

Three types of permanent structures for mounting DMS are overhead or "span," cantilever and center-mount. All DMSs should be mounted on either overhead or cantilever structures. Center-mount structures can be considered as an exception in urban areas.

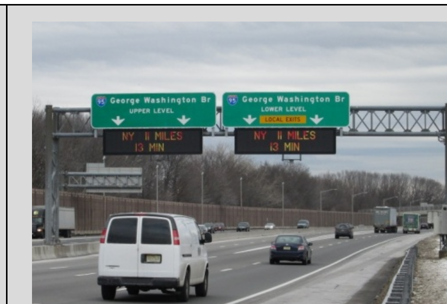
 Center-mount	 Overhead	 Cantilever

Figure 4-9: DMS Structure Types

The lateral placement guidelines in Section 4.3.2 Lateral Placement and the nature of the road, including the road width(including all lanes and hard shoulders), speed characteristics and available right-of-way (ROW), are main factors in determining placement and structure type of the DMS. See Table 4-8 for the advantages and disadvantages of these different support types, and for portable DMS (typically only used for construction) as shown in Figure 4-10.

Figure 4-10: Portable DMS

Table 4-8: DMS Support Types

Support Type	Pros	Cons	Other Considerations
Overhead	• Best for visibility • Best support for large DMS	• Highest in cost • Requires more preventative maintenance than offset DMS	• Good alternative if limited ROW available • Can be used on any road type • Good for use on high volume roads
Cantilever	• Less expensive than overhead • Alternative if full-span cannot be installed	• Structural issues, including failures, have occurred in some locations • More difficult to support large DMS • Visibility can be an issue on tangent sections • Visibility can be an issue if truck volumes are high	• Alternative if limited ROW • Can be used on any road type
Center-mount	• Best benefit-to-cost ratio • Easy to maintain • Lower structural cost	• Visibility can be an issue on tangent sections • Visibility can be an issue if truck volumes are high • Typically not appropriate for large DMS	• Should be located on outside of curve or on tangent section • Should be limited to urban areas
Portable	• Good temporary alternative.	• Smaller display • Typically requires the most preventative maintenance	• Suitable for construction activities and temporary emergency measures

Portable DMS should not be deployed as a permanent installation to substitute for a permanent DMS. Portable DMS should only be deployed as temporary installations.

4.6.1. **Structural Design Guidance**

Sign structures should be designed based on the diagrammatic details included in the PA ITS Standard Details where applicable. Design calculations, plans and details shall be based on the diagrammatic details and layouts provided in the ITS Standard Drawings. Each DMS structure should be assigned its own structure number in coordination with the PA's master plans.

The general order of preference for DMS support structure types is as follows:

- Overhead
- Cantilever
- Center-mount

Design calculations should include:

- List of design assumptions:
  - Sign weight, dimensions and appurtenances
  - Any non-standard loadings
  - Fatigue Importance Category
  - Design wind speed
- Foundation design
  - One test boring should be completed at each DMS foundation location. Where exceptions are granted and no borings are completed, use worst-case soil conditions found in the Standard Drawings.
- Additional calculations may be required if the design criteria specified in the PA standard specifications are not met. The following list of items that may need calculations is not all-inclusive, and may vary by structure type and details:
  - Post/Base plate connection
  - Base plate design
  - Anchor bolt design
  - Chord splices
  - Bolted connections
  - Ladder connections

- Miscellaneous weld checks
- Catwalk loading and connections

Note: The Standard Drawings establish basic sign structure layouts. Additional calculations may be required.

Design Plans should include:

- "General Notes" sheet
- Signed and sealed certification letter from the manufacturer regarding DMS cabinet and connection
- Drawing sheets showing, at a minimum, the applicable views and details shown on the ITS standard drawings
- Panel connection details
- Complete connection details with weld symbols
- Unique structure number, provided by the PA
- A standalone drawing package is required for each DMS structure. Multiple structures shall not be presented without detail sheets.

4.7 DMS in Advance of Tunnels

DMS that are deployed in advance of any tunnel shall meet all requirements of National Fire Protection Association (NFPA) 502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways. These DMS focus on alerting drivers of tunnel closures due to collisions, fires or other unplanned incidents within a tunnel. Refer to the NFPA 502 standard for design requirements.

4.8 ITS Enclosure Placement

The enclosure and its associated components must be included in the design process. Design criteria for a suitable ITS enclosure location include the following:

- The enclosure should be ground-mounted, approximately 1,000 feet upstream of the DMS.
    - Locate a ground-mounted enclosure at a minimum distance from the barrier, based on the design and type of barrier used. See PA standard drawings for appropriate minimums.
    - Orient the enclosure so that the maintainer is facing the road while performing maintenance at the cabinet location.
- If no suitable location is available for the enclosure to be ground-mounted, it may be pole-mounted on the DMS (or other existing structure) to minimize cost or eliminate ROW takings.
- A level concrete pad should be provided at the front of the enclosure for the maintenance worker to stand on while accessing the enclosure.
- Where possible, there should be adequate and safe parking conditions in the vicinity of the enclosure for a maintenance vehicle. Where this is not possible, locate the enclosure where it is accessible by on-foot maintenance personnel.
- See PA and manufacturer specifications to determine the maximum distance between the enclosure and the field device it services.
- Consider elevating the critical electronic components above the flood elevation.

In some cases, co-located ITS devices may share the same enclosure, which will influence enclosure size requirements.

Design standards for the ITS enclosure can be found in the PA ITS specifications.

5. Lane Use Control Signals

5.1 System Purpose & Design Flow

Lane use control signals are special overhead signals on a street or limited access facility that indicate whether travel in a lane is prohibited or allowed. The primary function of lane use control signals (LUCS) is to maximize road capacity and safety. The information is transmitted though specific dynamic road traffic symbols displayed on signals located above each travel lane, as shown in Figure 5-1. Evacuation scenarios shall be incorporated into every PA ITS implementation program. Applications for LUCS include lane closures for construction or emergency access, variable traffic restrictions, temporary shoulder use and reversible lanes. Signals with a green downward arrow are used to indicate a lane which is open to traffic facing the signal. A red cross indicates that a lane is closed to traffic. A flashing yellow arrow or red cross indicates that the signal is changing from green to red, and traffic facing the signal must immediately clear the lane.

Figure 5-1: Existing LUCS

To maximize the effectiveness of a LUCS system and to support driver safety, the sign type, placement and supporting structure must all be carefully considered when designing and deploying any new system. Table 5-1 highlights some of the more important industry standards.

Figure 5-2: Existing LUCS

Table 5-1: LUCS Standards

Criteria	Relevant Standard
Lane Use Control Signal and Controller	• PA ITS Specifications – Lane Use Control Signals • MUTCD
Communications and Software	• National Transportation Communications for ITS Protocol
Mounting Structure	• PA Civil and Structural Standards and ITS details
Enclosure	• PA ITS Specifications

5.2 Design Considerations

Table 5-2 provides an overview of the design considerations in this chapter. It is intended to be a high-level guide to assist designers through the criteria associated with LUCS system design. Each section of the Table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for a LUCS system.

The criteria and guidelines in this chapter should be followed when designing new LUCS systems and when adding components to an existing system. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer. The goal of this process is to provide practitioners with guidance as well as providing consistency with respect to PA LUCS installations.

For a design checklist, see Section 13.3 Appendix A - LUCS Design Checklist

The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set; however, it must be submitted as backup for review by PA ITS.

Table 5-2: LUCS Design Considerations

Deployment Purpose
• Is this deployment consistent with the needs outlined in the Concept of Operations? • Is this deployment consistent with the regional ITS architecture?
Longitudinal Placement
• Is the LUCS visible and unobscured? • Is the spacing between LUCS appropriate so that drivers have enough time to read and react to the signals (e.g. if a yellow signal requires drivers to exit the lane)?
Vertical Placement
• Is the approaching segment of road relatively flat (between 0% and 4% vertical grade)?
Sign Matrix Type
• Has a sign matrix type been chosen consistent with the visibility and message requirements of the road?
Structure
• Have visibility, road speed / volume, right-of-way and maintenance / cost issues all been considered when selecting the sign structure type? • Is there sufficient vertical clearance for the sign and the structure?
Control Cabinet Enclosure
• Is the enclosure located within a reasonable distance of the LUCS? • Is the sign face visible from the enclosure location? • Do the location and orientation provide adequate protection for the enclosure? • Has a maintainer's pad been provided at the enclosure's main door? • Does the enclosure conform to the PA's specifications? • Can the maintainer safely park a vehicle and safely access the enclosure? • Are the Enclosure and Electrical/Electronic components above the flood elevation?
Power Requirements
• Have the power requirements for the LUCS and all of the system components been determined?

Power Availability
• Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the LUCS site? • Have Step-Up/Step-Down requirement calculations been performed? • Have the metering options been determined?
Power Conditioning
• Have the UPS and power backup requirements been determined and accounted for?
Communications
• Have the communication requirements for the LUCS been determined? • Has an appropriate communications infrastructure been located and confirmed within a reasonable proximity to the site? • If there are multiple communications options, have the pros/cons been studied? • Has the chosen communications option been reviewed with the PA? • If using public communications infrastructure, has service been coordinated with the PA?
Environmental
• Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

5.3 Location / Placement Guidelines

The dimensions and weight of most LUCS allow easy installation and configuration for different road infrastructures including tunnels, bridges, expressways and interchanges. All messages should be clearly legible under any lighting conditions. In the case of lane closures, the signs must clearly indicate where the roads will be open or closed to avoid driver confusion.

Figure 5-3: LUCS on Existing Structure

The LUCS system should be coordinated so that the indications along the controlled section of road are operated uniformly and consistently. For example:

- Reversible- lane use control signs must not display simultaneous green or yellow indications over the same lane to both directions of travel. At least one direction must always have a red cross.
- When an open lane is to be closed, the green arrows should be turned to red crosses (or, as an intermediate step, to yellow flashing arrows or crosses) starting with the first signal encountered by approaching traffic, and progressing in sequence to the last signal encountered.
- Under all circumstances, the operator must confirm that the lane is clear of all obstructions (e.g. stalled vehicles) and oncoming traffic before switching from a red cross indication.

All LUCS faces should be located in a straight line across the road, approximately at a right angle to the road alignment.

*5.3.1. **Spacing between Signals***

The placement of LUCS should allow drivers to decide and confirm in which lane(s) they are allowed to drive and should provide maximum visibility of the message. At freeway speeds, the LUCS symbol should be visible to the approaching driver from 1,000 to 2,000 feet away. The color of the LUCS indication should be clearly visible for at least 2,000 feet at all times under normal atmospheric conditions, unless otherwise physically obstructed. LUCS should be placed at a maximum spacing of 1,500 feet apart on major arterials and limited access facilities.

*5.3.2. **Vertical Placement***

The signal placement should not be lower than the vertical clearance of the structure to which it is attached.

5.4 Selection of Signal Type

Each LUCS is independently controlled to indicate the status of each travel lane. LUCS can be co-located with a DMS to provide additional travel information. There are two types of LUCS that can display the different indications for lane use control:

- Arrow/Cross
- Graphic Displays

All lane use control signal indications should be in units with rectangular signal faces and should have opaque backgrounds. The minimum nominal height and width of each signal indication should be 18 inches for typical freeway or expressway applications.

Figure 5-4: Regulatory Combined with a Lane Use Control Signal. Photo Credit: VDOT

*5.4.1. **Arrow/Cross***

The arrow/cross type of LUCS consists of a series of elements that can be switched to display either a red cross or green arrow, or potentially yellow crosses and arrows as well. These are the only possible display elements for an arrow/cross type LUCS. Typically, the display consists of a series of red, yellow and green lights in the arrow and cross patterns, with a non-reflective dark background. Another type of arrow/cross LUCS uses separate elements for each signal with a programmable lens.

*5.4.2. **Graphic Displays***

The graphic display type of LUCS consists of a full matrix. Full-color, high-resolution pixels should be used to allow for crisp displays of pictograms.

5.5 **Selection of Structure**

The enclosure and its associated components must be included in the design process. Design criteria for a suitable ITS enclosure location include the following:

- The enclosure should be ground-mounted, approximately 1,000 feet upstream of the LUCS.
    - o Locate a ground-mounted enclosure at a minimum distance from the barrier, based on the design and type of barrier used. See PA standard drawings for appropriate minimums.
    - o Orient the enclosure so that the maintainer is facing the road while performing maintenance at the cabinet location.
    - o Consider elevating the critical electronic components above the flood elevation.
- If no suitable location is available for the enclosure to be ground-mounted, it may be pole-mounted on the LUCS (or other existing structure) to minimize cost or eliminate ROW takings.
- A level concrete pad should be provided at the front of the enclosure for the maintenance worker to stand on while accessing the enclosure.
- Where possible, there should be adequate and safe parking conditions in the vicinity of the enclosure for a maintenance vehicle. Where this is not possible, locate the enclosure where it is accessible by on-foot maintenance personnel.
- See PA and manufacturer specifications to determine the maximum distance between the enclosure and the field device it services.

In some cases, co-located ITS devices may share the same enclosure, which will influence enclosure size requirements.

Design standards for the ITS enclosure can be found in the PA ITS specifications.

6. **Vehicle Detection and Monitoring Systems**

6.1 **System Purpose and Design Flow**

Vehicle detection and monitoring systems are standalone detectors that detect the presence and characteristics of vehicles. They can detect and provide valuable real-time and historical data, including speed, volume, vehicle presence, lane occupancy, gaps and incident occurrence. This data can then be used for a variety of functions, including:

- Real time traffic and incident management
- Traveler information
- Historical analysis
- Origin-destination information
- Road capacity analysis
- Performance measures
- Planning and design purposes

To design a detection location, consider the following:

- Detector purpose derived from the system requirements
- Appropriate technology
- Deployment criteria such as structure type and orientation of the sensor (detector)

Figure 6-1 illustrates a detector design process.

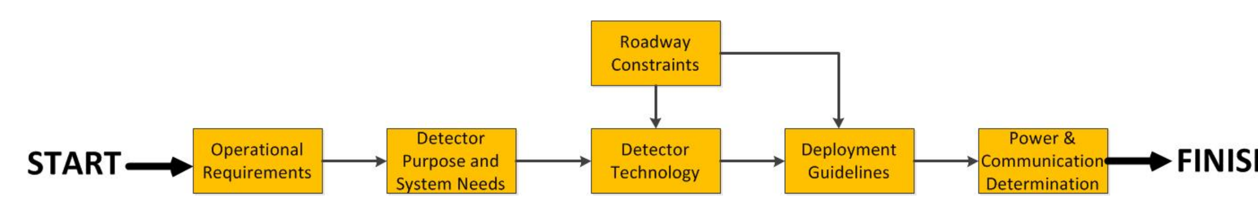


Figure 6-1: Detector Design Flow Chart

6.2 **Design Considerations**

Table 6-1 provides an overview of the design considerations in this chapter. The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set; however, it must be submitted as backup for review by PA ITS.

Table 6-1: Vehicle Detection Design Considerations

Detection Purpose
• Is this deployment consistent with the needs outlined in a Concept of Operations? • Is this deployment consistent with the regional ITS architecture?
Design Considerations
• Does the detector deployment satisfy the (location) precision considerations established in the system requirements? • Does the detector deployment satisfy the spacing considerations established in the system requirements? • Does the detector deployment satisfy the accessibility considerations (for maintenance) established in the system requirements?
Detector Technology Selection
• Does the detector technology satisfy the accuracy, accessibility and cost requirements established in the system requirements?
Deployment Guidelines
• Does the detector deployment take steps to minimize new structures and co-locate devices where possible? • Does the detector deployment include sufficient detector coverage to satisfy system needs?
Control Cabinet Enclosure
• Is an enclosure required at this location? • Is the enclosure located within 150 feet of the detector? • Is the enclosure mounted on an existing structure (where possible)? • Do the location and orientation provide adequate protection? • Has a maintainer's pad been provided at the enclosure's main door? • Can the maintainer safely park a vehicle and safely access the enclosure? • Are the Enclosure and Electrical/Electronic components above the flood elevation?
Power Requirements
• Have the power requirements for the detector and all of the system components been determined?
Power Availability
• Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the detector site? • Have Step-Up/Step-Down requirement calculations been performed? • Have the metering options been determined?
Power Conditioning
• Have the UPS and power back-up options been determined and accounted for?
Communications
• Have the communication requirements for the detector been determined? • Has an appropriate communications source been located and confirmed within a reasonable proximity to the site? • If there are multiple communications options, have the pros/cons been studied? • If using public communications infrastructure, has service been coordinated with the PA?
Environmental
• Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

For a design checklist, see Section 13.4, Appendix A - Vehicle Detector Design Checklist.

The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set, however, it must be submitted as backup for review by PA ITS.

Two types of detectors are covered in this chapter: point detectors and probe detectors. The following subsections present the design guidelines for each type. Existing systems or systems that have been planned for implementation should be compatible and interoperable, so procurement by sole source should be investigated if applicable.

6.3 Point Detection Systems

6.3.1. Highway Point Detection Systems

Primary considerations for the placement of point detectors are:

1. **Spacing and Lane Coverage.** Vehicle point detectors are ordinarily spaced 0.5 to 1.5 miles apart. Generally, all lanes of travel are covered by detector(s) at each detection point.
2. **Ramps.** Detectors are normally placed on entrance and exit ramps along the road.
3. **Cost.** Choose detector types, locations and communication methods to deploy a cost-efficient detection system. Co-locate detectors on existing structures (e.g. CCTV poles) where possible to minimize need for new structures, while adhering to spacing guidelines.
4. **Accessibility.** Accessibility of the device for maintenance and repair is of high importance, especially when many devices are necessary for the system. Ease of accessibility reduces maintenance costs, and also reduces the need to close lanes and disrupt traffic to perform maintenance.
5. **Comprehensive Data Capabilities.** Data for incident detection, speed, volume and occupancy are typically required.
6. **Accuracy.** Speed data must be accurate within a range of approximately 5 mph. Preferred accuracy of volume and occupancy is 5%.
7. **Location Precision.** In placing detectors, precision is secondary to maintaining exact spacing. Reducing costs by shifting detection points takes higher priority.

Certain types of detectors are not appropriate for all facilities. For instance, loop detectors should not be used on a bridge or road span to avoid invading the deck structure, and while typically installed in pavement, lower depth magnetometers may be utilized in an under deck configuration so as to not compromise the deck. Microwave radar sensors in tunnels may be subject to spurious returns from wave reflections.

6.3.2. *Urban Point Detection Systems*

Point detection systems are used at specific locations, usually at traffic signals as part of the traffic signal system. Detector locations should be in accordance with the signal system supplier's recommendations. Locations should:

- Be sufficiently upstream of expected queues
- Avoid locations where double parking is likely to occur
- Generally avoid any locations with anomalous traffic, geometric or other conditions

6.3.3. *Tunnel Point Detection Systems*

Vehicle detection systems for use in tunnels shall comply with all requirements of National Fire Protection Association (NFPA) 502 - Standard for Road Tunnels, Bridges, and Other Limited Access Highways. Refer to the NFPA 502 standard for design requirements.

If detectors or ancillary equipment are to be exposed to harsh cleaning solvents, they must remain impervious to these solvents. Equipment should also be impervious to build up or penetration of soot and other common exhaust particles. Equipment should be placed to minimize exposure to flooding.

6.4 Point Detection Technologies

Common detector technologies currently available for vehicle point detection include inductive loops, magnetometers, microwave radar and video image processing. Table 6-2 shows design considerations and the advantages and disadvantages for each technology. Note that maintenance costs are an important factor in selecting detector technologies for the Port Authority.

Table 6-2: Point Detector Type Advantages and Disadvantages

Detection Technology	Advantages	Disadvantages
Inductive Loop	• Mature, tested technology • Provides volume, presence, lane occupancy, gap and speed (in speed trap configuration) • Not affected by inclement weather	• Installation requires pavement cut • Cannot perform maintenance without interrupting traffic • Can reduce pavement life • One detector may be required for each travel lane, increasing cost and complexity • Requires software to interpret data • May require series of detectors to provide vehicle classification
Magnetometer	• Provides volume, lane occupancy, speed • Not affected by inclement weather • Longer lasting than loops • Relatively easy to maintain	• In-pavement installation • Cannot perform maintenance without interrupting traffic • Does not provide accurate lane occupancy • One detector may be required for each travel lane, increasing cost and complexity • Lane occupancy less accurate than loops • Requires software to interpret data • Difficult to detect stopped vehicles • Some magnetometers can have small detection zones
Microwave Radar	• Widely used and tested technology • Non-intrusive technology – no pavement work necessary • Multiple lanes can be detected using a single detector • Can be mounted on existing structures • Low installation costs	• Can be affected by rain • May require calibration after storm events • Obstructions such as barriers, road cut sections and retaining walls may decrease accuracy • May experience false calls due to echoes in tunnels • Requires setback from road – may cause problems in situations where ROW is limited • Requires software system to interpret data
Video Image Detection System (VIDS)	• Widely used and tested technology • Non-intrusive technology – no pavement work necessary • Can provide video images of the road to a Facility Traffic Management Center (TMC/OCC/Comm Desk)	• When mounted above road, traffic may be interrupted during installation • Can be affected by shadows, fog, snow, changing ambient light • Requires video processing technology • Requires software to interpret data feed

Table 6-3 summarizes appropriate detector technologies by facility type. Note that the actual selection of technology will be based on several factors not limited to, but including:

- Detection data type required (volume, occupancy, speed, vehicle type)
- Detection area (by lane, by area)
- Availability of mounting locations
- Pavement Type/Condition
- Weather/Environmental conditions in the surrounding area

Table 6-3: Point Detector Technologies by Facility Type

Facility Type	Encouraged or Recommended	Discouraged or Prohibited
Bridges	• Recent advances in magnetometer technology allow detectors to be installed underneath bridge decks, rather than embedded within.	• Microwave Radar, while not ruled out, is discouraged due to the high cost of maintenance. Maintenance costs are an important factor in selecting detector technologies to the Port Authority. • Loop Detectors are not appropriate as they must be embedded in the pavement.
Tunnels	• VIDS can be utilized for detection of stopped vehicles, lane-changing, and wrong way detection. Note that optical equipment may have issues with dirt and grime build up.	• Magnetometers and Inductive Loops are not appropriate as they must be embedded in the pavement. • Microwave Radar can be problematic in tunnels and controlled environments due to reflections off the walls and ceiling of the facility.
Open Road	• All technologies may be appropriate	
Intersections	• All technologies may be appropriate	

Table 6-4 shows how each of the technologies fulfills system requirements. This table should be used as a starting point for selecting the appropriate detector technology.

Table 6-4: Point Detector Technology Options

Detector Technology	Structure Type	Available Data	Accuracy	Accessibility	System Cost
Inductive Loop	None (in-pavement)	• Volume • Occupancy • Speed and Classification (special software and additional detectors required)	Moderate	Difficult / Intrusive	Low (single point) – High (multiple lanes and locations)
Magnetometer	None (in-Pavement)	• Volume • Occupancy • Speed and classification (length-based)	Moderate	Easy / Intrusive	Low-Moderate
Microwave Radar	Pole or Existing Structure	• Speed • Volume • Occupancy (special software required) • Classification (special software required)	Moderate	Easy	Low-Moderate
Video Imaging Detection Systems (VIDS)	Pole or Existing Structure	• Speed • Volume • Occupancy • Classification	Moderate-High	Moderate	Moderate-high (Also must consider additional hardware / software needed)

The remainder of this chapter identifies design considerations and guidelines for each detection system.

6.5 **Point Detection Deployment Guidelines**

This section identifies deployment guidelines and criteria for each detector technology. The designer should use this section as a guide for deployment of the detector or system of detectors.

6.5.1. *Inductive Loop Detection*

Loop vehicle detectors consist of a wire loop buried several inches beneath the pavement surface of the road, positioned in the center of each travel lane. The detectors use electrical induction from vehicles passing over the loop to detect vehicle presence.

For specifics and additional guidance concerning the size and placement of the loop within the travel lane, refer to the Traffic Detector Handbook[3] and PA Traffic Standard Details for ITS.

6.5.2. *Magnetometer Detection System (MDS)*

The magnetometer sensor is a type of magnetic field sensor used for vehicle point detection. The sensor detects the passage of a vehicle by measuring changes in the Earth's magnetic field and converting them into electronic signals. The sensor is placed in the middle of a traffic lane in a core drilled into the road surface. Detection data is transmitted in real time via wireless radio communications to an access point (AP) or Repeater Unit (RU) where the data is processed, stored, forwarded to an ITS enclosure and sent to the Facility Traffic Management Center (TMC/OCC/Comm Desk).

Magnetometers can be used to measure volume, occupancy and speed. Generally, occupancy and speed measurements are less accurate that those of induction loop detectors. A portion of the vehicle must pass over the sensor for it to be detected. A magnetometer can detect two vehicles that are separated by a distance of 1 foot or more.

Figure 6-2: Magnetometer Sensor. Photo credit: Sensys Networks

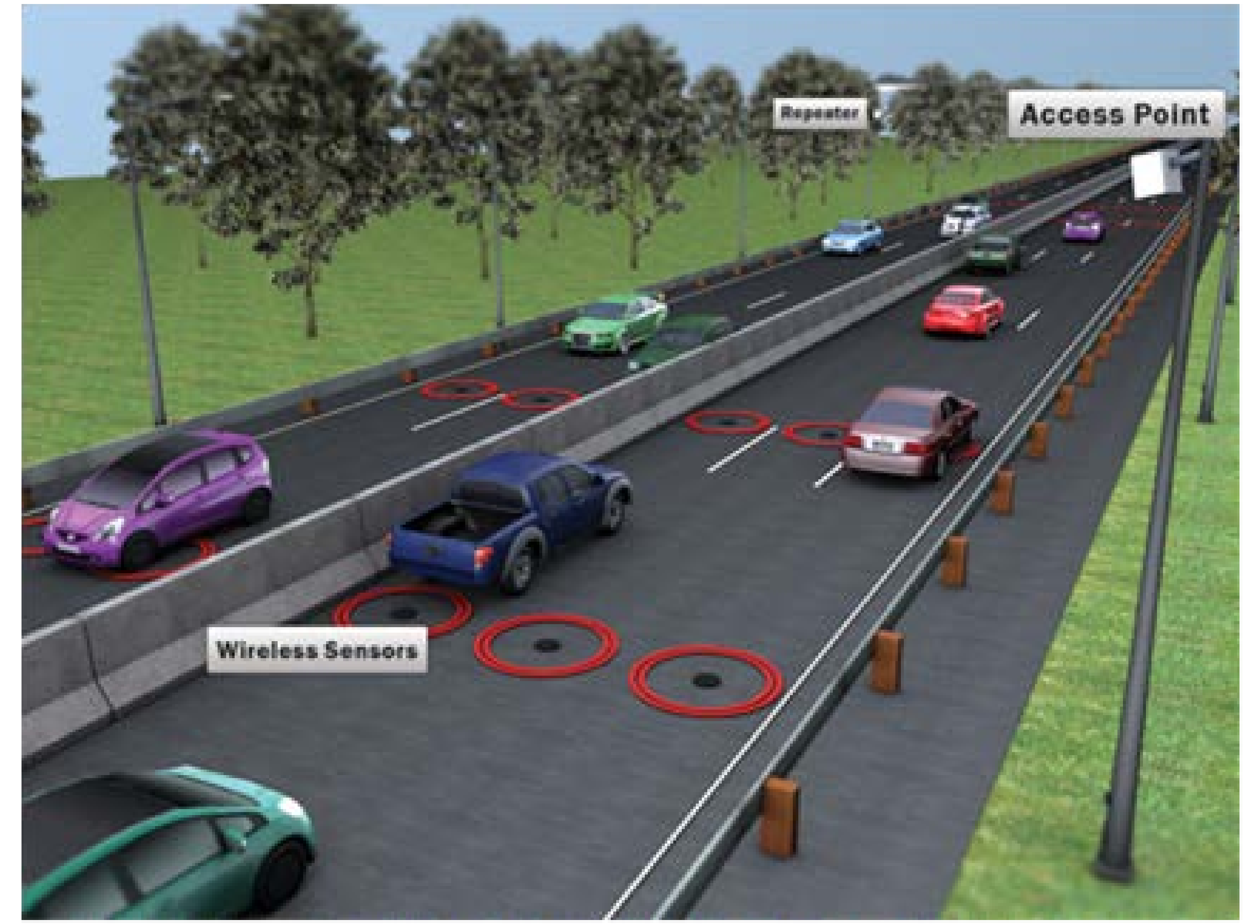


Figure 6-3: Typical Highway MDS. Photo credit: Sensys Networks

When designing a magnetometer detector location, the designer should determine, in the following steps:

1. **Detector Location.** Detector locations will vary based on their use – either data collection or incident detection.
   - If the detector is used for point data collection, the system needs may require a very specific detection area (e.g., a specific lane or entrance ramp, or a point on the mainline). The designer should not place the detector outside of this detection area.
   - If the detectors are part of a corridor data collection system, they should be spaced approximately 1 to 1 ½ miles apart.
   - If detectors are part of an incident detection system, they should be spaced approximately ⅓ to ½ mile apart.
2. **Detector Quantity.** One or more magnetometers must be used in each lane. In typical arterial and highway management applications, a sensor is placed in the middle of a traffic lane to detect the passage of vehicles and provide counts. Vehicle speeds are measured by installing at least two sensors in the same lane. The recommended distance between sensors depends on the range of expected speeds to be measured. For typical highway applications, a separation of approximately 20 to 23 feet is recommended. For typical arterial applications, a separation of 10 to 13 feet is preferred.

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[3] FHWA-HRT-06-108, Traffic Detector Handbook: Third Edition, May 2006

3. **Access Points and Repeater Units.** The number of APs and RUs will be determined by the geometry of the road, mounting height, the number of lanes, and the location of the ITS enclosure. The AP should be placed near the ITS enclosure and the power source when possible. Note that if the AP/RU structure is located on an embankment or hill, the mounting height from the base of the structure may vary depending on the structure elevation. Table 6-5 is an example of the setback and height requirements as a function of the number of lanes. This will vary depending on the actual equipment used and setback from first travel lane, so manufacturer's recommendations must always be considered during the site design.

Table 6-5: Maximum Distance between Access Point and Magnetometer Sensor

Mounting Height of AP/RU (feet)	**Maximum Distance to Magnetometer Sensor** (feet)
15	100
20	150
30	165

4. **Structure Type.** Access Points and Repeater Units can be either free-standing on a pole, or co-located with any existing structure (see Figure 6-4), such as:
   - Sign Structure
   - Overhead Truss Structure
   - Bridge Structure
   - CCTV Pole
   - Dynamic Message Sign

AP/RUs are amenable to different mounting configurations from those listed above. The designer should co-locate AP/RU on any of the above structures where the structure coincides with required detector spacing and satisfies the mounting height guidelines. Mounting AP/RUs on existing or new wooden poles is not acceptable.

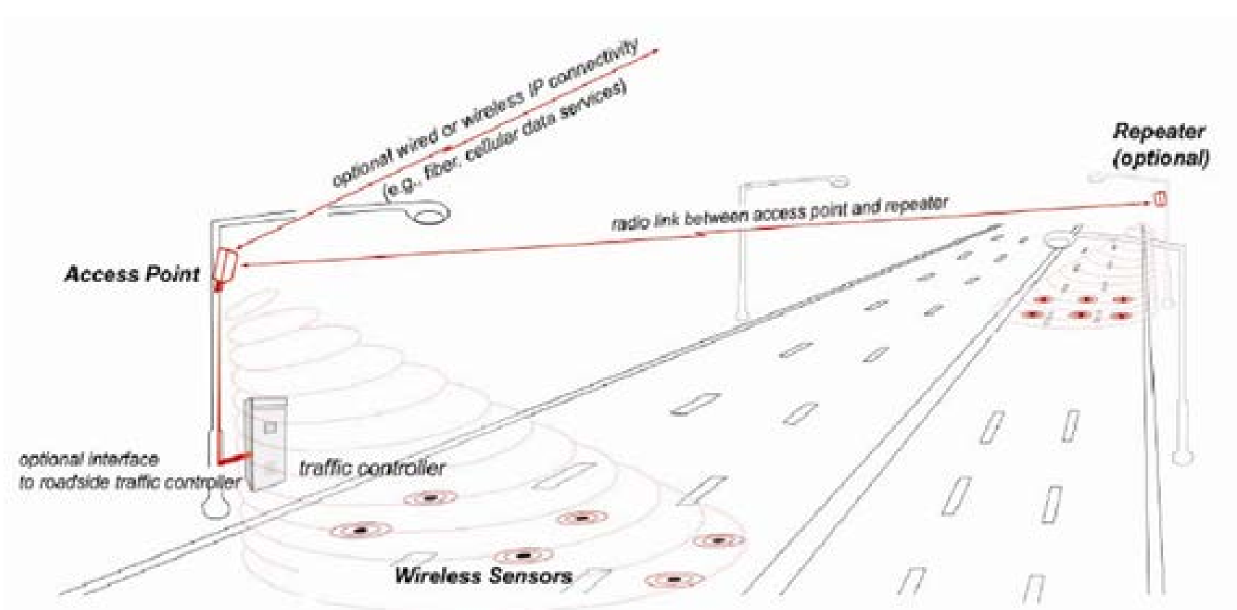

Figure 6-4: Typical MDS and Communications. Photo Credit: Clearview Traffic

6.5.3. *Microwave / Radar Detection*

Radar detectors consist of sensors mounted on the side of the road, angled down towards the travel lanes of the road. These sensors use a beam of microwave energy to collect vehicle data, including speed and volume, and sometimes occupancy depending on the manufacturer and type.

See Figure 6-5 for an illustration of a radar detector and its detection area. The detector software divides this area into user-definable "detection zones," where one zone is typically set up to correspond to one lane.

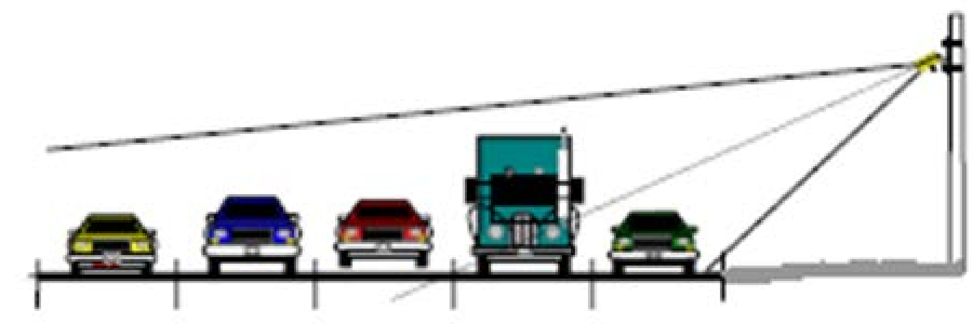

Figure 6-5: Side-Fire Radar Detector Orientation

When designing a microwave/radar detector location, the designer should determine, in the following steps:

1. **Detector Location.** Detector locations will vary based on their use for either data collection or incident detection.
   - If the detector is used for point data collection, the system needs may require a very specific detection area (e.g. a specific lane or entrance ramp, or a point on the mainline). The designer should not place the detector outside of this detection area.
   - If detectors are part of a highway data collection and incident detection system, they should be spaced approximately ⅓ to ½ miles apart.
   - Radar detectors should not be used within tunnels.
   - Additional precaution should be taken when specifying microwave/radar subsystems within a continuous structure. Multiple overhead detectors may be necessary in areas where reflections may cause multipathing issues.
2. **Detector Quantity.** Radar detectors have a range of approximately 250 feet from the detector structure to the farthest detection point. At locations where the detection zone exceeds 250 feet, multiple detectors must be used. This typically occurs at locations where two directions of travel must be captured. When the zone exceeds the detection capabilities of a detector, one detector on either side of the road is necessary to capture all travel lanes.
3. Mounting Height and Setback.
   - **Mounting Height.** For a standard detection range of approximately 150 feet, the sensor should be mounted approximately 25 feet above the road. Note that if the detector structure is located on an embankment or hill, the mounting height may be more or less than 25 feet from the base of the structure, depending on the structure elevation.

- **Setback.** Detector setback is the distance from the edge of the nearest travel lane in the detection area to the detector itself. This setback is required so that the detector's radar beam can expand to cover the detection area. Newer radar detectors may not require a setback. A 20-foot setback from the edge of the closest detection lane is recommended, subject to manufacturer recommendations for a specific device to be used.

Table 6-6 is an example of the setback and height requirements as a function of the number of lanes to be covered in the detection zone. This will vary depending on the actual equipment used and setback from the first travel lane, so manufacturer's recommendations must always be considered during the site design.

Table 6-6: Microwave/Radar Detector Recommended Height and Setback

# of 12-foot Lanes (Including Median)	Minimum Setback (feet)	Recommended Height (feet)
1-3	10 - 13	17
4	15	17
6	20	17
8	25	20
8 + Median	> 30	> 23

4. **Structure Type.** Microwave detectors can be either free-standing on a steel or concrete pole or co-located on an existing structure, such as:
   - Sign Structure
   - Overhead Truss Structure
   - Bridge Structure
   - CCTV Pole
   - Dynamic Message Sign

- Microwave detectors are amenable to other mounting configurations. For example, they can be mounted on a traffic signal mast arm if a suitable detection area can be obtained. The designer should co-locate radar sensors on any of the above structures where the structure coincides with required detector spacing and satisfies the mounting height and setback guidelines.

5. **Obstructions.** Microwave sensors can experience interference and disruption due to barriers or high retaining walls within the detection area. To minimize this interference, locations should be selected that minimize these obstructions. If obstructions are unavoidable, the designer should consider using multiple detectors to avoid the conflict. For example, if a road is separated by a jersey barrier median, one detector on either side of the road may be needed to capture all travel lanes. See Figure 6-6.

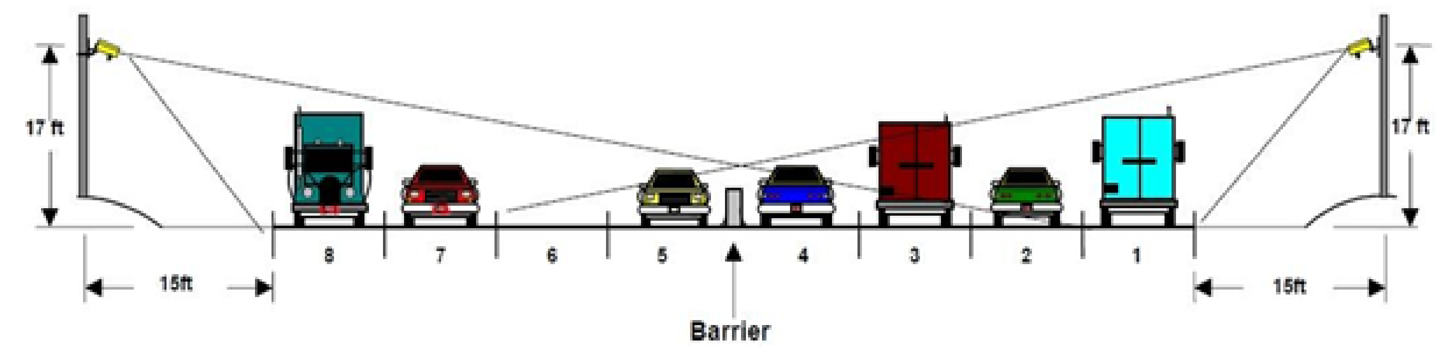

Figure 6-6: Side-Fire Detectors on Road with Barriers

6.5.4. Video Imaging Detection System (VIDS)

A Video Imaging Detection System (VIDS) consists of a video camera mounted above or along the road, angled towards the travel lanes. The system is configured using software to collect data only from predetermined "zones" within the travel lanes. Video images are processed by software to detect vehicle presence, speed and volume in each zone. Figure 6-7 displays an image from a VIDS camera and the detection zones as defined in the system software.

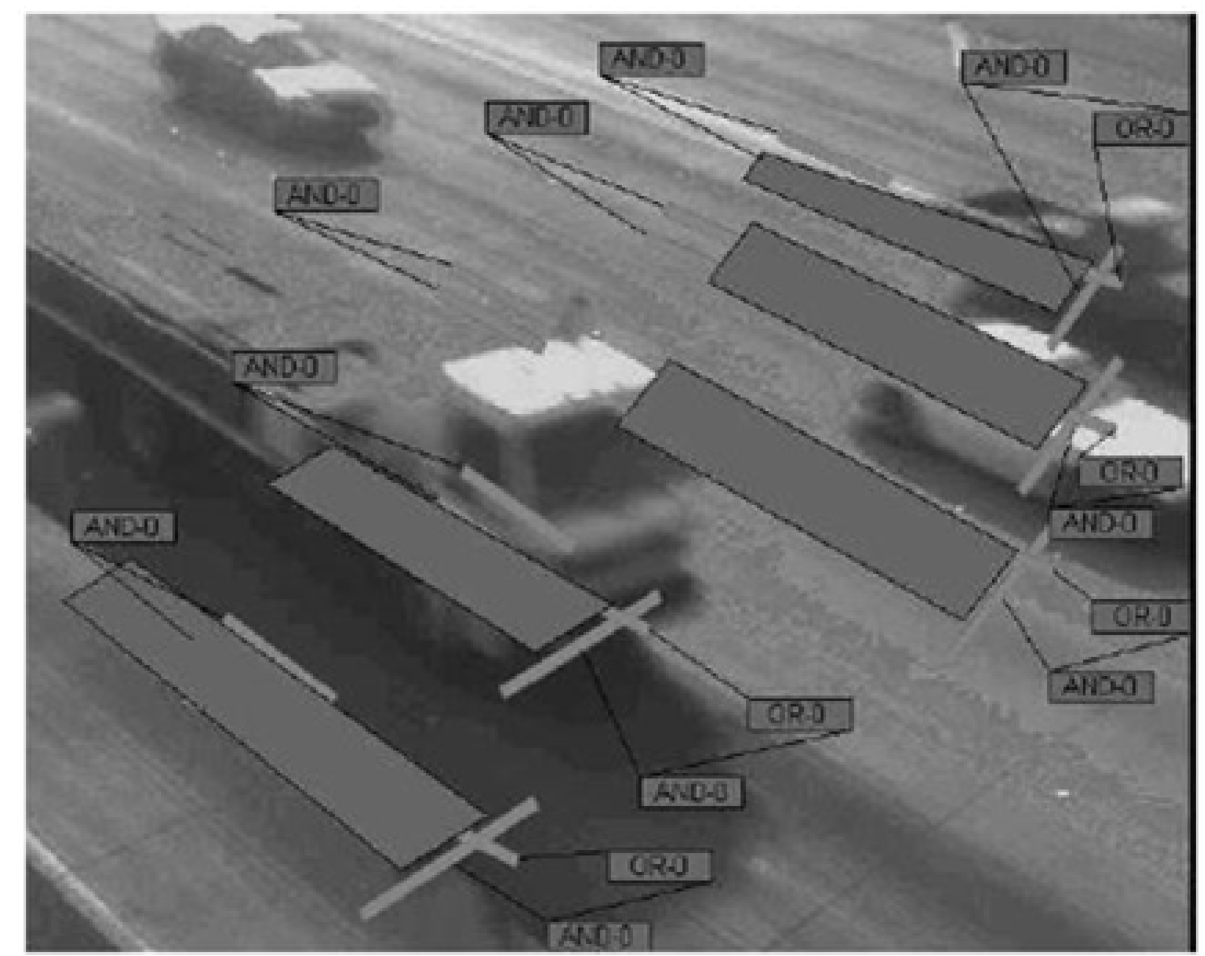

Figure 6-7: VIDS Camera Image and Detection Zones

When designing a VIDS, the designer should determine, in the following steps:

1. **Detector Location.** Detector locations will vary based on whether they are used for data collection or incident detection.
   - If the detector is used for point data collection, the system needs may require a very specific detection area (e.g. a specific lane or entrance ramp, or a point on the mainline). The designer should not place the detector outside of this detection area.
   - If the detectors are part of a corridor data collection system, they should be spaced approximately 1 to 1½ miles apart.
   - Full coverage of all tunnels should be provided for incident detection, as per the requirements of NFPA 502.
2. **Detector Structure.** Because VIDS detectors are above-road systems, it is highly recommended that they be co-located on existing structures, such as:
   - Bridges
   - Truss Structures
   - Mast Arms
   - Poles
   - Tunnel Ceilings / Walls

For urban areas, traffic signal mast arms are the preferred structure for mounting VIDS cameras. If mast arms are used, they must meet the vertical clearance guidelines shown on the standard drawings. If co-location is not possible because of spacing or other system needs, new overhead structures must be constructed. Any above-lane structure must comply with AASHTO standards for minimum clearance.

3. **Detector Vertical Clearance and Quantity.** VIDS can detect vehicles on as many lanes as are present in the video image. At a height of 30 feet, VIDS can detect up to three lanes simultaneously. At a height of 20 feet, VIDS can detect up to two lanes simultaneously. At heights less than 20 feet, only one lane can be detected per VIDS camera.
4. **Detection Zone Configuration (Post-Construction).** VIDS systems detect vehicles on the road based on "detection zones" established within the detector software. Once installed, these zones must be defined for each travel lane from which data is collected. Each supplier of VIDS technology uses proprietary software system to define the detection zones. Each detection zone must be defined such that only vehicles within the detected lane cross the zone. This will ensure that each detection zone gathers lane-specific data, and that vehicles are not counted more than once. See Figure 6-7 for an example of defined detection zones.

6.6 Probe Vehicle Detection

6.6.1. TRANSMIT

6.6.1.1. TRANSMIT System

TRANSMIT (TRANSCOM's System for Managing Incidents and Traffic) is a traffic surveillance and incident detection system that uses *E-ZPass*^{TM} electronic toll collection tags as traffic probes. One of the primary uses of the TRANSMIT system is to provide en-route motorists with an estimated travel time to a destination. These travel times may be displayed to the public in a variety of ways, including Dynamic Message Sign (DMS) displays, websites and kiosks. TRANSMIT adds value to the ITS network by providing travelers with current information so they can make more informed decisions about their current or planned travel. TRANSMIT readers should be considered along limited access facilities in urban areas, major commuter routes and areas of frequent recurring congestion.

The TRANSMIT system includes TRANSMIT readers in the field and central servers to analyze the TRANSMIT reader data. Vehicles are detected via their *E-ZPass*^{TM} tags by TRANSMIT readers deployed at specific points along roads in the TRANSMIT system. The TRANSMIT system is deployed for travel time estimation, data collection and incident detection purposes. The needs for a TRANSMIT system should stem from user needs established in the ConOps, and the functionality of the system should come directly from the project's Operational Requirements document.

6.6.1.2. Travel Time Estimation

The TRANSMIT system's primary function is to estimate vehicle travel times. When a vehicle first enters the TRANSMIT system, a reader stores its *E-ZPass*^{TM} identification number as a randomized number, along with the date, detection time, vehicle location and lane number. The randomized number is reusable, and as a vehicle passes through the TRANSMIT system, its randomized number will be recognized multiple times. This surveillance data is acquired on a 24-hour basis by TRANSMIT readers. The data is transmitted from the TRANSMIT reader back to TRANSCOM's servers, where travel times between successive readers are acquired from the data.

6.6.1.3. Incident Detection

Incidents can be detected using the TRANSMIT system by an incident detection algorithm. This algorithm compares real-time travel times to continuously updated historical travel times for the same period of day and day type. When the algorithm detects multiple successive vehicles arriving late at a reader, an alarm is triggered to indicate the possibility of an incident. To ensure that a false alarm is not triggered, the algorithm computes the probability of a false alarm, assuming that some vehicles may exit a road or some vehicles may be delayed by something other than an incident. A threshold of missing or delayed vehicles is computed to ensure that a false alarm is not sent to the Facility TMC/OCC/Comm Desk. Once this threshold is reached, and therefore the probability of a false alarm is sufficiently low, an alarm is sent to notify the Facility TMC/OCC/Comm Desk that an incident may be in progress. The algorithm is adjusted to balance the probability of a false alarm with the response time to an incident, ensuring that response times are kept under a certain value, normally five minutes,

6.6.1.4. Origin / Destination Data

Origin / Destination (OD) data is an important source for the development and update of travel demand forecasting. OD data provides insight into when and where people are traveling. The TRANSMIT system is capable of providing OD trip information, including by vehicle type.

6.6.2. Design Considerations

Table 6-7 provides an overview of the design considerations in Section 6.6. It is intended to be a high-level guide to assist designers through the criteria associated with TRANSMIT system design. Each section of the Table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for a TRANSMIT system.

The criteria and guidelines in this chapter should be followed when designing new TRANSMIT systems and when adding components to an existing TRANSMIT system. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer. The goal of this process is to provide practitioners with guidance as well as providing consistency with respect to PA TRANSMIT installations.

Table 6-7: TRANSMIT Design Considerations and Section Outline

Pre-Design Planning

- Is this deployment consistent with the needs outlined in the Concept of Operations?
- Is this deployment consistent with the regional ITS architecture?
- Have DMS display capabilities been considered in selecting the reporting needs?

Detector Placement

- Have the reporting needs been used in selecting the locations to be monitored?
- Have the DMS display capabilities been used to determine the number of travel time destinations?
- Do the selected locations conform to spacing requirements? A minimum of 1 mile spacing should be utilized unless conditions exist to warrant intermediate detection sites.
- Are existing structures, power and communications being used wherever possible?
- Are all field devices protected by a barrier and/or located outside of the road clear zone?
- Are devices located in such a way that they are accessible to maintenance staff?
- If incident detection is a need, does the detector deployment satisfy the spacing considerations established in the system requirements?

Enclosure

- Is the enclosure located within 150 feet of the detector?
- Is the enclosure mounted on an existing structure (where possible)?
- Do the location and orientation provide adequate protection for the enclosure?
- Has a maintainer's pad been provided at the enclosure's main door?
- Does the enclosure conform to the PA's specifications?
- Can the maintainer safely park a vehicle and safely access the enclosure?

Power Requirements

- Have the power requirements for the detector and all of the system components been determined?

Power Availability

- Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the detector site?
- Have Step-Up/Step-Down requirement calculations been performed?
- Do the location and orientation provide adequate protection for the enclosure?
- Have the metering options been determined?

Communications

- Have the communication requirements for the detector been determined?
- Has an appropriate communications source been located and confirmed within a reasonable proximity to the site?
- If there are multiple communications options, have the pros/cons been studied?
- Has the chosen communications option been reviewed with the PA?
- If using public communications infrastructure, has service been coordinated with the PA?

Environmental

- Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

6.6.3. PA Detection Method

The detection method for TRANSMIT is Radio-Frequency Identification (RFID) Transponder-based Vehicle Detection. Radio-Frequency Identification Transponder-based Vehicle Detection detects origin-to-destination travel time using an RFID tag, in this case an *E-ZPass*™ tag. The TRANSMIT Radio-Frequency Identification Transponder-based Vehicle Detection components include:

- Lane Kit (1 per lane)
- Tag Reader (in cabinet)
- TRANSMIT software hosted at TRANSCOM

Due to TRANSMIT's reliance on RFID tag usage, it may be necessary to first complete a Penetration Study along the selected route. The purpose of the Penetration Study is to determine if there is sufficient tag usage along the targeted route to provide enough data to calculate accurate travel times. A penetration rate exceeding 4% is required[4], but it is recommended that the penetration rate be 10% or greater. Due to the proliferation of *E-ZPass*™ tags throughout the tri-state region, this should be readily satisfied.

The TRANSMIT System consists of the following elements:

- *E-ZPass*™ detectors
- *E-ZPass*™ detector equipment (in field enclosure)
- Dynamic Message Signs
- DMS control equipment (in field enclosure)
- Communications cable/conduit
- Electrical cable/conduit
- Travel time software/hardware at TRANSCOM
- DMS software/hardware at TRANSCOM
- Control workstation at TRANSCOM
- Travel time calculation algorithm at TRANSCOM

[4] Sanwal, K. and Walrand, J., Vehicles as Probes, California PATH Program, Institute of Transportation Studies, University of California at Berkeley, 1995

Roadside tag readers deployed at strategic locations throughout the transportation system can detect *E-ZPass*™ tag identification numbers. These roadside tag readers immediately code *E-ZPass*™ tag ID numbers into the roadside terminal as a random number, in the interest of preserving traveler anonymity. The randomized number is assigned a detection time, location and lane position and is reused as long as the vehicle remains within the system. This allows TRANSMIT readers to generate data that can be used to complete a variety of functions, including:

- Real time traffic and incident management
- Traveler information
- Historical analysis
- Origin-destination information, including vehicle type
- Road capacity analysis
- Performance measures

Figure 6-8: Travel Time Display on a DMS

TRANSCOM aggregates the TRANSMIT data and makes it available to TRANSCOM member agencies via a direct feed. Detailed probe data, such as OD trip information, is available from the TRANSMIT OpenReach Servers.

As TRANSMIT uses DMS for display, the location(s) and capabilities of existing DMS must be considered during design. If new TRANSMIT detectors are being installed along with new DMS, the same factors must be considered. To effectively design a travel time system, the reporting needs must consider where the travel times can be displayed and how many travel times can be displayed on each DMS. If a DMS is only capable of displaying one travel time, then it will only be useful to provide a detection system for one destination for that DMS. If the DMS is capable of displaying multiple travel times, detection for multiple destinations may be used.

6.6.4. Detector Placement

Detector placement is determined by the function desired. For travel times, detectors should be placed at major entry points to the system (e.g. upstream mainline and major interchanges), at the message display point (e.g. DMS) and at important destinations (e.g. major interchanges and downstream mainline). The number of destinations should not exceed DMS display capabilities. For O/D data, a reader may be needed for every on-ramp and off-ramp on the road facility.

For incident detection, TRANSCOM recommends a 1-1.5 mile spacing of detectors as the ideal. This spacing achieves a goal of a false alarm rate below 2% and a mean incident detection time below 5 minutes. Reducing the spacing between detectors may reduce detection time, but at the expense of installation and maintenance cost.

Ideally, detectors would be located on existing structures, and use existing communications and power connections. If this is not possible, the considerations outlined in Table 6-8 should be taken into account when selecting the site and placement of the field device.

Table 6-8: TRANSMIT Site Selection Considerations

TRANSMIT Field Device Site Selection and Placement Considerations	
Utility Availability	• Consider proximity to power and communications • If fiber optic communication is used, try to place device on same side of road to eliminate lateral crossings
Safety and Device Longevity	• Protect mounting structure with guiderail inside of clear zone, but consider lateral deflection and maintenance vehicle access • Avoid locating the mounting structure on sections that have a fill slope of greater than one vertical to three horizontal (1V:3H) to reduce site erosion, reduce construction costs and provide longer device structure life.
Operational Considerations	• Install in urban areas, along major commuter routes and in other areas with frequent recurring congestion
Maintenance Considerations	• Device should be located such that a maintenance vehicle can park in the immediate vicinity, without necessitating a lane closure or blocking traffic • A concrete maintainer pad in front of the enclosure opening should be provided per PA ITS details
DMS Display Capabilities	• If the DMS is only capable of displaying one destination, detection will only be necessary for one destination for that particular DMS. If the DMS can display multiple destinations, more detectors may be deployed.

TRANSMIT Vehicle Detectors involve an overhead lane kit and an RFID tag reader located in a roadside cabinet. One lane kit is required for each lane of traffic. The lane kit should be mounted on an overhead structure. All installations must maintain a minimum vertical clearance of 17 feet, with a maximum height of 20 feet. Instructions for the cabinet are in the PA's TRANSMIT specification and drawing.

6.6.5. ITS Enclosure Placement

The ITS enclosure and its associated components must be included in the design process. Design criteria for a suitable ITS enclosure location include the following:

- When possible, the enclosure for the travel time controller should be pole-mounted on the detector pole or existing structures to minimize cost.
- If possible, the TRANSMIT Reader cabinet components should be co-located within another PA ITS field device enclosure.
- In locations where the pole is difficult to access, the enclosure may be ground-mounted at a more convenient location with easier access, such as adjacent to a frontage or access road.
    - Place the enclosure at the safest possible location, generally along the right shoulder.
    - Locate a ground-mounted enclosure at a minimum distance from the barrier, based on the design and type of barrier used. See PA standard drawings for appropriate minimums.
    - Orient the enclosure so that the maintainer is facing the road while performing maintenance at the cabinet location.
    - The enclosure should be at a level where the maintainer does not need a stepladder to perform maintenance at the cabinet location.
- A level concrete pad should be provided at the front of the enclosure for the maintenance worker to stand on while accessing the enclosure.
- Where possible, there should be adequate and safe parking in the vicinity of the enclosure for a maintenance vehicle. Where this is not possible, locate the enclosure where it is accessible by on-foot maintenance personnel.
- See PA and manufacturer specifications to determine the maximum distance between the enclosure and the field device it services.
- Consider elevating the critical electronic components above the flood elevation.

Use standard NEMA cabinets wherever possible. Specific equipment manufacturers may have different interior space requirements. In some cases, co-located ITS devices may share the same enclosure, which will further influence enclosure size requirements.

Design standards for the ITS enclosure can be found in PA ITS specifications.

6.6.6. Bluetooth

Technologies are currently in use by other agencies in the region to track devices that communicate with Bluetooth protocols. These devices include cell phones, GPS, vehicle installed audio components and other devices that are often carried in vehicles.

Bluetooth detectors read the MAC (Media Access Control) addresses of Bluetooth-enabled devices. The MAC addresses are anonymous and cannot be traced to a particular device or user, but remain assigned to a device throughout the user's travel in the system. As the user travels through the system, successive Bluetooth detectors pick up the same MAC address(es) belonging to that user, and transmit the information through cellular or Ethernet protocol, depending on the product specifications, back to a central processing center.

Travel times are calculated at a processing center based on the time and distance between detection locations and can be provided in real time. Data can be accessed over the Internet, or can be transmitted directly to a traffic management center. Historical data is archived to allow analysis of trends or the effects of changes within the system.

Detectors are recommended to be mounted at 12 to 15 feet above the road surface, but any location that is protected from traffic or vandalism is acceptable. The units self-calibrate using a built-in GPS antenna. Each detector operates with a 150-foot radius of detection, so one detector should be sufficient at each detection location. Detectors should be placed at major entry points to the system (e.g. upstream mainline and major interchanges), at the message display point (e.g. DMS) and at important destinations (e.g. major interchanges and downstream mainline). The number of destinations should not exceed DMS display capabilities.

Each Bluetooth detector can be powered by solar panels with a battery backup. The central processing center remotely monitors battery voltage and provides a system alert to the end user if there is insufficient voltage. An insufficient voltage reading may indicate the need to clear snow or debris from the solar panel or may indicate the need to relocate or provide a larger solar panel. Based on specifications, expected battery life is five to seven years.

7. Over-height Vehicle Detection Systems

7.1 System Purpose & Design Flow

Over-height detectors are used to monitor vehicle height to determine the presence of over-height vehicles. The goal of over-height vehicle detection systems (OVDS) is to prevent vehicles from causing damage to infrastructure and affecting traffic safety and operations as a result of exceeding legal height limitations. When these limits are violated, damage to the infrastructure can be significant and there may be unsafe traffic operations. OVDS can automatically alert the Facility TMC/OCC/Comm Desk when vehicles over the allowable height pass an over-height sensor.

Several industry standards / requirements relate to OVDS. Table 7-1 highlights some of the relevant standards.

Table 7-1: Over-height Vehicle Detection System Standards

Criteria	Relevant Standard
Sensor and warning signs	PA ITS Specifications – Over-height Vehicle Detection System specification
Communications and Software	National Transportation Communications for ITS Protocol (NTCIP)
Mounting Structure	PA Civil and Structural Standards and ITS details
Enclosure	PA ITS Specifications

7.2 Design Considerations

Table 7-2 provides an overview of the design considerations in this chapter. It is intended to be a high-level guide to assist designers through the criteria associated with over-height vehicle detection system design. Each section of the Table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for an over-height detection system.

The criteria and guidelines in this chapter should be followed when designing new over-height detection systems and when adding components to an existing system. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer.

The goal of this process is to provide practitioners with guidance as well as providing consistency with respect to PA Over-height Vehicle Detection System installations.

For a design checklist, see Section 13.5 Appendix A - Over-height / WIM Enforcement Design Checklist The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set; however, it must be submitted as backup for review by PA ITS.

Table 7-2: Over-height Vehicle Detection System Design Considerations and Chapter Outline

Detection Purpose
• Is this deployment consistent with the needs outlined in the Concept of Operations? • Is this deployment consistent with the regional ITS architecture?
Enforcement System Study
• Has a comprehensive Over-height Vehicle Detection System Study been performed? • Do the results of the study support continuing with the deployment of the project?
Enforcement System Location
• Is the sensor placed such that enough distance is available to warn drivers to take an alternate route?
Enforcement System Signals
• Are the warning signs placed at critical points to allow drivers to stop or exit the road? • Are the signs designed in compliance with MUTCD and with PA requirements?
Enforcement System Sensors
• Does the system design include all of the necessary detection areas? • Does the complexity / configuration of the system require additional detection areas?
Signing and Pavement Markings
• Do the signs and markings meet MUTCD standards?
Control Cabinet Enclosure
• Is an enclosure required at this location? • Is the enclosure located within 150 feet of the detectors? • Is the enclosure mounted on an existing structure (where possible)? • Do the location and orientation provide adequate protection for the enclosure? • Has a maintainer’s pad been provided at the enclosure’s main door? • Does the enclosure conform to the PA’s specifications? • Can the maintainer safely park a vehicle and safely access the enclosure? • Are the Enclosure and Electrical/Electronic components above the flood elevation?
Power Requirements
• Have the power requirements for the detector and all of the system components been determined?
Power Availability
• Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the detector site? • Have Step-Up/Step-Down requirement calculations been performed? • Have the metering options been determined?
Power Conditioning
• Have the UPS and power back-up requirements been determined and accounted for?
Communications
• Have the communication requirements for the detector been determined? • Has an appropriate communications infrastructure been located and confirmed within a reasonable proximity to the site? • If there are multiple communications options, have the pros/cons been studied? • Has the chosen communications option been reviewed with the PA? • If using public communications infrastructure, has service been coordinated with the PA?
Environmental
• Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

7.3 Enforcement Purpose

Over-height vehicle detection systems are deployed to prevent road or structure damage by oversized vehicles. Over-height warning systems can identify those vehicles that do not comply with the limits and warn drivers and the Facility TMC/OCC/Comm Desk when a vehicle exceeds the maximum height for the upcoming infrastructure or obstacle.

7.3.1. Over-height Warning System

Applications of over-height detection include bridges, over-road walkways, tunnels, overpasses and parking structures. The system should activate a visual and/or audible alarm, warning signs, flashing lights and/or traffic signals to prevent a potential collision. The system should also send an alarm to the Facility TMC/OCC/Comm Desk when activated.

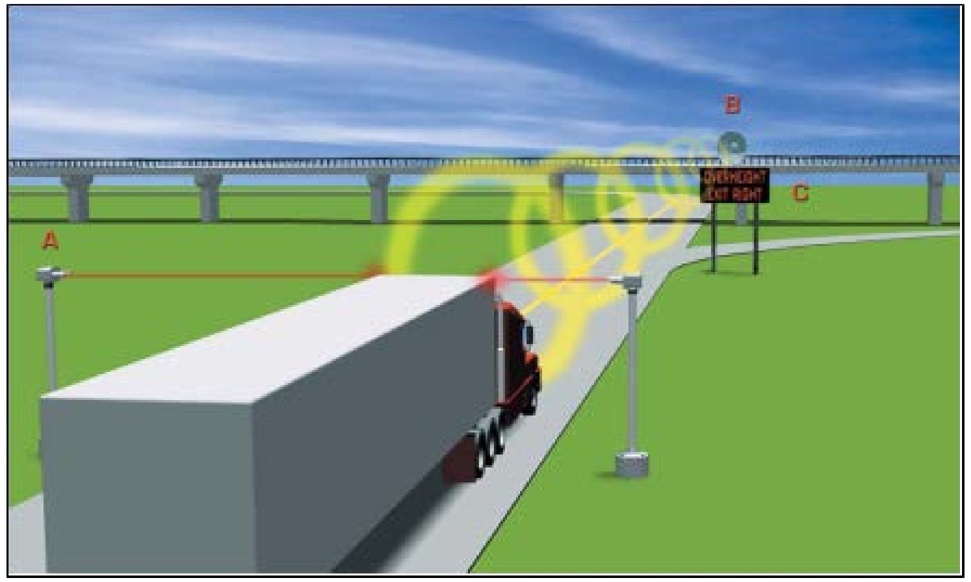

Figure 7-1: Over-height Warning System.
Photo Credit: Trigg Industries

7.3.2. Technology Choices

Over-height detection can be accomplished via visible red or infrared emitters. Video detection for the purposes of over-height detection is a technology that has been explored, but is currently not cost-effective compared to the alternatives.

Both visible red and infrared emitters provide good penetration of rain and fog.

- Visible red also provides high rejection of stray or intrusive light, and requires a 3° sun angle clearance.
- Infrared also provides an invisible light source and beam, and requires an 8° sun angle clearance.

Some vendors supply a unit with both visible red and infrared emitters for less susceptibility to sun blinding, while one vendor offers a proprietary "Z-Pattern" installation. Advantages of the "Z-Pattern" deployment are:

- not susceptible to sun blinding
- high reliability
- proper function in adverse weather conditions

Figure 7-2 illustrates the Z-Pattern concept:

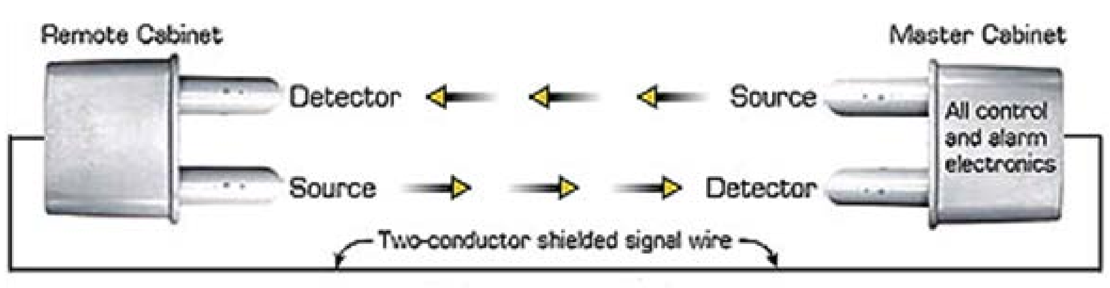

Figure 7-2: Z-Pattern® Concept.
Photo Credit: Trigg Industries

7.4 Deployment Guidelines

This section identifies deployment guidelines for over-height detectors or a system of detectors.

Enforcement systems provide information on vehicle classification that can be used for regulation and automatic enforcement. The locations and system depend on the characteristics of the road and its traffic volume.

Over-height detectors consist of a sensor mounted on each side of the road. Over-height vehicle detection systems are deployed to warn drivers if their vehicle exceeds the maximum height for the upcoming infrastructure, such as a tunnel entrance, low bridge/overpass or sign gantry. Typically, the over-height detector system includes transmitters and receivers, electronic warning sign and uninterruptible power supplies. When designing an over-height detector or system location, the designer must determine detector location, quantity, height and setback. The structure type must be approved by the PA. In some cases, over-height detectors can also be used to support WIM systems.

Table 7-3 lists items that the designer should consider when designing over-height detectors. Figure 7-3 shows a typical installation.

Table 7-3: Deployment Considerations

	Consideration	Significance
1	What is the posted speed limit and actual travel speed at the installation site?	Vehicle speed determines (in part) the distance from the detector that the warning sign must be placed to provide sufficient time for drivers to react to directions given.
2	What exits, pull-offs or U-turns are available between the detector and the obstruction?	Availability of such options must be taken into account as courses of actions for over-height vehicle drivers, and directions provided accordingly.
3	Will the detection system monitor one-way or two-way traffic across the road?	Determines whether the system must discern between directions. Note that each detection location would be one-way for a particular obstacle or infrastructure element.
4	What are the numbers of lanes in the direction of interest?	May contribute to determining distance required between detection and warning sign/exit if vehicle may need to change lanes.
5	What is the height of the obstruction (clearance required) and is there the same clearance for each lane?	The shape and/or contour of the obstruction or road may require more than one detector to monitor multiple heights or axes.
6	Are there any weather or airport radars within ¼ mile of the OVDS installation site?	Since both the visible red and infrared detectors are made from silicone substrate, it may be possible to generate a false alarm if the detector is looking directly into the radar.
7	What will be the smallest sun angles encountered with respect to the detection site?	Visible red detectors require a 3° clearance from direct sunlight and infrared detectors require an 8° clearance.

Consideration		Significance
8	Is there 115V AC power available on both sides of the road at the installation site?	If AC power is not available, solar power may be an option. There can be a combination of both AC and solar power within the same system if necessary.
9	What is the desired duration of the alarm?	This is the cumulative time requirement for the alarm to remain activated considering speed, distance, number of lanes and required driver response. Available systems offer timings of 1 to 30 seconds or 5 to 60 seconds as a standard feature, with customizable alarm durations up to 5 minutes.
10	Is remote reporting of an over-height detection and/or fault condition required?	If so, this requirement will contribute to determining the choice of system.
11	What are the local traffic patterns?	These may influence directions given to drivers in over-height situations.
12	Has consideration been given to elevating the critical electronic components above the flood elevation?	Equipment should be located so as to not be affected by flooding.

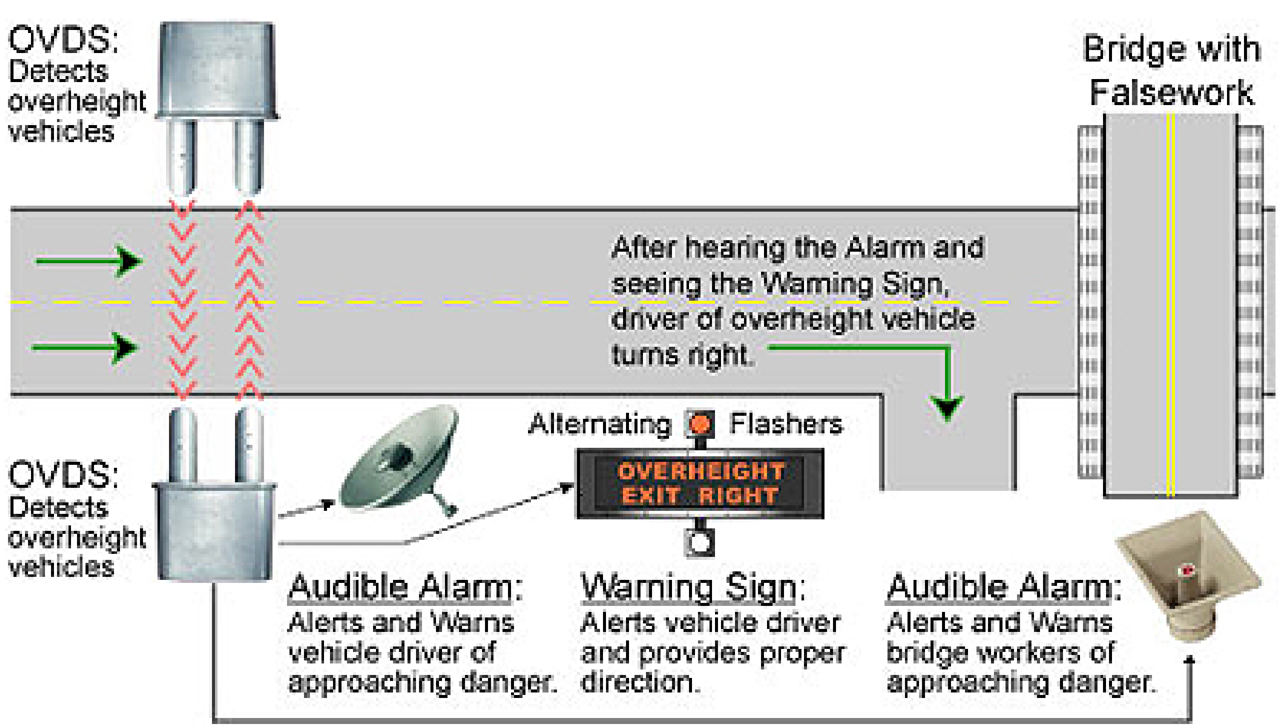

Figure 7-3: Typical Over-height Vehicle Detection System Installation. Photo Credit: Trigg Industries

8. Overweight or Weigh-in-Motion (WIM) Detection Systems

8.1 System Purpose & Design Flow

Overweight or weigh-in-motion (WIM) detectors are used to monitor vehicle weight to determine the presence of oversized vehicles. The goal of WIM systems is to prevent vehicles from causing damage to infrastructure and affecting traffic safety and operations as a result of exceeding legal weight limitations. When these limits are violated, damage to the infrastructure can be significant and there may be unsafe traffic operations. These systems can automatically alert the Facility TMC/OCC/Comm Desk when vehicles over the allowable weight pass a WIM sensor.

Several industry standards / requirements relate to Overweight Detection Systems. Table 8-1 highlights some of the relevant standards.

Table 8-1: Overweight Detection System Standards

Criteria	Relevant Standard
Sensor and Warning Signs	PA ITS Specifications – Weigh-in-Motion specification
Communications and Software	National Transportation Communications for ITS Protocol (NTCIP)
Mounting Structure	PA Civil and Structural Standards and ITS details
Enclosure	PA ITS Specifications – Weight-in-Motion specification

8.2 Design Considerations

Table 8-2 provides an overview of the design considerations contained in this chapter. It is intended to be a high-level guide to assist designers through the criteria associated with Overweight Detection System design. Each section of the Table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for an overweight detection system.

The criteria and guidelines in this chapter should be followed when designing new overweight detection or WIM systems and when adding components to an existing system. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer. The goal of this process is to provide practitioners with guidance as well as providing consistency with respect to PA Overweight Detection System and WIM installations.

For a design checklist, see Section 13.5 Appendix A - Over-height / WIM Enforcement Design Checklist The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set, however, it must be submitted as backup for review by PA ITS.

Table 8-2: Overweight Detection System Design Considerations and Chapter Outline

Detection Purpose
• Is this deployment consistent with the needs outlined in the Concept of Operations? • Is this deployment consistent with the regional ITS architecture?
Enforcement System Study
• Has a comprehensive Overweight Detection System Study been performed? • Do the results of the study support continuing with the deployment of the project?
Enforcement System Location
• Is the sensor placed such that enough distance is available to warn drivers to take an alternate route?
Enforcement System Signals
• Are the warning signs placed at critical points to allow drivers to stop or exit the road? • Are the signs designed in compliance with MUTCD and with PA requirements?
Enforcement System Sensors
• Does the system design include all of the necessary detection areas? • Does the complexity / configuration of the system require additional detection areas?
Signing and Pavement Markings
• Do the signs and markings meet MUTCD standards?
Control Cabinet Enclosure
• Is an enclosure required at this location? • Is the enclosure located within 150 feet of the detectors? • Is the enclosure mounted on an existing structure (where possible)? • Do the location and orientation provide adequate protection for the enclosure? • Has a maintainer's pad been provided at the enclosure's main door? • Does the enclosure conform to the PA's specifications? • Can the maintainer safely park a vehicle and safely access the enclosure? • Are the Enclosure and Electrical/Electronic components above the flood elevation?
Power Requirements
• Have the power requirements for the sensor and all of the system components been determined?
Power Availability
• Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the sensor site? • Have Step-Up/Step-Down requirement calculations been performed? • Have the metering options been determined?
Power Conditioning
• Have the UPS and power back-up requirements been determined and accounted for?
Communications
• Have the communication requirements for the detector been determined? • Has an appropriate communications source been located and confirmed within a reasonable proximity to the site? • If there are multiple communications options, have the pros/cons been studied? • Has the chosen communications option been reviewed with the PA? • If using public communications infrastructure, has service been coordinated with the PA?
Environmental
• Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

8.3 Enforcement Purpose

Overweight detection systems are deployed to prevent road or structure damage by overweight vehicles. WIM warning systems can identify those vehicles that do not comply with the limits and warn the Facility TMC/OCC/Comm Desk when a vehicle exceeds the maximum weight.

The WIM automatically indicates when vehicles are over the permitted weight as they drive over a sensor. Unlike static weigh stations, WIM systems do not require the vehicles to stop, making enforcement more efficient. Proper forensic documentation for law enforcement requires use of static scales to verify specific axle weights.

8.3.1. *Weigh-in-Motion Technologies*

WIM devices are designed to capture and record vehicle weights as they drive over sensors installed in the road pavement. The sensors are embedded in the pavement so that they can estimate the load of a moving vehicle without disrupting traffic flow. WIM systems are used for collection of statistical traffic data, support of commercial vehicle enforcement, structural inventory management and traffic management.

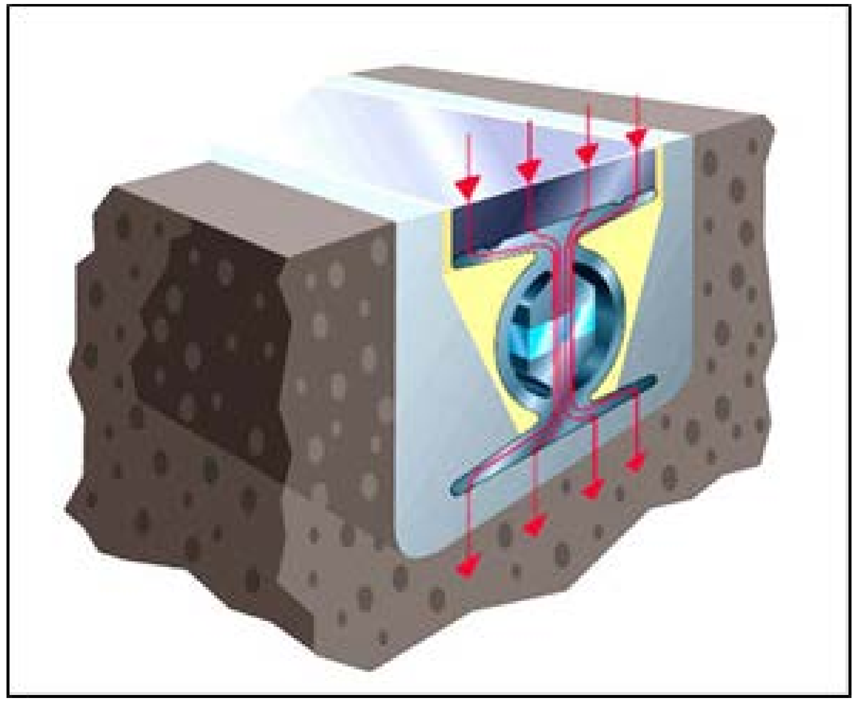

Figure 8-1: Cross Section of Piezoelectric WIM Sensor Installed in Asphalt.
Photo credit: KISTLER

The most common WIM sensors are piezoelectric sensors, which are used to measure wheel and axle loads of moving vehicles. These sensors consist of a light metal material fitted with quartz discs, embedded in the pavement. When an external force is applied to the surface of the sensor, the load causes the quartz discs to yield an electrical charge proportional to the applied force through the piezoelectric effect. In the case of a WIM system, the force on the sensor is exerted through deformation induced by tire loads on the pavement surface. A charge amplifier converts the electric charge into a proportional voltage that can be measured and correlated with the applied force. This sensor offers great accuracy as well as low maintenance and has a stable response over a large temperature range, but the sensor's performance is affected by variations in the flatness of the pavement.

Another type of WIM sensor is the load cell sensor. Scales using this technology typically consist of a series of load cells located under a weighbridge, which vehicles drive over. The load cell sensor consists of a vertically oriented strain gauge that measures the force is applied to it. As a vehicle drives over the weighbridge of the scale, each strain gauge deflects. The deflection is electronically measured and a digital output is produced. Load cells often contain internal diagnostic capabilities to identify any problems that occur. Load cell sensors are most accurate at lower to medium speeds, whereas other technologies are better suited for mainline highway speeds.

8.4 Deployment Guidelines

This section identifies deployment guidelines for the deployment of an overweight detector or system of detectors.

Enforcement systems provide information on vehicle classification that can be used for regulation and automatic enforcement. The locations and system depend on the characteristics of the road and its traffic volume.

A standard WIM system should cover all lanes of the road where trucks are permitted. The travel lanes are instrumented with induction loops and piezoelectric sensors. All vehicles driving through the WIM site are measured. The legal weight and height limits are as defined by local or state law.

The installation of WIM includes cutting and restoring pavement for the inductive loops and piezoelectric sensors. Loop vehicle detectors and piezoelectric sensors are buried several inches beneath the pavement surface of the road. For specific requirements concerning the size and placement of the loop and piezoelectric sensor within the travel lane, see PA ITS Weigh-in-motion specifications and design details.

Consider elevating the critical electronic components above the flood elevation.

Figure 8-2 illustrates a typical WIM installation:

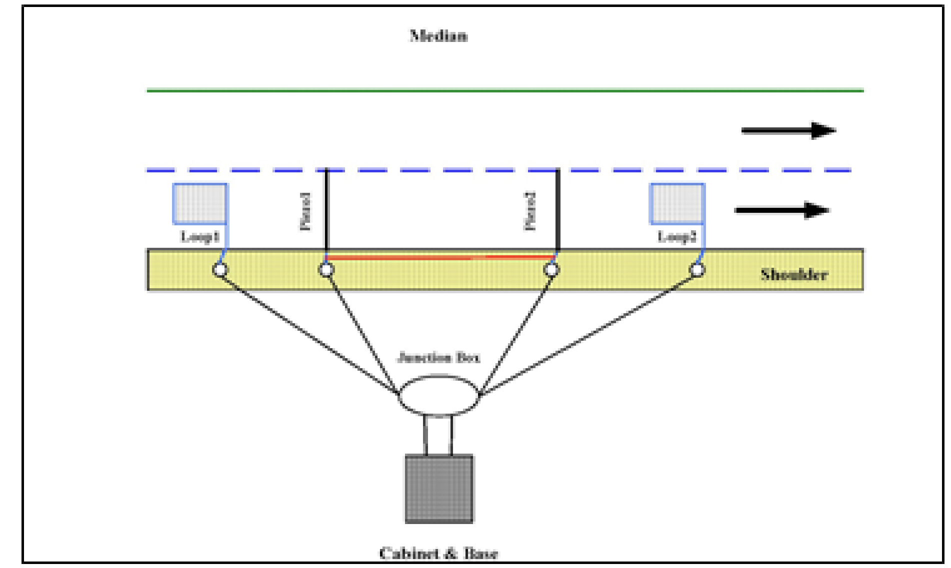

Figure 8-2: Piezoelectric WIM System Layout.
Photo credit: NJDOT

9. Road Weather Information Systems (RWIS) and Air Quality Monitoring Sites

9.1 System Purpose & Design Flow

A Road Weather Information System (RWIS) (see Figure 9-1) measures and monitors road weather conditions using an array of different sensors. RWIS installations assist PA and other agencies in determining road conditions. This information can be shared with drivers and/or used internally to assist in scheduling maintenance. RWIS installations collect atmospheric, pavement surface, and sub-surface data to provide the most accurate weather information available. Table 9-1 lists standards relevant to RWIS.

Figure 9-1: Weather Station.
Photo Credit: GDOT

The Road Weather Information System (RWIS) Station collects weather data via a combination of sensors that gather and transmit pavement and sub-surface pavement temperature, wind speed and direction, air temperature, visibility, precipitation, and humidity data. These sensors are controlled by a field controller, called a Remote Processing Unit (RPU), which then sends the sensor data to the Facility TMC/OCC/Comm Desk. The information can be used to inform drivers of adverse conditions or to determine when to conduct road maintenance operations in a safe and effective manner. RWIS data should be used with an information dissemination source, such as Dynamic Message Signs (DMS), to reach motorists to aid in reducing weather-related traffic collisions.

Table 9-1: RWIS Standards

Criteria	Relevant Standard
Sensors, Tower and Pole Type	PA ITS Specifications – RWIS Specification
Communications and Software	National Transportation Communications for ITS Protocol (NTCIP)
Structure	Per manufacturer's requirements and PA details
Enclosure	PA ITS Specifications and Details RWIS Specification

9.2 Design Considerations

Table 9-2 provides an overview of the design considerations in this chapter. It is intended to be a high-level guide to assist designers through the criteria associated with RWIS design. Each section of the Table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for RWIS.

The criteria and guidelines in this chapter should be followed when designing new RWIS installations and when adding components to an existing RWIS. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer. The goal of this process is to provide practitioners with guidance as well as providing consistency with respect to PA RWIS installations.

The design for each RWIS site should include the communications design for that site. Power is required for the collection of the data at the RPU and for transmission of the road weather data to its intended users. Existing systems or systems that have been planned for implementation should be compatible and interoperable, so procurement by sole source should be investigated if applicable.

For a design checklist, see Section 13.6 Appendix A - RWIS Design Checklist. The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set; however, it must be submitted as backup for review by PA ITS.

Table 9-2: RWIS Considerations and Chapter Outline

Detection Purpose
• Is this deployment consistent with the needs outlined in the Concept of Operations? • Is this deployment consistent with the regional ITS architecture?
Location/Placement Guidelines
• Has the RWIS location been chosen / designed with consideration to typical or worst-case atmospheric conditions in the area? • Has a site for the RWIS been chosen that considers the available utilities and the costs or constraints associated with connection to those utilities? • Has the site been chosen with consideration to protecting the RWIS structure and ensuring that it will last without undue maintenance necessary to the structure and the surrounding site? • Has a site been chosen that makes the best use of the operational needs of an RWIS (e.g. low-visibility sites)? • Has a site been chosen that satisfies safety requirements for personnel performing maintenance on the system? • Has the site been chosen so that it will minimize maintenance costs and facilitate maintenance (e.g., there is sufficient shoulder to park a bucket truck without the need for a full lane closure and significant traffic control activities)?
Sensor Type
• Are the sensor types appropriate for the desired location? • Is the mounting height appropriate? • Is the equipment sufficiently hardened to withstand major storms?

Sensor Mount

- Have PA standards been followed in the design of the mount / structure?

Control Cabinet Enclosure

- Is an enclosure required at this location?
- Is the enclosure mounted on the RWIS pole, tower, ITS gantry, or on an existing structure (where possible)?
- Do the location and orientation provide adequate protection for the enclosure?
- Has a maintainer's pad been provided at the enclosure's main door?
- Does the enclosure conform to the PA's specifications?
- Can the maintainer safely park a vehicle and safely access the enclosure?
- Are the Enclosure and Electrical/Electronic components above the flood elevation?

Power Requirements

- Have the power requirements for the RWIS components been determined?

Power Availability

- Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the site?
- Have Step-Up/Step-Down requirement calculations been performed?
- Have the metering options been determined?

Power Conditioning

- Have the UPS and power back-up options been determined and accounted for?

Communications

- Have the communication requirements for the RWIS been determined?
- Has an appropriate communications infrastructure been located and confirmed within a reasonable proximity to the site?
- If there are multiple communications options, have the pros/cons been studied?
- Has the chosen communications option been reviewed with the PA?
- If using public communications infrastructure, has service been coordinated with the PA?

Environmental

- Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

9.3 The RWIS System

The typical RWIS site consists of a tower, pole, enclosure and several outstations. The RWIS outstations may include some or all of the following:

- Road sensors in travel lanes to measure surface temperature, sub-surface temperature and surface condition.
- Atmospheric sensors adjacent to the road to measure air temperature, relative humidity, wind speed and direction, visibility and precipitation.
- A power source supplemented by an electric connection.
- A data logger, connected to all the sensors, to translate and record the signals received from the sensors.
- A communications device, such as a modem, to allow remote collection and transfer of data.

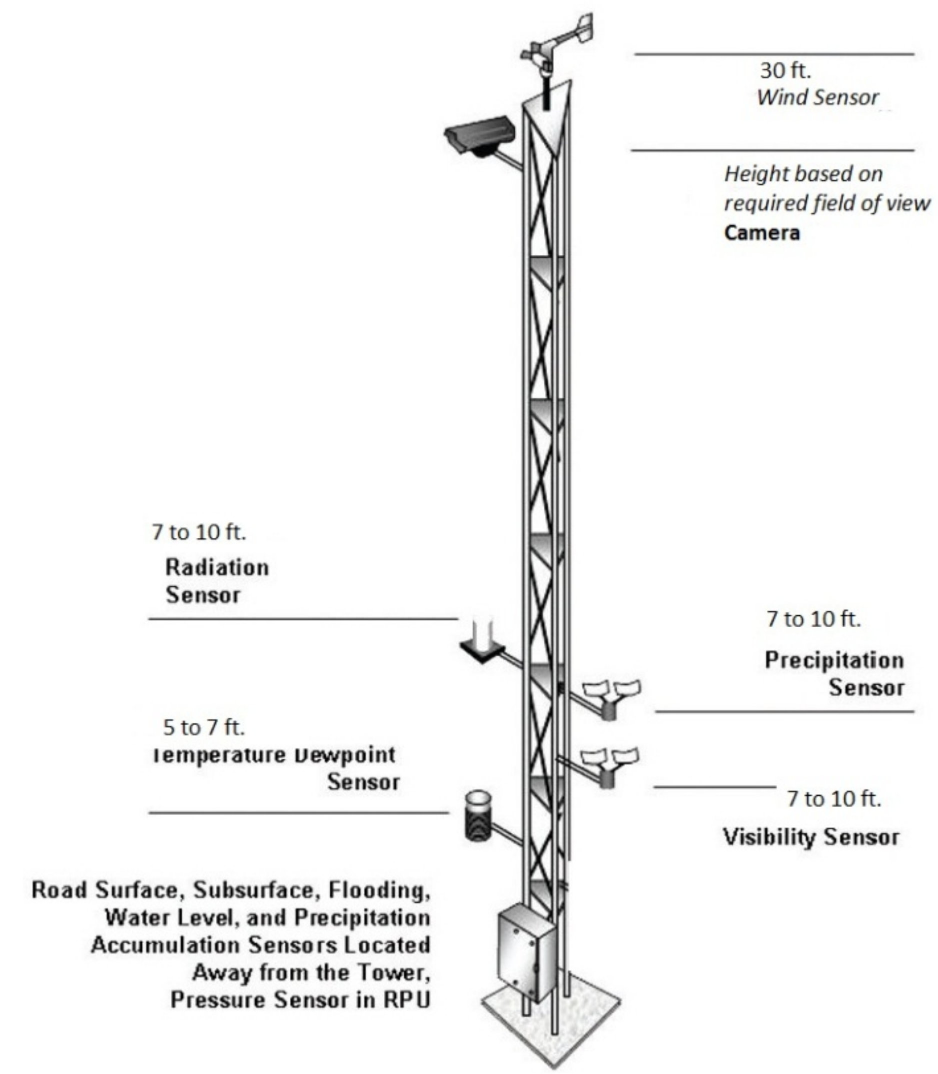

Figure 9-2: Typical Location of Pole-Based Sensors.
Photo Credit: FHWA

9.3.1. Types of Sensors

Most of the sensors on an outstation are installed above the road, affixed to a tower. The sensors typically included are the ultrasonic wind speed and direction sensor, precipitation and visibility sensor, air temperature/relative humidity sensor and pavement and sub-surface pavement sensor. These sensors are typically part of a complete weather station, but there are also some sensors that are installed either on the road surface or in the sub-surface, beneath the road surface.

9.3.1.1. Wind Speed and Direction

Wind speed and direction measurements are made either by a combination sensor or by individual sensors. A common type of wind speed sensor is the ultrasonic, which uses a robust and reliable ultrasonic anemometer to sense wind speeds. There are a variety of types of anemometers that vary in appearance but have the same basic principles of operation. This sensor should be positioned approximately 30 feet above ground level. Obstructions to the wind flow should be avoided.

9.3.1.2. Air Temperature and Humidity

Air temperature and humidity sensors can provide air temperature, dew point temperature, wet bulb temperature and relative humidity. Typically, a single sensor provides both air temperature and relative humidity measurements. To minimize errors induced by solar heating, the sensor is typically mounted in a solar radiation shield. These sensors should be mounted approximately 5 to 7 feet above ground level and should be installed towards the predominant wind direction.

9.3.1.3. Pavement Sensor

The identification of road temperature and condition is crucial for the accuracy of a RWIS. By reporting the road surface temperature and whether the road surface is wet or dry, the RWIS can monitor conditions for road icing. These sensors are located in the pavement.

Recent developments have led to the introduction of remote sensing of road temperature and condition. These non-intrusive pavement sensors are much like CCTV cameras and can be aimed at the road surface to sense the conditions remotely. Separate devices are available to measure temperature and sense surface conditions.

9.3.1.4. Visibility and Precipitation

Visibility sensors measure meteorological optical range, and can be extremely useful in low-visibility or fog-prone areas. These sensors typically use infrared forward scatter technology, but anything in the optical path that attenuates or scatters the infrared beam, such as dirt or even spiderwebs, may cause erroneous readings. To avoid this problem, multiple sensors can be used to check and adjust for any contamination errors. These sensors should be installed at a height of approximately 7 to 10 feet above the ground.

Precipitation sensors measure the type, intensity and accumulation of precipitation. This includes the detection of freezing precipitation and snow, conditions that can present safety hazards along roads. This precipitation information is used in planning road maintenance operations.

9.3.2. RWIS Structure

The RWIS structure can be a tower, pole, or ITS Gantry. The RWIS structure must have a concrete foundation to provide a sturdy platform. Given the Authorities varying soil conditions, the foundation size must be designed for the specific site conditions, and in accordance with the manufacturer's minimum specifications. The structure should be sturdy and meet manufacturer's requirements for deflection to reduce contamination of sensor data by turbulence and wind flow around the structure.

The structure height should be sufficient to accommodate the sensor/sensors. If installing wind sensors, tower should be at least 30 feet high. Towers are most frequently installed within a range of 35 to 50 feet from the edge of the paved surface (see Figure 9-3) and, if possible, at the same elevation as the surface of the road.

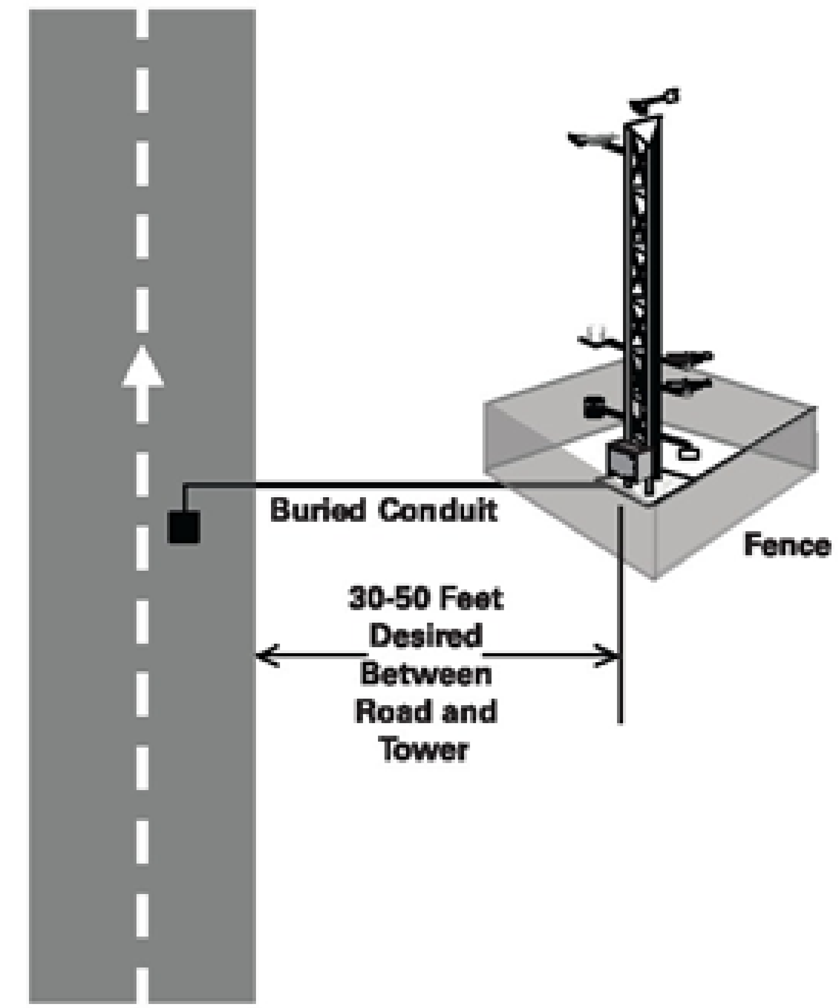

Figure 9-3: RWIS Pole Location.
Photo Credit: FHWA

9.4 **RWIS Site Selection**

A poorly chosen site can result in incorrect readings, service difficulties or even damage from passing traffic. The site should not be sheltered in such a way that sensor readings give a false indication of conditions closer to the road. At the same time, the sensors and the outstation should not be located so close to the road that wind from passing traffic will give inaccurate readings. The height of sensors above the ground and their orientation can also affect readings, and need to be taken into account when selecting locations and installing equipment.

The number and spacing of sites in the network is dependent upon a variety of factors, including topography, soil type, land use, microclimate zones, proximity to utilities and road classification. Generally, the greater the variability in these factors, the more sites will be required in the network. RWIS deployments should focus on roads where visibility issues or road icing are prevalent. The observation points and pavement sensors should be installed at critical points along the roads. Variations in sensor or structure siting may be unavoidable due to many circumstances, such as limited road right-of way, access for maintenance, geography and security concerns.

9.5 ITS Enclosure Placement

The RWIS controller system consists of an enclosure, controller, load switches, power distribution unit, and other miscellaneous devices. Design criteria for a suitable ITS enclosure location include the following:

- When possible, the enclosure for the travel time controller should be pole-mounted on the detector pole or existing structures to minimize cost.
- If possible, the cabinet components should be co-located within another PA ITS field device enclosure.
- In locations where the pole is difficult to access, the enclosure may be ground-mounted at a more convenient location with easier access, such as adjacent to a frontage or access road.
  - Place the enclosure at the safest possible location, generally along the right shoulder.
  - Locate a ground-mounted enclosure at a minimum distance from the barrier, based on the design and type of barrier used. See PA standard drawings for appropriate minimums.
  - Orient the enclosure so that the maintainer is facing the road while performing maintenance at the cabinet location.
  - The enclosure should be at a level where the maintainer does not need a stepladder to perform maintenance at the cabinet location.
- A level concrete pad should be provided at the front of the enclosure for the maintenance worker to stand on while accessing the enclosure.
- Where possible, there should be adequate and safe parking in the vicinity of the enclosure for a maintenance vehicle. Where this is not possible, locate the enclosure where it is accessible by on-foot maintenance personnel.
- See PA and manufacturer specifications to determine the maximum distance between the enclosure and the field device it services.
- Consider elevating the critical electronic components above the flood elevation.

Use standard NEMA cabinets wherever possible. Specific equipment manufacturers may have different interior space requirements. In some cases, co-located ITS devices may share the same enclosure, which will further influence enclosure size requirements.

Design standards for the ITS enclosure can be found in PA ITS specifications.

10. Highway Advisory Radio (HAR)

The primary function of Highway Advisory Radio (HAR) is to provide information to the traveling public. The nature of this information is varied, but the goal is to disseminate road condition information to travelers so that they can make informed decisions regarding their intended route and/or destination. In addition, as part of the PA ITS implementation program, Highway Advisory Radio shall be incorporated into evacuation scenarios.

Some typical HAR uses include notifying travelers of:

- Incidents and Road/Lane Closures
- Adverse Conditions
- Construction and Maintenance Operations
- Amber Alerts
- Homeland Security Issues
- Scheduled Safety Messages
- Special Event Conditions
- Evacuation-related messages

To maximize the effectiveness of HAR and to support driver safety, transmitter location must be carefully considered when designing and deploying any new HAR system. First, the design must satisfy the system purpose established in the operational requirements; for example, components of the design will differ if HAR is deployed to serve one interchange or if it is deployed along a corridor. After this, the most important design consideration is the correct placement of the transmission structure and the HAR signs. Figure 10-1 illustrates the design process.

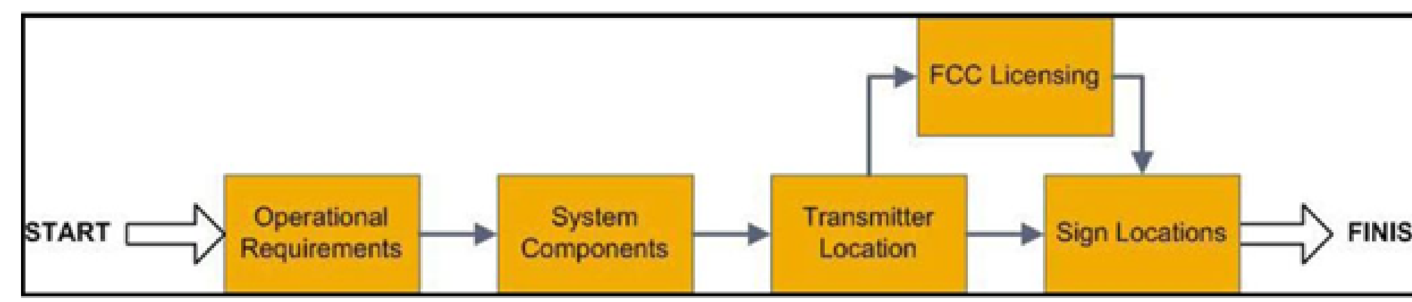

Figure 10-1: HAR Design Flow Chart

Several industry standards / requirements relate to HAR, although there is no ITS Standard specific to HAR control. Table 10-1 highlights some of the relevant standards

Table 10-1: HAR Standards

Criteria	Guidance
Sign	Manual on Uniform Traffic Devices (MUTCD) 2009 Edition with Revision Numbers 1 and 2 Incorporated, Section 2I.09, Radio Informational Signing.
Structure	American Association of State Highway and Transportation Officials (AASHTO)
Enclosure	National Electrical Manufacturers Association (NEMA) TS4 standards
Beacon	Manual on Uniform Traffic Devices (MUTCD) 2009 Edition with Revision Numbers 1 and 2 Incorporated, Chapter 4L (Flashing Beacon Signs)

10.1 Design Considerations

Table 10-2 provides an overview of the design considerations in this chapter. It is intended to be a high-level guide to assist designers through the criteria associated with HAR system design. Each section of the Table corresponds to a section of this Chapter and includes the background, details and specific regulations or guidance related to the design process for a HAR system. Evacuation scenarios shall be incorporated into every PA ITS implementation program.

The criteria and guidelines in this chapter should be followed when designing new HAR systems and when adding components to an existing system. However, there will be instances where all criteria cannot be met. Justification for deciding to proceed with an installation despite not meeting all criteria should be detailed by the designer. The goal of this process is to provide practitioners with guidance as well as providing consistency with respect to PA HAR installations. Existing systems or systems that have been planned for implementation should be compatible and interoperable, so procurement by sole source should be investigated if applicable. Consider elevating the critical electronic components above the flood elevation.

The design for each HAR site should include the power and communications design for that site.

For a design checklist, see Section 13.7 Appendix A - HAR Design Checklist. The designer shall submit the completed checklist with or before each design submission. The checklist will not be included in the drawing set; however, it must be submitted as backup for review by PA ITS.

Table 10-2: HAR Design Considerations

Deployment Purpose
• Is this deployment consistent with the needs outlined in the Concept of Operations? • Is the deployment consistent with the regional ITS architecture?
Control Software
• Is the HAR compatible with the Facility TMC/OCC/Comm Desk device control software?
Site Selection
• Are there any adjacent existing HAR systems, and if so, has coordination taken place with the operating agencies? • Has a frequency search taken place? • Has an on-site listening survey been performed? • Has reception of the NOAA All-Hazards Alert System been verified? • Have existing traveler information systems, e.g. AM news radio, been considered when justifying a new HAR system deployment?
Transmitter Location
• Is the potential transmitter site free of significant vertical (25′ or higher) obstructions? • Are power (115 volts, 60 Hz) and communication (telephone/wireless/owned wire line) services available at the site? • Is there sufficient open ground for the cabinet and antenna installation? • If there are adjacent HAR transmitters, has message synchronization been built into the design?
Beacon Sign Location
• Have MUTCD sign standards been followed? • Are the signs visible and unobstructed? • Is the sign placed such that a motorist is entering the proposed broadcast range of the HAR transmitter? • Does the location of the sign permit the traveler to safely tune and then react to the message? • Is it possible to co-locate the sign/beacon with an existing CCTV camera for the purpose of visual verification?
Licensing and Permits
• Has consideration been given to other HAR transmitters (not adjacent to the new site) along a particular route so that the same frequency can be used?
Control Cabinet Enclosure (both transmitter location and beacon location)
• Is the enclosure location within 150 feet of the device? • Do the location and orientation provide adequate protection for the enclosure? • Has a maintainer's pad been provided at the enclosure's main door? • Does the enclosure conform to the PA's specifications? • Can the maintainer safely park a vehicle and safely access the enclosure? • Are the Enclosure and Electrical/Electronic components above the flood elevation?
Power Requirements
• Have the power requirements for the HAR and all of the system components been determined?
Power Availability

• Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the HAR site? • Have Step-Up/Step-Down requirement calculations been performed? • Have the metering options been determined?
Power Conditioning
• Have the UPS and power backup requirements been determined and accounted for?
Communications
• Have the communication requirements for the HAR been determined? • For wired communications, has an appropriate source been located and confirmed within a reasonable proximity to the site? • For cellular communications, has the required signal strength been verified at the site? • If there are multiple communication options, have the pros/cons been studied? • Has the chosen communications option been reviewed with the PA? • If using public communications infrastructure, has service been coordinated with the PA?
Environmental
• Have all the necessary environmental, community and cultural impact studies, processes and concerns been addressed?

The HAR system consists of three basic components:

- The device control software (located at the Facility TMC/OCC/Comm Desk)
- A transmitter and antenna assembly
- Roadside signs / beacons

When an operator at the Facility TMC/OCC/Comm Desk activates the HAR system, a signal is sent to the HAR transmission tower, which then begins to broadcast either a pre-recorded or custom message on the pre-designated frequency. The sign/beacon assembly contains a receiver which receives this signal and activates the flashing beacons, alerting drivers that there is a message being broadcast. Drivers then tune their car radios to the frequency posted on the sign to listen to the traveler advisory/warning.

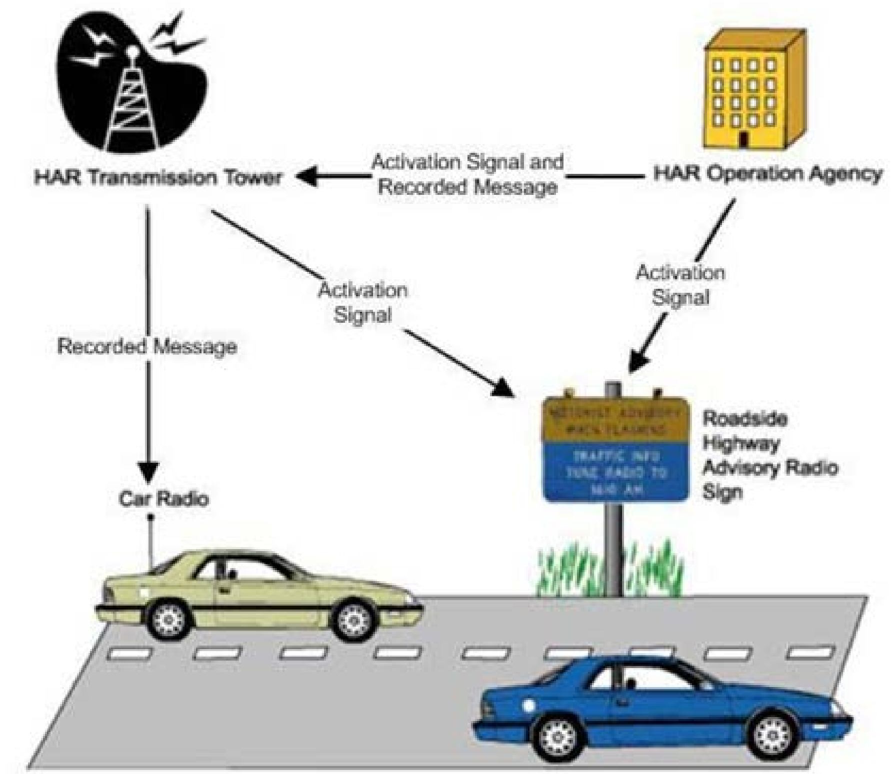

Figure 10-2: HAR System Mode

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*10.1.1. **HAR Transmitter***

The transmitter site setup typically consists of the following equipment:

- **AM Transmitter.** The transmitter should be located in the control cabinet. The amplitude modulated transmitter must be FCC type approved.
- **Digital Recorder/Player.** The recorder/player should digitally record and store messages, or audio files, and be capable of transmitting and receiving digital messages.
- **GPS Synchronization Unit.** This unit is only necessary if synchronizing HAR systems. The GPS synchronization unit provides the capability to phase-lock the transmitters to a common reference carrier.
- **NOAA Weather Receiver.** This unit receives real-time information directly from the National Weather Service (NWS). This unit should have fully programmable entry capability so that only the alerts specifically needed for this HAR are broadcast.
- **Cabinet.** The cabinet should house HAR electronic components in a locking, weather resistant, aluminum cabinet that completely protects the equipment.

- **Mounting Pole.** The mounting pole used to mount the antenna should be a freestanding, vertical wooden or fiberglass pole between 30 and 35 feet high.
- **Antenna.** The antenna should be omnidirectional and vertically polarized, providing high-efficiency performance. The antenna length will depend on the final selected frequency, but together with mounting pole the total height should not exceed 49.2'.
- **Power Supply.** The power supply should be capable of operating from a power source of 115 volts, 60 Hz, and should have fuse protection against internal short circuits and power surges.

Consult PA Highway Advisory Radio specification, including detailed drawings of the above equipment.

The most common method of transmission is 10-Watt AM transmission. As of 2000, the FCC allows low-power FM transmission to be used for traveler information, although this technology has limited application to-date. Therefore, all HAR systems should be designed based on using this transmission method. The maximum broadcast range, operating under ideal conditions (no buildings, flat terrain), is usually 3 to 5 miles from the transmission tower (6 to 10 miles in diameter). This is highly dependent on topography, atmospheric conditions and the time of day.

10.1.2. HAR Beacon Signs

HAR signs direct motorists to tune to the HAR broadcast frequency when the beacons above the signs are flashing. HAR signs are typically located on major roads and the approaches to major freeway interchanges, bridges or tunnels to give the motorist sufficient time to plan to avoid a conflict or closure.

Flashing beacons and advisory signs are required at any HAR system installation where a DMS cannot be used to alert motorists to tune into the HAR transmitter. However, beacons and signs are encouraged for all locations, regardless of DMS presence, to allow any potential DMS to disseminate other travel information not provided in a HAR broadcast.

The sign/beacon assembly consists of the following major components:

- **Sign.** The sign must comply with MUTCD standards.
- **External Illumination and Flashing Beacons.** These are activated remotely when there is a HAR broadcast message. All beacons must be 12" amber LED.
- **Flashing Unit.** Controls the flashing of the beacons, which should be one flash per second in accordance with MUTCD standards.
- **Control Cabinet.** The cabinet should be a NEMA type 3R aluminum cabinet, with a hinged door lockable by key and accessible from ground level.

Consult PA Highway Advisory Radio specification, including detailed drawings of the above equipment.

10.1.3. HAR Control Software

HAR control software allows for monitoring, control and change of HAR broadcasts from a remote location, usually a facility TMC/OCC/Comm Desk. In addition, this type of software can alert facilities of problems or issues relating to HAR equipment.

For more information on HAR Control Software, consult PA Highway Advisory Radio specification.

10.2 HAR Site Selection

These six steps should be followed to locate HAR transmitters and signs properly as part of an HAR system:

1. **Coordinate with Adjacent Systems.** If there are existing HAR systems in the deployment area, coordinate the design and deployment of the new HAR with these other systems. This may include checking for HAR systems operated by adjoining agencies, such as NYSDOT, NYCDOT, Metropolitan Transportation Authority (MTA) or NJDOT. Depending on the location of the transmitter, coordination can be accomplished in one of two ways:
   - The first option is to use a GPS synchronization unit within the HAR rack that coordinates the message between two or more transmitters. This allows a seamless transmission of the message when going from the coverage area of one transmitter to another.
   - The second option is to turn down the broadcast range of the transmitter by decreasing the power of each transmitter. This will allow for each transmitter to play a different message without an overlap area in which both messages are heard when tuning into the radio station, such that neither of the messages can be distinguished.
2. **Conduct a Frequency Search.** Develop a list of AM frequencies that are available. Consider what frequencies the PA is currently using, as well as frequencies used by neighboring agencies along the same route. To maintain consistency for drivers, determine if these frequencies can be used for the proposed transmitter. This should be written into the contract for the contractor to verify the available AM frequencies using site survey equipment.
3. **Survey Onsite Listening.** Survey all roads where it is intended for motorists to tune into the HAR broadcast when so instructed, using an automobile digital AM radio tuned to the candidate frequencies from Step 1. Monitor all of the candidate frequencies throughout the listening area at least once during daylight hours and at least once during the night. Again, this should be written into the contract so that the contractor is responsible for obtaining the correct frequency. The contractor should provide the PA a list of available frequencies at the site location, and the PA can direct the contractor to obtain a license for a particular frequency.
4. **Choose a General Location for Coverage.** Find the approximate geographic center of the desired listening area for each transmitter. The HAR signal should propagate to a minimum radius of 4 miles from this point in all directions (highly dependent on the terrain and topography). If this coverage does not encompass all of the roads that require coverage, consider the possibility of adding repeater stations. Consider where HAR signs will be placed to announce to motorists entering the area that the signal is available.
5. **Determine the Desired NOAA All-Hazards Alert System Notification Coverage.** Verify reception of a National Weather Service channel (162.400-162.500 MHz) at the desired location. See coverage areas online at this NOAA web link: http://www.nws.noaa.gov/nwr/Maps/.
6. **Choose a Specific Antenna Location.** See specific site guidance below in Section 10.2.1

10.2.1. Transmitter Locating Considerations

For best transmission coverage, the immediate location of the transmitter should be free of tall buildings, trees, terrain features, lighting, power / communication poles and towers, overpasses and overhead highway signs. Make certain that 115 volt, 60 Hz power and communications are available at the site and that there is sufficient area of open ground for cabinet, grounding grid and antenna installation where possible.

Table 10-3: HAR Transmitter Site Guidance

Criteria	Guidance
Site Obstructions	• Provide a 50′ radius clear zone around the antenna. • The transmitter should be on the highest ground possible to aid in reception of the transmission. • The transmitter site should be free of objects that exceed 25′ (approximately 2 stories).
Facility Approaches (Such as Bridges and Tunnels)	• Take advantage of existing utilities. • The distance from the HAR sign to an alternative route or the last exit before a facility should be a minimum of 1½ to 2 miles on a 55 mph freeway.
Adjacent Transmitters	• It is important to avoid overlaps so that conflicting messages are not transmitted. • GPS Synchronization Units can be utilized to synchronize messages on overlapping HAR frequencies to avoid conflicting messages. • Adjacent transmitters should be placed as close as possible to avoid gaps in coverage.
Existing Private Radio Traveler Information Providers	• Consider the usefulness of an additional radio source as compared to existing private radio traveler information providers. Even if many traveler information stations exist, HAR is still an effective tool for disseminating real-time, site specific information that can be tailored by the PA to meet the needs of road users.

10.2.2. Sign / Beacon Siting Considerations

Strategic placement of the signs announcing the HAR is important to its success. If signs are positioned poorly in relation to the transmitter range or not present on major approaches to the broadcast area, motorists are likely to think the station is not working and might be tempted to tune out, missing crucial information.

Table 10-4: HAR Sign/Beacon Site Guidance

Criteria	Guidance
Activation Signal	• Preliminary design or investigation of proposed sign sites must include a signal strength test if wireless communication is being used.
Sign Visibility	• Signs should be placed on straight sections of road where possible. • Signs should be placed at least 800′ from other static or dynamic signs or other visual obstructions.
Sign Placement	• Signs should be located at the edge of the broadcast range of the HAR transmitter. • Signs should be located far enough from an alternate route to give the motorist time to locate the radio channel (15-20 seconds), listen to the message twice (approximately 120 seconds), and divert to the alternate route. • The distance from the HAR sign to an alternative route should be a minimum of 1½ to 2 miles on a 55 mph freeway. • Motorists should not have to divert their attention from a complex road segment (sharp curves, merges, etc.) to tune their radio to the HAR frequency.
Device Collaboration	• Where possible, design a HAR sign within sight of an existing (or planned) CCTV camera so that the status of the flashing beacons can be visually confirmed. This is not necessary if the HAR system will have bi-directional communications with the Facility TMC/OCC/Comm Desk.

10.3 Licensing and Permits

A FCC RF (radio-frequency) license is issued specifically for the RF band, RF transmission level, related antenna type and location (including height). A FCC RF license is therefore required for each HAR application, including additions based on RF bands used in existing HAR systems.

Traditionally, the choice of a HAR RF band has been left to the system supplier because HAR system suppliers are typically more familiar with the process of FCC RF license acquisition. However, note the following considerations:

- FCC licenses for RF bands at or near the bottom and top ends of the AM radio band are usually easier to obtain, as these are commercially least desirable. However, avoid accepting an RF band outside of the standard AM frequency range (520 KHz to 1610 KHz) because not all AM radios used in vehicles have the "extended" AM range (below 520 KHz, and between 1610 KHz to 1710 KHz).
- Where an existing HAR system is deployed along a corridor, give preference to the same RF band used in the existing system so that related HAR signs along the same road are uniform, if possible.
- FCC licensing is typically completed by the contractor during construction, as the FCC will only issue a permanent license once the HAR transmitter is fully constructed. The FCC may issue a temporary license for a 3-month period before issuing a permanent license.

10.3.1. *ITS Enclosure Placement*

The ITS enclosure and its associated components must be included in the design process. Design criteria for a suitable ITS enclosure location include the following:

- The enclosure for the HAR controller should be mounted on the antenna pole.
- The enclosure for the beacon should be mounted on the sign structure.
- The enclosure should be oriented so that the maintainer is facing the road while performing maintenance at the cabinet location.
- The enclosure should be at a level where the maintainer does not need a stepladder to perform maintenance at the cabinet location.
- A level concrete pad should be provided at the front of the enclosure for the maintenance worker to stand on while accessing the enclosure.
- Where possible, there should be adequate and safe parking in the vicinity of the enclosure for a maintenance vehicle. Where this is not possible, locate the enclosure where it is accessible by on-foot maintenance personnel.
- See PA and manufacturer specifications to determine the maximum distance between the enclosure and the field device it services.

Use standard NEMA cabinets wherever possible. Specific equipment manufacturers may have different interior space requirements. In some cases, co-located ITS devices may share the same enclosure, which will further influence enclosure size requirements.

Design standards for the ITS enclosure can be found in PA ITS specifications.

11. Power

11.1 Power Considerations

Generally, these are the important steps to design the electric power system for an ITS device deployment:

- Determine the total power requirement.
- Select a suitable power source based on availability.
- Determine step-up/step-down transformer requirements, where applicable. The need for transformers will be based on voltage drop calculations.
- Determine meter options. Where possible, arrange a flat rate fee with the electric utility provider.
- Verify that electrical/electronic component locations are above flood elevation.

11.1.1. *Power Requirements*

The total power requirement for an ITS deployment is the sum of the power drawn by the following components:

- The device(s) (e.g. detectors, CCTV camera, RWIS, lane use control signs, DMS, etc.).
- The controller cabinet components (refer to ITS Enclosure specification in PA ITS Specifications – General Provisions for ITS).
- Convenience outlet inside the device cabinet.

Conductor and breaker sizes should be selected based on the "worst-case" scenario in which all connected electric components are operating at full capacity. Where two devices for ancillary services perform opposing services and are not expected to operate simultaneously (e.g. heater and air conditioner), only the device that draws more power is factored into the calculations. For the preliminary sizing calculation, the expected load drawn from the convenience outlet is assumed to be 12 amperes at 120 volts.

Conductor size should be selected to keep voltage drop over long lengths to 7.2 V or less (refer to Section 11.1.3 Voltage Drop).

See Table 11-1 for typical power requirements for commonly used ITS devices. Listed power loads are for estimation purposes only; actual power loads should be obtained from the related manufacturer(s) of the equipment being specified or provided.

Table 11-1: Typical Power Requirements (Device Only, No Enclosure)

Device Type	Power Requirement
CCTV	Typical
CCTV Camera	≈ 30 watts
CCTV Camera with heater	≈ 100 watts
DMS (18" Yellow LED characters)	Maximum / Typical
Three 15-character lines, 15-degree view	2800 / 500 watts
Three 15-character lines, 30-degree view	3600 / 700 watts
Three 18-character lines, 15-degree view	3100 / 500 watts
Three 18-character lines, 30-degree view	4400 / 700 watts
Three 21-character lines, 15-degree view	3700 / 600 watts
Three 21-character lines, 30-degree view	4800 / 800 watts
DMS (18" RGB LED characters) (Color)	Maximum / Typical
Three 15-character lines, 30-degree view	4300 / 650 watts
Three 18-character lines, 30-degree view	5200 / 900 watts
Three 21-character lines, 30-degree view	6200 / 1300 watts
HAR	Typical
HAR Transmitter Antenna	≈ 10 watts
HAR Beacon Signal Set (LED)	≈ 25 watts
Detector	Typical
Inductive Loop	≈ 5 watts
Magnetometer	≈ 3 watts
Microwave Radar	2-3 watts
Bluetooth	≈ 3 watts
TRANSMIT	Typical
TRANSMIT Station	≈ 150 watts

11.1.2. Power Availability

The standard electrical service of 240/120V AC, single phase, 60 Hz, 100 A is the most common service used for most ITS deployments. Occasionally, a higher voltage/ampere service is required when the point of service is located a significant distance from the ITS device. Along limited access facilities, it is often difficult to locate a device near a power source and still meet all operational requirements.

Emergency means to disconnect power must be available within convenient distance from the powered device. In most DMS installations, the power needed to operate the DMS board (display portion of the DMS) is fed from the related DMS controller cabinet, and a power disconnect switch is usually installed outside the DMS controller cabinet. An additional power disconnect switch at the base of the DMS board support structure will not be necessary for such cases.

Once power supply is made available in the ITS device enclosure, the electric power must be converted to the voltage and type (AC or DC) as appropriate for the electronic devices.

11.1.3. Voltage Drop

Special consideration should be taken to verify that voltage drop is within the specific tolerances of the electrical and electronic devices for the desired ITS system. Typical ITS industry standards are to limit the voltage drop to 3% or less.

At certain ITS deployment sites a long distance from the intended power source, voltage drop becomes an important consideration. Given a fixed distance between an ITS deployment site and related power source, a designer has to decide which method will be used to keep the related voltage drop within the design limits. The two most common methods are either to use larger power conductors or to transmit the electric power over the power cable at a higher voltage. Transmission at a higher voltage commonly involves using a step-up transformer near the power source and a step-down transformer at the related ITS deployment site. This choice is often dominated by cost considerations.

Power supply arrangements shall be coordinated with the utility having jurisdiction and shall be designed in accordance with the PA Electrical Design Guidelines.

11.1.4. Metering

Metering for power draw shall be provided at each ITS deployment site from a power-supply point. In locations that do not use Automatic Meter Reader (AMR) systems, safe and convenient meter reader access for utility personnel is an important consideration in selecting the deployment location. Roads with small or no shoulders should be avoided for meter location. One way to circumvent this limitation is to arrange for non-metered (flat-rate) electric service through the electric utility.

Some AMR systems use short range radio-frequency (RF) communication systems, which allow drive-by meter data collection using mobile RF units. Some AMR systems use cellular data service, which allows utility offices to poll the meters from greater distances.

Coordination with the power utility should be undertaken early in the design process to determine metering options. The following power metering options may be considered:

- Metered, with safe and convenient personnel access.
- Non-metered, flat usage rate.
- Metered with AMR, using a drive-by RF data reader.
- Metered with AMR, using a cellular data service.

11.2 Installation of Power Cable

Power cable(s) should be routed in ducts and junction boxes separate from those used for communications cables.

Junction boxes should be located such that the duct centerline is aligned with the centerline of the junction box to facilitate cable pulling. Junction boxes are typically installed at a maximum separation of 250 feet to avoid damaging the power cable from excessive pulling tension. Junction boxes should not be installed in roads, driveways providing access to properties, drainage ponds or bottoms of drainage ditches. The covers of the junction boxes should be labeled in accordance with the ITS Standard Drawings. All junction boxes should be grounded in accordance with the applicable codes and PA specifications.

In urban areas, junction boxes should be flush with sidewalks or surface level to avoid the potential for pedestrians tripping. Concrete aprons should be provided for all junction boxes not installed in a sidewalk. In addition, the concrete apron should be sloped away from the junction box to reduce water intrusion. Raceway fill ratios should be in accordance with the NEC.

11.3 Power Conditioning

Lightning spikes, transients and line noise will degrade electronic devices over time. Power conditioning provides protection from these conditions. It regulates against sags (brownouts) and surges, thus reducing premature failure, improving equipment performance and maintaining Uninterruptible operation of key equipment.

11.3.1. Voltage Surge Suppression

Lightning strikes are a common cause of power surges to the ITS field system. The resulting voltage surges can propagate long distances along the cable to the connected devices. To protect the related ITS deployment, appropriate surge protection measures must be provided for ITS devices. These measures include:

- Lightning rods at the top of or near the support structure.
- Grounding system, usually consisting of one or more ground rod electrodes.
- Surge suppression hardware in the control cabinet.
- Grounding conductor bonding the three above components.

The provision of lightning rods is preferred for deployments involving heights, such as CCTV cameras and radio antennas at the top of tall poles, or DMS boards on structures that “stand out” among the surrounding landscape and vegetation. The use of a lightning rod is usually omitted for deployments involving relatively low heights and where taller structures are present nearby.

In general, surge suppressors provide protection from energy (electric) surges by diverting and draining the excess (surge) energy to surrounding soil. It is therefore important to combine the use of surge suppressors with a properly designed grounding conductor and a grounding system.

The provision of one or more lightning rods over the ITS device, in conjunction with one or more grounding conductors, can often help to divert the lightning discharges away from the field device assembly. Lightning abatement measures such as this are only effective if the lightning rod, related terminations and the grounding conductors are sufficiently robust to conduct and to survive lightning discharges.

Lightning rods, grounding system and diversion hardware for lightning discharge energy should be provided at ITS installation sites.

Telecommunications cables and sensor cables from nearby locations are subject to the same possibility of lightning strikes. The requirement for appropriate surge protection measures must therefore be extended to all cables brought into the enclosures of all ITS deployments.

A proper grounding arrangement must be provided at the support structure and at the controller cabinet for the system. Where the controller cabinet is installed at or close to the base of the support structure, both the support structure and the cabinet may be bonded to the same grounding system.

It is important that the related grounding system is able to disperse the electric charge from the lightning strike quickly to the surrounding ground. This requirement is translated in the performance requirement on the grounding system to be in accordance with the NEC.

Where sensitive equipment is utilized in the ITS system that requires ground resistances lower than the NEC standard requirements, separate criteria should be detailed and shown on the contract drawings.

Grounding rod, systems and testing procedures are specified in PA Specifications Section 16450. The designer should assess the site environmental conditions to determine if the grounding system is sufficient for the device location. Some devices require more robust grounding requirements, such as HAR Transmitters or CCTV cameras located at the tops of hills and mounted to high structures.

11.3.2. Uninterruptible Power Supply (UPS)

Frequent shutdowns and restarts of electronic devices generally cause the electronic device to fail prematurely. Intermittent device shutdowns are generally triggered by low power-supply voltage, often the result of brief drops in supply voltage (brownouts) lasting seconds, and to a lesser degree complete power outages (blackouts) lasting more than a few minutes.

Brief power interruptions can result in ITS controller reboot requirements. This can render the device unavailable for several minutes upon a loss of power that lasts a fraction of a second. Although it may not be feasible to maintain a large DMS display under UPS power, the controller can be protected from brief outages that could result in loss of the effectiveness of the ITS resource for several minutes.

The provision of a UPS is part of the power-supply arrangement to help bridge periods of short and intermittent drops in power voltages. Most commercial UPS products also include other desired features such as power conditioning, which helps to filter out unwanted fluctuations in power quality and delivers “clean” power to the connected loads.

Reliable periodic maintenance is needed to replace batteries, which typically last between three and six years.

UPS providing fifteen minutes of power should be provided for all ITS field controllers and field communications hubs.

11.4 Solar Power

Solar power may be an option for some low-power ITS applications, depending on factors including:

- The amount of power the system needs
- The percentage of time that the system is operating (for example, beacons that only flash during certain infrequent events)
- The amount of time that the system must operate in the absence of sunlight
- The geographic location, which affects the amount of sunlight received

A solar power system is typically comprised of solar panels, a battery bank, cabling and a power converter/charging system that converts power generated from the solar panel to battery storage, and then furnishes this battery power to the connected operating loads. A solar power system may be used as a standalone power source or as a supplement to installations where the electric power from the utility company is only available during part of the day (such as a highway lighting circuit controlled by a daylight sensor or timer).

A solar power system may only be used in areas where sufficient sunlight is generally available, which is defined as at least three 8-hour sunlit periods per week in typical conditions. Related average insulation data can be acquired, using the latitude and longitude of the deployment site, from the NASA Surface Meteorology and Solar Energy (SSE) division through its web site at http://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?uid=1.

To receive the maximum amount of sunlight each day and throughout the year, solar panels must be oriented to face south. The inclination of the solar panel(s) should roughly correspond to the latitude of related deployment site. As an example, solar panels used near New York City (approximate latitude 40.7° N) should be mounted at approximately 40.7 degrees from the azimuth, facing south.

The battery bank and the solar panel assembly of a solar power system must be of sufficient sizes to support full operation of the connected loads for a minimum of 24 hours for applications where daily maintenance service is performed, and for a minimum of seven days for other conditions. For solar power systems installed as a supplement to utility company electric power, the solar power system components must support full operation for only the portion of the day that power is not available from the utility company, for one day where daily maintenance service is performed and for a minimum of seven days for other conditions.

Due to these sizing requirements, the use of a solar power system is generally limited to devices requiring 100 watts or less to operate. Devices requiring higher wattage for only brief periods may also be considered. In all cases, credible solar panel and battery sizing calculations must be obtained from the system provider for all related loads, at all expected usage patterns, prior to acceptance of the related design.

The following devices may be candidates for solar power:

- HAR beacons
- HAR transmitters
- Detectors
- Portable devices (HAR, Detectors, DMS)
- CCTV cameras (typically portable) that do not include a heater

Typical battery voltage used in ITS deployments is 12 volts per unit; if higher voltages are needed, the simplest way to achieve it is by connecting batteries in series. Where feasible, the main operating voltage of the device enclosure should be a whole multiple of 12 volts (e.g. 12V, 24V, 36V, 48V, etc.). In all cases, credible solar panel and battery sizing calculations must be obtained from the system provider for all related loads, at all expected usage patterns, prior to acceptance of the related design.

Energy delivery performance of the batteries diminishes at extreme high and low temperatures and as a result of rapid temperature swings. Explicit mechanical measures must be provided to isolate the batteries from extreme ambient temperatures.

Note that solar power should only be used as a last resort, where power points of service are extremely expensive, where there is no power available or as a backup to another power source. Explicit approval must be obtained from the PA prior to proceeding with a solar power system design. Detailed calculations must be performed to determine the required load of the device and the appropriate number of batteries.

11.5 Optional Back-Up Power Generator

The designer should consider adding a provision for an ITS deployment to include the means of accepting power from a mobile generator as an alternate, temporary power source. This provision usually includes the following:

- A twist-lock power receptacle behind a lockable window to accept the power cord from this alternate power source.
- A selector switch behind the lockable window that allows the choice between regular and alternate power sources.
- A notch at the lower edge of the lockable window to allow passage of the extension cord with the window closed and locked.

11.6 Utility Billing

In the majority of ITS construction projects, the utilities are set up in the contractor's name, since the ownership of the device/system resides with the contractor until the project is complete. Once the 90-Day Burn-in Test has been conducted and accepted, ownership and billing will be transferred from the contractor to the PA.

These utility subscription accounts must be transferred officially and properly to PA when the period for which the contractor is responsible expires. Such transfers may require official endorsement by the existing account holder, and therefore cannot be arranged by PA even if such an arrangement may be more expedient. The contractor must submit documented proof of official transfers (to PA) of subscription to power, communications and other utility services as a payment condition for the related contract phase.

12. Communications

A telecommunications connection is typically required between the facility designated Facility TMC/OCC/Comm Desk and the ITS components.

All center-to-field (C2F) communications associated with the ITS system should be designed to maximize interoperability. The designer should require conformance with the AASHTO/ITE/NEMA National Transportation Communications for ITS Protocol (NTCIP), when applicable. The use of proprietary communication protocols is not permitted unless NTCIP is not available for that type of ITS device. In addition, all communications should conform with the *Standards and Guidelines for Port Authority Technology*, produced by the Technology Services Department.

Remote ITS field devices may use wireless connections to the nearest location containing a wireline drop point. The capacity and security of the designed wireless solution should be of the same quality as a similar wired connection.

In order to maintain standards, uniformity and maintainability, the PA Technology Services Department (TSD) will provide standard workstations, routers and switches that are compatible with their existing network and can be maintained by PA.

12.1 Communications Design Considerations

Generally, these are the key design considerations for a C2F communication system for an ITS deployment:

- Determine the required communication characteristics, mainly the required bandwidth (in Kbps or Mbps).
- Investigate what telecommunication options are available at/near the planned deployment site(s).
- Coordinate with the PA Line Department and TSD to ensure that their requirements are being met.
- If using public infrastructure, confirm with telecommunication service providers that the required communication service is available at the deployment location.
- Compare the related costs, benefits, security aspects of different communication options. Select a suitable communication means based on the options available at the deployment site.
- Incorporate the chosen communication means into the overall design.
- Communications routed through the public internet are acceptable only on a case-by-case basis. Any connection using public internet must be accepted by the PA for security reasons.
- Verify that communication systems and critical electronic components are located above flood elevation.

12.2 Device / System Characteristics and Requirements

Each ITS system brings with it particular communication needs. The communication pattern and bandwidth requirement are the two principal factors in evaluating what the system or device needs to operate effectively.

Table 12-1 contains the typical bandwidth requirements for various ITS devices. These requirements must be accommodated by the selected communication medium.

Table 12-1: Typical ITS Communications Requirements

System Type	Typical Usage Pattern	Required Bandwidth Range
CCTV Camera	Continuous	386 Kbps to 1.544 Mbps
DMS	Periodic, intermittent, short bursts	9.6 Kbps to 56 Kbps
Vehicle Detector	Intermittent, short bursts	9.6 Kbps to 115 Kbps

With the exception of CCTV cameras, a typical communication session between an ITS device controller and the Facility TMC/OCC/Comm Desk usually involves a small amount of data. Such communication sessions may take place only when specific needs arise or may be scheduled on a periodic basis, typically every ten minutes or longer. A communication session with a small amount of transmission content and with an intermittent usage pattern can usually be supported by low-bandwidth communications with a bandwidth of 9.6 Kbps to 56 Kbps, such as that afforded with voice-grade dial-up telephone service. Due to the long pauses between communication sessions, the communication connection does not need to be engaged all the time (always on); a "dial-up" arrangement may suffice.

CCTV cameras, unless strictly used to transmit still images, require an always-on, continuous communication session. The continuous transmission of the video image and transmission of pan/tilt/zoom commands back to the camera requires a relatively large communication bandwidth. A full T-1 (1.544 Mbps) service is typically used for video transmission to the Facility TMC/OCC/Comm Desk, though lower bandwidths (such as fractional T1) could be used for video streams with low frame rate (frames-per-second) or low resolution.

12.2.1. *TRANSMIT*

Most of the data and sensor reading collected from the ITS field devices are collected from a server at a PA facility, such as the Facility TMC/OCC/Comm Desk. However, the data collected by the TRANSMIT field equipment go directly to TRANSCOM's servers, located at TRANSCOM in Jersey City, NJ, where the TRANSMIT reader data is processed into travel times. TRANSCOM then sends processed data to PA Communications at a Facility TMC/OCC/Comm Desk for use by facility personnel and as traveler information.

12.2.2. *TRAFFIC SIGNALS*

The PA has a traffic signal management system, used to operate, control and maintain all of the PA's traffic signals. All traffic signals should be integrated into this traffic signal management system, currently the Siemens TACTICS. See the PA's Design Guidelines - Traffic for more information about adding any new traffic signals, and any attached vehicle detectors to the traffic signal management system.

12.3 Availability

Potential C2F communication arrangements appropriate for ITS systems:

- Fiber optic cable. Owned or leased.
- **Telephone service.** Dial-up, voice-grade, land-line telephone service.
- **Leased land-line.** Telephone cable with Frame-relay service at fractional T-1 or full T-1 capacity.
- **Broadband radio.** Data radio system involving WiMAX, Long Term Evolution (LTE) or proprietary Radio-Frequency (RF) technologies of comparable performances.
- **Broadband cellular.** Machine-to-Machine (M2M) data service involving 4G/LTE technologies.
- **Satellite internet.** Data service through commercial service provider.

Availability of a service is limited by both the availability of existing infrastructure to extend to the deployment sites and a usable transmission session when the need for data transmission arises. Commercial communication services that are "shared use" in nature can be affected by usage surges, which often occur during and near places of major events and incidents. In a shared-use arrangement, a potentially large number of users may be sharing a fixed data bandwidth, so a minimum bandwidth cannot be guaranteed unless special priority arrangements are made. It is advisable to obtain data service with guaranteed performance (bandwidth and quality of service), where offered by the service provider, for high-bandwidth data streams such as those related to video transmission.

Table 12-2: ITS Communications Capacity

Communications Method	Typical Available Bandwidth
Fiber Optic Cable	Up to 40 Gbps per carrier light wavelength
Telephone Service	54 Kbps
Leased Land-line	Fractional (¼ or ½) T-1, full T-1, T-3
Broadband Radio	Up to 100 Mbps, depending on technology used
Broadband Cellular	Up to 4 Mbps, depending on service plan
Satellite Internet	Up to 5 Mbps, depending on service plan

Every potential communication option presents unique capabilities, risks and limitations. This chapter summarizes the major design considerations and the advantages and disadvantages of each option.

Unless otherwise specifically stated, single-mode fiber optic cable should be used for all communications infrastructure. Cellular data services may be used for portable ITS deployments and some stationary DMS installations.

Table 12-3 provides an overview of communications options, including design considerations and advantages and disadvantages of each relevant option.

Table 12-3: Communications Options

Communications Option	Design Considerations	Advantages	Disadvantages
Fiber Optic Cable	Verify that the cable installation through the intended route is feasible, and does not require extreme challenges.	Virtually unlimited bandwidth.	Potential difficulties in achieving clear Right-of-Way for installation.
		No danger of voltage surges.	High installation cost of cable.
Telephone Service	Verify that the cable installation through the intended route is feasible, and does not require extreme challenges.	Very widely used and understood in ITS deployments.	Limited to low bandwidth (54 Kbps maximum) applications.
			Extension of utility infrastructure (e.g. poles) can be expensive.
		Generally inexpensive.	Usage surges may affect service and availability.
		Widely available.	Does not provide "always on" capability. Connection initiation can be time consuming.
Leased Land-Lines	Supports bandwidths of up to T-1 over distances of up to 1 mile without the use of repeaters.	Lower initial investment.	Recurring usage fees.
	Per the latest tariffs, this type of connection is limited to T-1 service only. PA has agreements with Verizon for certain locations to provide continuous leased T-1 connections at costs that are similar to local dial-up service.		Reliance on service provider for repair services.
	Abatement measures against voltage surges are necessary.		Voltage surges can propagate from a third-party system.
Broadband Radio Service	Except for short-range paths that can be visually evaluated, a path study, performed by a communications consultant or a system integrator, is recommended for new installations. A path study predicts the signal strength, reliability and fade margin of a proposed radio link. While terrain, elevation and distance are the major factors in this process, a path study must also consider antenna gain, feed line loss, transmitter power and receiver sensitivity to arrive at a final prediction.	High bandwidth, (up to 100 Mbps per channel for short range, or up to 70 Mbps at 50 km). Point-to-point, multi-point or repeater configurations possible, depending on technology used.	A clear transmission path is not always possible.
	Abatement measures against lightning strikes are necessary for outdoor installations.	Low infrastructure costs.	Requires an RF license application/acquisition, unless license-exempt RF bands are used.
	The manufacturer-specified maximum data bandwidth and maximum transmission distance can each be achieved separately, but not simultaneously.		Periodic tree trimming may be required to maintain clear line-of-sight.
Broadband Cellular Data Service	Adequate cellular signal strength must be verified at the planned deployment site. This may simply involve using a portable computer, equipped with a compatible wireless adapter module and antenna, to measure signal strength and confirm upload bandwidth.	Allows flexibility in the planning of device deployment sites.	Availability of data channels is low in/near densely populated areas.
		Available along a majority of regional freeways and expressways.	Where data transmission is routed through the public domain, significant security measures are required.
	The availability of Machine-to-Machine (M2M) service with guaranteed bandwidth must be confirmed in the related deployment area.	Antenna does not have to be very high.	
		Low setup and infrastructure costs.	Recurring costs incurred.
		Where available, M2M service provides guaranteed high (up to 4 Mbps) bandwidth.	

12.4 Communications Interface

An interface is a shared boundary across which information is passed. It is the hardware or software component that connects two or more other components for passing information from one to another.

This section discusses the logical (communications) interface between a TMC/OCC/Comm Desk and the roadside devices that the TMC/OCC/Comm Desk controls or monitors.

12.4.1. Use of Open Communications Standards

Where available, communication protocols should use open data communication standards such as NTCIP. Proprietary or closed standards should only be considered where open standards are not available. The benefits of adopting open standards include:

- **Interoperability.** Interoperability in this context is the ability of the Facility TMC/OCC/Comm Desk to exchange information with different devices for some common purpose. Interoperability allows system components from different vendors to communicate with each other to provide system functions and to work together as a whole system. Interoperability is desirable because it helps to reduce the total costs of a system (procurement, operations and maintenance) over its lifespan.
  - Open standards support interoperability and allow PA the choice of several vendors when considering products for an ITS system. This decreases implementation and maintenance costs because vendors compete to provide and maintain the field devices. Operational costs may also decrease because the Facility TMC/OCC/Comm Desk needs to support only one communications protocol.
  - Because different ITS deployments require different components, it is necessary to communicate with field devices procured from different vendors. If a closed proprietary communications interface is used, future ITS deployments or upgrades will require either using the same vendors as currently deployed components or PA upgrading the Facility TMC/OCC/Comm Desk software to support a different vendor's components. Either of these options is likely to add cost compared with the use of open standards. Open standards allow new devices to be added from different vendors with a shared communications protocol, facilitating competition between vendors for providing and maintaining ITS devices and avoiding the need to upgrade Facility TMC/OCC/Comm Desk software.
- **Avoiding Early Obsolescence.** By adopting an open standard that is widely used, PA ITS devices will remain compatible with the rest of the ITS infrastructure throughout their lifespan, including compatibility with new and upgraded devices. With closed proprietary communications protocols, maintenance support and options for extending the life of existing equipment are limited to only those vendors who are familiar with the protocol, which becomes more expensive as protocols become outdated or as vendors either go out of business or stop supporting the protocols. In a worst-case scenario, using a closed protocol can result in no support being available to maintain the existing system, requiring the expense of purchasing and installing a new system when components begin to fail or when new components are to be added or upgraded.

12.4.1.1. NTCIP

NTCIP is an example of a family of open standards used for remotely controlling and monitoring roadside equipment from a TMC/OCC/Comm Desk. NTCIP defines open, consensus-based communications protocols and data definitions for the traffic management industry. NTCIP allows a Facility TMC/OCC/Comm Desk to communicate with a variety of field devices on the same communications channel. This may provide significant cost savings on a project because the communications network is usually the most expensive component of a transportation management system.

The NTCIP Framework, shown in Figure 12-1, uses a layered or modular approach to communications standards, similar to the layering approach adopted by the Internet and International Organization for Standardization (ISO). The NTCIP family identifies five layers, or "levels", for defining the communications interface between the Facility TMC/OCC/Comm Desk and the field device: Information, Application, Transport, Subnetwork and Plant.

For more information about using NTCIP and the NTCIP Framework, the NTCIP Guide is available at www.ntcip.org.

When using NTCIP, the designer should specify which NTCIP standard(s) to use for each level. Multiple profiles may be selected for an implementation. For example, at the subnetwork level, communication is currently PMPP (point to multi-point protocol), but Ethernet is expected to be used in the future. Thus, both standards should be specified (NTCIP 2101 for PMPP and NTCIP 2104 for Ethernet).

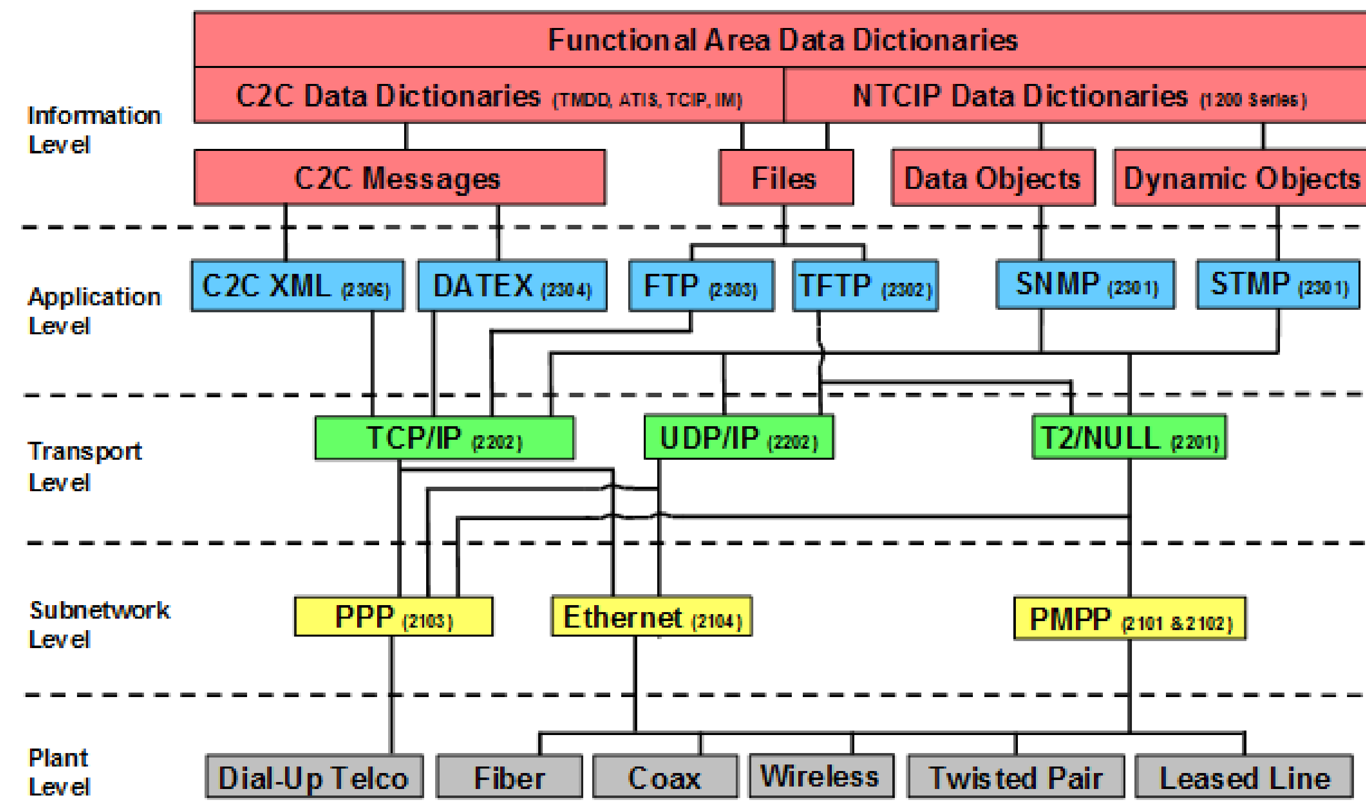

Figure 12-1: NTCIP Framework

- **Information Level.** The NTCIP Information Level defines the data to be used for exchanging information between the Facility TMC/OCC/Comm Desk and the field devices. It also defines the functions the system is to support.
- **Application Level.** The application level standards define the rules and procedures for exchanging information data. The NTCIP 2300 series defines the application profiles that can be used. NTCIP 2302, Trivial File Transfer Protocol – Application Profile and NTCIP 2303, File Transfer Protocol – Application Profile, which are primarily used to transfer files, may also be applicable.
- **Transport Level.** The transport level standards define the rules and procedures for exchanging the application data between two points on a network, including any necessary routing and network management functions. The NTCIP 2200 series defines the protocol stacks that can be used in managing the communications network. At least one of the following transport profiles should be included in the specifications if deploying NTCIP:

- NTCIP 2201, Transportation Transport Profile, which defines the mechanism for exchanging information data when the devices are directly connected to the Facility TMC/OCC/Comm Desk and do not require network services; or
  - NTCIP 2202, Internet (TCIP/IP and UDP/IP) Transport Profile, which defines the mechanism for exchanging information data over a network using the Internet suite of protocols.
- **Subnetwork Level.** The subnetwork level standards define the rules and procedures for sharing the same communications line with other devices using the same subnetwork profile. At least one subnetwork profile should be included in the specifications if deploying NTCIP. The current applicable NTCIP subnetwork profiles are:
  - NTCIP 2101, Point to Multi-Point Protocol Using RS-232 Subnetwork Profile, which defines how to communicate over a multi-drop serial communications link;
  - NTCIP 2103, Point-to-Point Protocol over RS-232 Subnetwork Profile, which defines how to communicate over a dial-up link or a point-to-point serial communications link; and
  - NTCIP 2104, Ethernet Subnetwork Profile, which defines how data is transferred over ethernet links.
- **Plant Level.** The plant level is shown in the NTCIP Framework only as a means of providing a point of reference to visualize the standards profile when learning about NTCIP.

12.4.1.2. Other Communications Interface

If an open, standards-based communications interface is not specified for a roadside system, then it is important that the communications interface used and provided by the vendor be thoroughly documented and the documentation made fully available to PA. The proper documentation and licenses are necessary to provide PA with the ability to operate, maintain, expand and upgrade the roadside system. For example, it allows PA to procure a systems integrator to develop a common hardware and software platform from which PA can manage all of its transportation resources and assets, such as from a Facility TMC/OCC/Comm Desk. Without the proper documentation and licenses, a systems integration effort would be more costly and difficult.

All of the following conditions should be satisfied if a closed (non-standards based) communications interface is provided for an ITS deployment:

- The vendor will provide a perpetual, non-exclusive, irrevocable license, at no additional cost, to PA to use for its communications interface. The license allows PA (or its employees, agents or contractors) to reproduce, maintain and modify the communications interface without restriction for PA's use and benefit and to use the communications interface on multiple processors with no additional licensing fee. The communications interface is defined to include all data elements and objects that are exchanged between the Facility TMC/OCC/Comm Desk and the field devices to perform all of the functions described in the specification.
- The vendor will provide PA with all documentation, including the source and object codes, for the communications interface. The documentation consists of the source code for the communications interface and all operator and user manuals, training materials, guides, listings, design documents, specifications, flow charts, data flow diagrams, commentary and other materials and documents that explain the performance, function or operation of the communications interface. The documentation includes a description of the data elements and objects required to perform each function required in the specification, including the conditions and the sequence of events by which the data elements and objects are exchanged between the Facility TMC/OCC/Comm Desk and the device. The software documentation will define the data elements and objects in the form of a management information base (MIB), using Abstract Syntax Notation One (ASN.1).
- Upon providing PA with the communications interface documentation, the vendor will provide and perform test procedures that will demonstrate to PA that the documentation provided is accurate and correct. The test procedures will demonstrate that as each function required in the specifications is performed, the proper sequence of events, conditions and exchange of data elements and objects occur as written in the provided documentation. If, during the performance of the test, additional details (or corrections) in the documentation are demonstrated to be needed, the vendor will update the documentation and resubmit the documentation to PA.

12.5 Functional Description of Communications Protocol

12.5.1. Communications Interface for CCTV Cameras

The communications interface between the CCTV camera system and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Configure the CCTV Camera System.** This feature allows an operator to determine the identity of the field device and its capabilities. This feature also allows an operator to configure the presets, pan/tilt/zoom limits, home position, step sizes (for pan/tilt) and timeout parameters.
- **Control the CCTV Camera System.** This feature allows an operator to control the pan/tilt unit, lens and camera. It allows an operator to control the zoom, command the camera to preset positions, activate camera features (e.g., wipers, washers, blower, auto iris, auto focus), set and clear alarms and alarm thresholds, and set camera zones and labels.
- **Monitor the CCTV Camera System Status**. This feature allows an operator to monitor the overall status of the field device, the status of each sensor, the output states and the status of each zone. This feature also allows an operator to determine presets, the position of pan/tilt unit, the status of features supported by the camera (wipers, washers, blower, auto iris, auto focus) and monitor alarms.

The communications protocol should support all features provided for this device.

12.5.1.1. NTCIP for CCTV Cameras

The following NTCIP Information Level standards are applicable:

- NTCIP 1205, Object Definitions for Closed Circuit Television (CCTV) Camera Control, is a data dictionary standard used to support the functions related to controlling and monitoring the status of cameras, lenses and pan/tilt units within a transportation environment. This standard defines data elements specific to a CCTV camera control subsystem, which consists of an assembly of a camera, lens and pan/tilt functions.
- NTCIP 1201, Global Object Definitions, is a data dictionary standard to support functions that may be needed by multiple device types. Such functions include device identification and addresses, time management, time schedulers, event logging and database management.

12.5.2. Communications Interface for Dynamic Message Signs

The communications interface between the dynamic message sign systems and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Configure the Dynamic Message Sign.** This feature allows an operator to determine the identity of the Dynamic Message Sign, determine its capability, manage fonts, manage graphics and manage brightness.
- **Control the Dynamic Message Sign.** This feature allows an operator to control the message, control the brightness output, control external devices connected to the Dynamic Message Sign, reset the Dynamic Message

Sign and perform preventative maintenance. This feature also allows a Dynamic Message Sign to be controlled from more than one location.

- **Monitor the Status of the Dynamic Message Sign.** This feature allows an operator to monitor the current message and perform diagnostics.
- **Upload Event Logs.** This feature allows an operator to upload any event logs maintained by the Dynamic Message Sign.

The communications protocol should support all features provided for the Dynamic Message Sign system.

12.5.2.1. NTCIP for Dynamic Message Signs

The following NTCIP Information Level standards are applicable:

- NTCIP 1203, Object Definitions for Dynamic Message Signs, is a data dictionary standard used to support the functions of DMS systems within a transportation environment. This standard defines data elements that allow for the display of messages and the configuration of DMS. The standard also defines data elements to support fonts, graphics, and message text so that the DMS may accurately render message on the sign face based on these data elements.
- NTCIP 1201, Global Object Definitions, is a data dictionary standard to support functions that may be needed by multiple device types, including device identification and addresses, time management, time schedulers, event logging and database management.

12.5.3. Communications Interface for Lane Use Control Signals

The communications interface between the lane use control sign systems and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Configure the Lane Use Control Signal.** This feature allows an operator to determine the identity of the LUCS, determine its capability and set its default values.
- **Control the Lane Use Control Signal.** This feature allows an operator to control the signal face of the LUCS, control external devices connected to the LUCS system, reset the LUCS system and perform preventative maintenance.
- **Monitor the Status of the Lane Use Control Signal.** This feature allows an operator to monitor the status of each signal and perform diagnostics.
- **Upload Event Logs.** This feature allows an operator to upload any event logs that are maintained by the LUCS system.

The communications protocol should support all features provided for the LUCS system.

12.5.3.1. NTCIP for Lane Use Control Signals

The following NTCIP Information Level standards are applicable.

- NTCIP 1203, Object Definitions for Dynamic Message Signs, is a data dictionary standard used to support the functions of Dynamic Message Sign system within a transportation environment. This standard defines data elements that allow for the display of messages and the configuration of DMS. The standard addresses Lane Use Control Signals by defining each signal as a DMS. Each possible indication (e.g. green arrow, red cross, etc.) is defined as a message.
- NTCIP 1201, Global Object Definitions, is a data dictionary standard to support functions that may be needed by multiple device types, including device identification and addresses, time management, time schedulers, event logging and database management.

12.5.4. Communications Interface for Traffic Detection and Monitoring

The communications interface between the traffic detection and monitoring (field) devices and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Configure the traffic detection and monitoring devices.** This feature allows an operator to determine the identity of the field device and its capabilities, and to configure the sensor zones and outputs.
- **Control the traffic detection and monitoring devices.** This feature allows an operator to reset the field devices, initiate diagnostics and manage the camera zones for video detection devices.
- **Monitor field device status and report equipment malfunctions.** This feature allows an operator to monitor the overall status of the field device, the status of each sensor, the output states and the status of each zone.
- **Upload event logs.** This feature allows an operator to upload any event logs that are maintained by the field devices.
- **Collect data from the field devices.** This feature allows an operator to retrieve the data from the in-progress sample period (started but not yet completed), the most recent completed sample period and historical sample periods.

The communications protocol should support all features provided for these devices.

12.5.4.1. NTCIP for Traffic Detection and Monitoring

The following NTCIP Information Level standards are applicable:

- NTCIP 1206, Object Definitions for Data Collection, is a data dictionary standard used to support the functions related to data collection and monitoring devices within a transportation environment. This standard defines data elements specific to transportation data collection sensors, supporting the collection of information about each vehicle, such as number of axles, vehicle dimensions (such as length, width and height), vehicle weight and axle weight. Other information that may be collected includes vehicle headways, vehicle speeds and vehicle acceleration.
- NTCIP 1209, Object Definitions for Transportation Sensor Systems, is a data dictionary standard used to support the functions related to transportation system sensors within a transportation environment. This standard defines data elements specific to transportation systems sensors, supporting the collection of traffic volumes, percentage occupancy and the average speed of traffic over the defined sensor zone.
- NTCIP 1201, Global Object Definitions, is a data dictionary standard to support functions that may be needed by multiple device types, such as device identification and addresses, time management, time schedulers, event logging and database management.

12.5.5. Communications Interface for TRANSMIT

The communications interface between the TRANSMIT field devices and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Monitor field device status and report equipment malfunctions.** This feature allows an operator to monitor the overall status of the field device, the status of each sensor, the output states and the status of each zone.
- **Upload event logs.** This feature allows an operator to upload any event logs maintained by the field devices.
- **Collect data from the field devices.** This feature allows an operator to retrieve the data from the in-progress sample period (started but not yet completed), the most recent completed sample period and historical sample periods.

12.5.6. Communications Interface for Over-height Detection Systems

The communications interface between the enforcement systems and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Configure the Over-height System Field Devices.** This feature allows an operator to determine the identity of each enforcement system device and configure the sensors.
- **Control the Over-height Detection System Field Devices.** This feature allows an operator to reset a field device and initiate diagnostics.
- **Monitor the Over-height Detection System Field Device Status.** This feature allows an operator to monitor the overall status of the field device and the status of each sensor.
- **Upload Event Logs.** This feature allows an operator to upload any event logs that are maintained by the enforcement system field devices.
- **Collect Data from the Field Devices.** This feature allows an operator to retrieve the data collected by the enforcement system field devices.

The communications protocol should support all features provided for the enforcement system.

12.5.7. Communications Interface for Overweight Detection

The communications interface between the enforcement systems and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Configure the Overweight Detection System Field Devices.** This feature allows an operator to determine the identity of each enforcement system device and configure the sensors.
- **Control the Overweight Detection System Field Devices.** This feature allows an operator to reset a field device and initiate diagnostics.
- **Monitor the Overweight Detection System Field Device Status.** This feature allows an operator to monitor the overall status of the field device and the status of each sensor.
- **Upload Event Logs.** This feature allows an operator to upload any event logs maintained by the enforcement system field devices.
- **Collect Data from the Field Devices.** This feature allows an operator to retrieve the data collected by the enforcement system field devices.

The communications protocol should support all the features desired for the enforcement system.

12.5.7.1. NTCIP for Enforcement Systems

The following NTCIP Information Level standards are applicable:

- NTCIP 1206, Object Definitions for Data Collection, is a data dictionary standard used to support the functions related to data collection and monitoring devices within a transportation environment. This standard defines data elements specific to transportation data collection sensors, supporting the collection of information about each vehicle, such as number of axles, vehicle dimensions (such as length, width and height), vehicle weight and axle weight. Other information that may be collected includes vehicle headways, vehicle speeds and vehicle acceleration.
- NTCIP 1201, Global Object Definitions, is a data dictionary standard to support functions that may be needed by multiple device types, including device identification and addresses, time management, time schedulers, event logging and database management.

12.5.8. Communications Interface for RWIS

The communications interface between the road weather information system (RWIS) sensors and the Facility TMC/OCC/Comm Desk is needed to facilitate the following functions:

- **Monitor RWIS Equipment Status.** This feature allows an operator to determine if any doors on the RWIS equipment are open, to monitor the electrical power for the RWIS equipment to ensure proper operation and to monitor the movements of a mobile RWIS station.
- **Monitor Weather Conditions.** This feature allows an operator to monitor the weather conditions that can directly or indirectly affect the transportation system, including wind conditions, temperature, humidity, precipitation and visibility. This feature also allows an operator to visually inspect and verify reported weather conditions through images collected at the RWIS equipment location.
- **Monitor Pavement Conditions.** This feature allows an operator to monitor the road conditions and conditions below the road surface that may adversely affect transportation operations, including pavement surface temperature, moisture conditions and surface friction.
- **Monitor Water Level.** This feature allows an operator to monitor the depth of water at one or more locations, such as over a road or in a stream.
- **Monitor Air Quality.** This feature allows an operator to monitor the current air quality in the vicinity of the RWIS equipment and determine whether there are airborne pollutants or biohazards.
- **Upload Event Logs.** This feature allows an operator to upload any event logs that are maintained by the RWIS equipment.

The communications protocol should support all features provided for RWIS equipment.

12.5.8.1. NTCIP for RWIS

The following NTCIP Information Level standards are applicable:

- NTCIP 1204, Environmental Sensor Station Interface Standard, is a data dictionary standard used to support the functions related to monitoring and collecting environmental sensor data, including weather data, pavement condition data, water level data and air quality data. This standard defines data elements specific to environmental sensors, which include sensors that monitor weather, road surface, water level and air quality conditions. These sensors are typically connected to a nearby RPU. An environmental sensor station (ESS), in the context of this standard, consists of an RPU plus the suite of sensors connected to it. Typically, the ESS is at a fixed location along the road, but ESS may be portable or even mobile.
- NTCIP 1201, Global Object Definitions, is a data dictionary standard to support functions that may be needed by multiple device types. Such functions include device identification and addresses, time management, time schedulers, event logging and database management.

13. Appendix A – Design Checklists

13.1 CCTV Design Checklist

Pre-Stage I			
Pre-Design Planning	**YES**	**NO**	**Notes**
Is this deployment consistent with the needs outlined in a Concept of Operations?	☐	☐	
Is this deployment consistent with the regional ITS architecture?	☐	☐	
Stage I			
As-builts	**YES**	**NO**	**Notes**
For existing ITS equipment, has as-built information been identified and reviewed?	☐	☐	
Location/Placement Guidelines	**YES**	**NO**	**Notes**
Has the camera location been chosen / designed with consideration to maximizing field of view?	☐	☐	
Has a site for the camera been chosen that considers the available utilities and the cost/constraints associated with connection to those utilities?	☐	☐	
Has the site been chosen with consideration to protecting the camera structure and ensuring that it will last without undue maintenance necessary to the structure and the surrounding site?	☐	☐	
Has a site been chosen that makes the best use of the operational needs of a CCTV camera subsystem (e.g. Incident Management)?	☐	☐	
Has a site been chosen that satisfies safety requirements for personnel performing maintenance on the subsystem?	☐	☐	
Has the site been chosen so that it will minimize maintenance costs (e.g., there is sufficient shoulder to park a bucket truck without the need for a full lane closure and significant traffic control activities)?	☐	☐	
Is all the equipment within the Port Authority's Right of way? If no, has the Project Manager been informed? If yes, has an MOU, MOA, or other agreement been initiated / is in place to allow for construction and maintenance of the subsystem equipment?	☐	☐	
Are critical electronic components above the flood level? If not, explain why it is not feasible.	☐	☐	
CCTV Type	**YES**	**NO**	**Notes**

Is the camera type (barrel vs. dome, pan & tilt vs. fixed) appropriate for the desired location and application?	☐	☐	
Do the devices/subsystems require any additional software integration, and if so have the requirements been identified?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage I comments been addressed?	☐	☐	
Stage II (If Project Manager determined that Stage II is not being performed, obtain direction from Project Engineer on which Stage II checklist items are to be completed under Stage I. The rest of Stage II checklist items shall be completed under Stage III.)			
Camera Mount	**YES**	**NO**	**Notes**
Have PA standards been followed in the design of the mount / structure?	☐	☐	
Is a camera lowering system needed?	☐	☐	
Control Cabinet Enclosure	**YES**	**NO**	**Notes**
Is an enclosure required at this location?	☐	☐	
Are there special requirements for the enclosure dictated by the location, e.g. tunnel or bridge?	☐	☐	
Can the maintainer safely park a vehicle and safely access the enclosure?	☐	☐	
Is the enclosure located within 150 feet of the camera?	☐	☐	
Is the enclosure mounted on the camera pole or on an existing structure (where possible)?	☐	☐	
Does the location and orientation provide adequate protection for the enclosure? (I.E.-Protection from site environment, traffic, pedestrian, mischief, etc.)	☐	☐	
Has a maintainer's pad been provided at the enclosure's main door?	☐	☐	
Power Requirements	**YES**	**NO**	**Notes**
Have the power requirements for the camera and all of the subsystem components been determined?	☐	☐	
Power Availability	**YES**	**NO**	**Notes**
Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the camera site?	☐	☐	

Have Step-Up/Step-Down requirement calculations been performed?	☐	☐	
Have the metering options been determined?	☐	☐	
Power Conditioning	**YES**	**NO**	**Notes**
Do the standard grounding specifications meet the needs of the subsystem?	☐	☐	
Have the UPS and power back-up options been determined and accounted for?	☐	☐	
Communications	**YES**	**NO**	**Notes**
Have the communication requirements for the camera been determined?	☐	☐	
Has an appropriate communications infrastructure been located and confirmed within a reasonable proximity to the site?	☐	☐	
If there are multiple communications options, have the pros/cons been studied?	☐	☐	
If using public communications infrastructure, has service been coordinated with the PA?	☐	☐	
Environmental	**YES**	**NO**	**Notes**
Have all the necessary environmental, community, and cultural impact studies, processes and concerns been addressed?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has a list of all sole source items been developed?	☐	☐	
Technology Services Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Services Department (TSD) reviewed and provided comments on the proposed communications, network integration, and software integration for the proposed equipment?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage II comments been addressed?	☐	☐	

13.2 DMS Design Checklist

Pre-Stage I			
Pre-Design Planning	**YES**	**NO**	**Notes**
Is this deployment consistent with the needs outlined in a Concept of Operations?	☐	☐	
Is this deployment consistent with the regional ITS architecture?	☐	☐	
Stage I			
As-builts	**YES**	**NO**	**Notes**
For existing ITS equipment, has as-built information been identified and reviewed?	☐	☐	
Longitudinal Placement	**YES**	**NO**	**Notes**
Is the DMS visible and unobscured?	☐	☐	
Is the DMS placed sufficiently in advance of a decision point that could be used as an alternate route?	☐	☐	
Is the DMS properly spaced away from existing guide signs?	☐	☐	
Lateral Placement	**YES**	**NO**	**Notes**
Is the DMS structure located beyond the clear zone or protected by a suitable safety barrier?	☐	☐	
Has the lateral offset of the DMS been accounted-for when calculating the length of the Reading and Decision Zone?	☐	☐	
Is all the equipment within the Port Authority's Right of way? If no, has the Project Manager been informed? If yes, has an MOU, MOA, or other agreement been initiated / is in place to allow for construction and maintenance of the subsystem equipment?	☐	☐	
Are critical electronic components above the flood level? If not, explain why it is not feasible.	☐	☐	
Vertical Placement	**YES**	**NO**	**Notes**
Is the approaching segment of road relatively flat (between 0-4% vertical grade)?	☐	☐	
Is there sufficient vertical clearance for the sign and the structure?	☐	☐	
Sign Matrix Type	**YES**	**NO**	**Notes**

Has a sign matrix size and type been chosen that is consistent with the visibility and message requirements of the road?	☐	☐	
Is the sign matrix type suitable for displaying graphic images, if there's a stated need for it?	☐	☐	
Sign Viewing Angle	**YES**	**NO**	**Notes**
Has a sign viewing angle been chosen that complements the road alignment and the DMS structure?	☐	☐	
Sign Access	**YES**	**NO**	**Notes**
Are there any traffic, environmental, or safety factors that warrant a specific type of sign access (front, rear, walk-in)?	☐	☐	
Software	**YES**	**NO**	**Notes**
Do the devices/subsystems require any additional software integration, and if so have the requirements been identified?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage I comments been addressed?	☐	☐	
Stage II (If Project Manager determined that Stage II is not being performed, obtain direction from Project Engineer on which Stage II checklist items are to be completed under Stage I. The rest of Stage II checklist items shall be completed under Stage III.)			
Structure	**YES**	**NO**	**Notes**
Have visibility, road speed/volume, right-of-way, and maintenance/cost issues all been considered when selecting a type of sign structure?	☐	☐	
Control Cabinet Enclosure	**YES**	**NO**	**Notes**
Can the maintainer safely park a vehicle and safely access the enclosure?	☐	☐	
Is the enclosure located within a reasonable distance of the sign?	☐	☐	
Is the sign face visible from the enclosure location?	☐	☐	
Does the location and orientation provide adequate protection for the enclosure? (I.E.-Protection from site environment, traffic, pedestrian, mischief, etc.)	☐	☐	
Power Requirements	**YES**	**NO**	**Notes**
Have the power requirements for the DMS and all of the subsystem components been determined?	☐	☐	

Power Availability	YES	NO	Notes
Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the DMS site?	☐	☐	
Have Step-Up/Step-Down requirement calculations been performed?	☐	☐	
Have the metering options been determined?	☐	☐	
Power Conditioning	**YES**	**NO**	**Notes**
Do the standard grounding specifications meet the needs of the subsystem?	☐	☐	
Have the UPS and power back-up requirements been determined and accounted for?	☐	☐	
Communications	**YES**	**NO**	**Notes**
Have the communication requirements for the DMS been determined?	☐	☐	
Has an appropriate communications infrastructure been located and confirmed within a reasonable proximity to the site?	☐	☐	
If there are multiple communications options, have the pros/cons been studied?	☐	☐	
Has the chosen communications option been reviewed with the PA?	☐	☐	
If using public communications infrastructure, has service been coordinated with the PA?	☐	☐	
Environmental	**YES**	**NO**	**Notes**
Have all the necessary environmental, community, and cultural impact studies, processes and concerns been addressed?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has a list of all sole source items been developed?	☐	☐	
Technology Services Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Services Department (TSD) reviewed and provided comments on the proposed communications, network integration, and software integration for the proposed equipment?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage II comments been addressed?	☐	☐	

13.3 LUCS Design Checklist

Pre-Stage I			
Pre-Design Planning	**YES**	**NO**	**Notes**
Is this deployment consistent with the needs outlined in a Concept of Operations?	☐	☐	
Is this deployment consistent with the regional ITS architecture?	☐	☐	
Stage I			
As-builts	**YES**	**NO**	**Notes**
For existing ITS equipment, has as-built information been identified and reviewed?	☐	☐	
Longitudinal Placement	**YES**	**NO**	**Notes**
Is the LUCS visible and unobscured?	☐	☐	
Is the spacing between LUCS appropriate where it would give drivers enough time to move from lane?	☐	☐	
Vertical Placement	**YES**	**NO**	**Notes**
Is the approaching segment of road relatively flat (between 0-4% vertical grade)?	☐	☐	
LUCS Sign Type	**YES**	**NO**	**Notes**
Has a sign size and type been chosen that is consistent with the visibility and message requirements of the road?	☐	☐	
Sign / Cabinet Access	**YES**	**NO**	**Notes**
Are there any traffic, environmental, or safety factors that warrant a specific type of sign access?	☐	☐	
Is all the equipment within the Port Authority's Right of way? If no, has the Project Manager been informed? If yes, has an MOU, MOA, or other agreement been initiated / is in place to allow for construction and maintenance of the subsystem equipment?	☐	☐	
Are critical electronic components above the flood level? If not, explain why it is not feasible.	☐	☐	
Software	**YES**	**NO**	**Notes**
Do the devices/subsystems require any additional software integration, and if so have the requirements been identified?	☐	☐	

Review Comments	YES	NO	Notes
Have all 100% Stage I comments been addressed?	☐	☐	
Stage II (If Project Manager determined that Stage II is not being performed, obtain direction from Project Engineer on which Stage II checklist items are to be completed under Stage I. The rest of Stage II checklist items shall be completed under Stage III.)			
Structure	**YES**	**NO**	**Notes**
Have visibility, road speed/volume, right-of-way, and maintenance/cost issues all been considered when selecting a type of sign structure?	☐	☐	
Is there sufficient vertical clearance for the sign and the structure?	☐	☐	
Control Cabinet Enclosure	**YES**	**NO**	**Notes**
Can the maintainer safely park a vehicle and safely access the enclosure?	☐	☐	
Is the enclosure located within a reasonable distance of the sign?	☐	☐	
Is the sign face visible from the enclosure location?	☐	☐	
Does the location and orientation provide adequate protection for the enclosure? (I.E.-Protection from site environment, traffic, pedestrian, mischief, etc.)	☐	☐	
Power Requirements	**YES**	**NO**	**Notes**
Have the power requirements for the LUCS and all of the subsystem components been determined?	☐	☐	
Power Availability	**YES**	**NO**	**Notes**
Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the LUCS site?	☐	☐	
Have Step-Up/Step-Down requirement calculations been performed?	☐	☐	
Have the metering options been determined?	☐	☐	
Power Conditioning	**YES**	**NO**	**Notes**
Have the UPS and power back-up requirements been determined and accounted for?	☐	☐	
Communications	**YES**	**NO**	**Notes**

Have the communication requirements for the LUCS been determined?	☐	☐	
Has an appropriate communications infrastructure been located and confirmed within a reasonable proximity to the site?	☐	☐	
If there are multiple communications options, have the pros/cons been studied?	☐	☐	
If using public communications infrastructure, has service been coordinated with the PA?	☐	☐	
Environmental	**YES**	**NO**	**Notes**
Have all the necessary environmental, community, and cultural impact studies, processes and concerns been addressed?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has a list of all sole source items been developed?	☐	☐	
Technology Services Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Services Department (TSD) reviewed and provided comments on the proposed communications, network integration, and software integration for the proposed equipment?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage II comments been addressed?	☐	☐	

13.4 Vehicle Detector Design Checklist

Pre-Stage I			
Pre-Design Planning	**YES**	**NO**	**Notes**
Is this deployment consistent with the needs outlined in a Concept of Operations?	☐	☐	
Is this deployment consistent with the regional ITS architecture?	☐	☐	
Stage I			
As-builts	**YES**	**NO**	**Notes**
For existing ITS equipment, has as-built information been identified and reviewed?	☐	☐	
Subsystem Needs	**YES**	**NO**	**Notes**
Does the detector deployment satisfy the (location) precision considerations established in the subsystem requirements?	☐	☐	
Does the detector deployment satisfy the spacing considerations established in the subsystem requirements?	☐	☐	
Does the detector deployment satisfy the accessibility considerations (for maintenance) established in the subsystem requirements?	☐	☐	
Detector Technology Selection	**YES**	**NO**	**Notes**
Does the detector technology satisfy the accuracy, accessibility, and cost requirements established in the subsystem requirements?	☐	☐	
Do the devices/subsystems require any additional software integration, and if so have the requirements been identified?	☐	☐	
Deployment Guidelines	**YES**	**NO**	**Notes**
Does the detector deployment take steps to minimize new structures and co-locate devices where possible?	☐	☐	
Does the detector deployment include sufficient detector coverage to satisfy subsystem needs?	☐	☐	
Is all the equipment within the Port Authority's Right of way? If no, has the Project Manager been informed? If yes, has an MOU, MOA, or other agreement been initiated / is in place to allow for construction and maintenance of the subsystem equipment?	☐	☐	
Are critical electronic components above the flood level? If not, explain why it is not feasible.	☐	☐	

Review Comments	YES	NO	Notes
Have all 100% Stage I comments been addressed?	☐	☐	
Stage II (If Project Manager determined that Stage II is not being performed, obtain direction from Project Engineer on which Stage II checklist items are to be completed under Stage I. The rest of Stage II checklist items shall be completed under Stage III.)			
Control Cabinet Enclosure	**YES**	**NO**	**Notes**
Is an enclosure required at this location?	☐	☐	
Is the enclosure located within 150 feet of the detector?	☐	☐	
Is the enclosure mounted on an existing structure (where possible)?	☐	☐	
Does the location and orientation provide adequate protection for the enclosure? (I.E.-Protection from site environment, traffic, pedestrian, mischief, etc.)	☐	☐	
Has a maintainer's pad been provided at the enclosure's main door?	☐	☐	
Can the maintainer safely park a vehicle and safely access the enclosure?	☐	☐	
Power Requirements	**YES**	**NO**	**Notes**
Have the power requirements for the detector and all of the subsystem components been determined?	☐	☐	
Power Availability	**YES**	**NO**	**Notes**
Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the detector site?	☐	☐	
Have Step-Up/Step-Down requirement calculations been performed?	☐	☐	
Have the metering options been determined?	☐	☐	
Power Conditioning	**YES**	**NO**	**Notes**
Have the UPS and power back-up options been determined and accounted for?	☐	☐	
Communications	**YES**	**NO**	**Notes**
Have the communication requirements for the detector been determined?	☐	☐	

Has an appropriate communications source been located and confirmed within a reasonable proximity to the site?	☐	☐	
If there are multiple communications options, have the pros/cons been studied?	☐	☐	
If using public communications infrastructure, has service been coordinated with the PA?	☐	☐	
Environmental	**YES**	**NO**	**Notes**
Have all the necessary environmental, community, and cultural impact studies, processes and concerns been addressed?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has a list of all sole source items been developed?	☐	☐	
Technology Services Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Services Department (TSD) reviewed and provided comments on the proposed communications, network integration, and software integration for the proposed equipment?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage II comments been addressed?	☐	☐	

13.5 Over-height / WIM Enforcement Design Checklist

Pre-Stage I			
Pre-Design Planning	**YES**	**NO**	**Notes**
Is this deployment consistent with the needs outlined in a Concept of Operations?	☐	☐	
Is this deployment consistent with the regional ITS architecture?	☐	☐	
Stage I			
As-builts	**YES**	**NO**	**Notes**
For existing ITS equipment, has as-built information been identified and reviewed?	☐	☐	
Enforcement Subsystem Study	**YES**	**NO**	**Notes**
Has a comprehensive Over-height or Overweight Detection Subsystem Study been performed, and recommends specific type of detection equipment to be utilized for deployment?	☐	☐	
Do the results of the study support continuing with the deployment of the project?	☐	☐	
Enforcement Subsystem Location	**YES**	**NO**	**Notes**
Is the sensor placed such that enough distance is available to warn drivers and take an alternate route?	☐	☐	
Is all the equipment within the Port Authority's Right of way? If no, has the Project Manager been informed? If yes, has an MOU, MOA, or other agreement been initiated / is in place to allow for construction and maintenance of the subsystem equipment?	☐	☐	
Are critical electronic components above the flood level? If not, explain why it is not feasible.	☐	☐	
Software	**YES**	**NO**	**Notes**
Do the devices/subsystems require any additional software integration, and if so have the requirements been identified?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage I comments been addressed?	☐	☐	
Stage II (If Project Manager determined that Stage II is not being performed, obtain direction from Project Engineer on which Stage II checklist items are to be completed under Stage I. The rest of Stage II checklist items shall be completed under Stage III.)			

Enforcement Subsystem Signals	YES	NO	Notes
Are the warning signs placed at critical points to allow drivers to stop or exit the road?	☐	☐	
Are the signs designed in compliance with MUTCD?	☐	☐	
Are the signs designed in compliance with PA requirements?	☐	☐	
Enforcement Subsystem Sensors	**YES**	**NO**	**Notes**
Does the subsystem design include all of the necessary detection areas?	☐	☐	
Does the complexity / configuration of the subsystem require additional detection areas?	☐	☐	
Signing and Pavement Markings	**YES**	**NO**	**Notes**
Do the signs and markings meet MUTCD standards?	☐	☐	
Control Cabinet Enclosure Placement	**YES**	**NO**	**Notes**
Is an enclosure required at this location?	☐	☐	
Can the maintainer safely park a vehicle and safely access the enclosure?	☐	☐	
Is the enclosure located within 150 feet of the detectors?	☐	☐	
Is the enclosure mounted on an existing structure (where possible)?	☐	☐	
Does the location and orientation provide adequate protection for the enclosure? (I.E.-Protection from site environment, traffic, pedestrian, mischief, etc.)	☐	☐	
Has a maintainer's pad been provided at the enclosure's main door?	☐	☐	
Power Requirements	**YES**	**NO**	**Notes**
Have the power requirements for the subsystem components been determined?	☐	☐	
Power Availability	**YES**	**NO**	**Notes**
Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the detector site?	☐	☐	
Have Step-Up/Step-Down requirement calculations been performed?	☐	☐	

Have the metering options been determined?	☐	☐	
Power Conditioning	**YES**	**NO**	**Notes**
Have the UPS and power back-up requirements been determined and accounted for?	☐	☐	
Communications	**YES**	**NO**	**Notes**
Have the communication requirements for the detector been determined?	☐	☐	
Has an appropriate communications source been located and confirmed within a reasonable proximity to the site?	☐	☐	
If there are multiple communications options, have the pros/cons been studied?	☐	☐	
Has the chosen communications option been reviewed?	☐	☐	
If using public communications infrastructure, has service been coordinated with the PA?	☐	☐	
Environmental	**YES**	**NO**	**Notes**
Have all the necessary environmental, community, and cultural impact studies, processes and concerns been addressed?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has a list of all sole source items been developed?	☐	☐	
Technology Services Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Services Department (TSD) reviewed and provided comments on the proposed communications, network integration, and software integration for the proposed equipment?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage II comments been addressed?	☐	☐	

13.6 RWIS Design Checklist

Pre-Stage I			
Pre-Design Planning	**YES**	**NO**	**Notes**
Is this deployment consistent with the needs outlined in a Concept of Operations?	☐	☐	
Is this deployment consistent with the regional ITS architecture?	☐	☐	
Stage I			
As-builts	**YES**	**NO**	**Notes**
For existing ITS equipment, has as-built information been identified and reviewed?	☐	☐	
Location/Placement Guidelines	**YES**	**NO**	**Notes**
Has the RWIS location been chosen / designed with consideration to typical or worse case atmospheric conditions in the area?	☐	☐	
Has a site for the RWIS been chosen that considers the available utilities and the cost/constraints associated with connection to those utilities?	☐	☐	
Has the site been chosen with consideration to protecting the RWIS structure and ensuring that it will last without undue maintenance to the structure and the surrounding site?	☐	☐	
Has a site been chosen that makes the best use of the operational needs of an RWIS (e.g. low visibility sites)?	☐	☐	
Has a site been chosen that satisfies safety requirements for personnel performing maintenance on the subsystem?	☐	☐	
Has the site been chosen so that it will minimize maintenance costs and facilitate maintenance?	☐	☐	
Is all the equipment within the Port Authority's Right of way? If no, has the Project Manager been informed? If yes, has an MOU, MOA, or other agreement been initiated / is in place to allow for construction and maintenance of the subsystem equipment?	☐	☐	
Are critical electronic components above the flood level? If not, explain why it is not feasible.	☐	☐	
Sensor Type	**YES**	**NO**	**Notes**
Are the sensor types appropriate for the desired location?	☐	☐	
Is the mounting height appropriate?	☐	☐	

Is the equipment sufficiently hardened to withstand major storms?	☐	☐	
Software	**YES**	**NO**	**Notes**
Do the devices/subsystems require any additional software integration, and if so have the requirements been identified?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage I comments been addressed?	☐	☐	
Stage II (If Project Manager determined that Stage II is not being performed, obtain direction from Project Engineer on which Stage II checklist items are to be completed under Stage I. The rest of Stage II checklist items shall be completed under Stage III.)			
Sensor Mount	**YES**	**NO**	**Notes**
Have PA standards been followed in the design of the mount / structure?	☐	☐	
Control Cabinet Enclosure	**YES**	**NO**	**Notes**
Is an enclosure required at this location?	☐	☐	
Can the maintainer safely park a vehicle and safely access the enclosure?	☐	☐	
Is the enclosure mounted on the RWIS pole or on an existing structure (where possible)?	☐	☐	
Does the location and orientation provide adequate protection for the enclosure? (I.E.-Protection from site environment, traffic, pedestrian, mischief, etc.)	☐	☐	
Has a maintainer's pad been provided at the enclosure's main door?	☐	☐	
Power Requirements	**YES**	**NO**	**Notes**
Have the power requirements for the RWIS and all of the subsystem components been determined?	☐	☐	
Power Availability	**YES**	**NO**	**Notes**
Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the detector site?	☐	☐	
Have Step-Up/Step-Down requirement calculations been performed?	☐	☐	
Have the metering options been determined?	☐	☐	

Power Conditioning	YES	NO	Notes
Have the UPS and power back-up options been determined and accounted for?	☐	☐	
Communications	**YES**	**NO**	**Notes**
Have the communication requirements for the RWIS been determined?	☐	☐	
Has an appropriate communications source been located and confirmed within a reasonable proximity to the site?	☐	☐	
If there are multiple communications options, have the pros/cons been studied?	☐	☐	
If using public communications infrastructure, has service been coordinated with the PA?	☐	☐	
Environmental	**YES**	**NO**	**Notes**
Have all the necessary environmental, community, and cultural impact studies, processes and concerns been addressed?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has a list of all sole source items been developed?	☐	☐	
Technology Services Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Services Department (TSD) reviewed and provided comments on the proposed communications, network integration, and software integration for the proposed equipment?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage II comments been addressed?	☐	☐	

13.7 HAR Design Checklist

Pre-Stage I			
Pre-Design Planning	**YES**	**NO**	**Notes**
Is this deployment consistent with the needs outlined in a Concept of Operations?	☐	☐	
Is this deployment consistent with the regional ITS architecture?	☐	☐	
Stage I			
As-builts	**YES**	**NO**	**Notes**
For existing ITS equipment, has as-built information been identified and reviewed?	☐	☐	
Control Software	**YES**	**NO**	**Notes**
Is the HAR compatible with the Facility TMC/OCC/Comm Desk device control software?	☐	☐	
Site Selection	**YES**	**NO**	**Notes**
Are there any adjacent existing HAR subsystems, and if so, has coordination taken place with them?	☐	☐	
Has a frequency search taken place?	☐	☐	
Has an onsite listening survey been performed?	☐	☐	
Has reception of the NOAA All-Hazards Alert System been verified?	☐	☐	
Have existing traveler information stations, e.g. AM news radio, been considered when justifying a new HAR placement?	☐	☐	
Is all the equipment within the Port Authority's Right of way? If no, has the Project Manager been informed? If yes, has an MOU, MOA, or other agreement been initiated / is in place to allow for construction and maintenance of the subsystem equipment?	☐	☐	
Are critical electronic components above the flood level? If not, explain why it is not feasible.	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage I comments been addressed?	☐	☐	
Stage II (If Project Manager determined that Stage II is not being performed, obtain direction from Project Engineer on which Stage II checklist items are to be completed under Stage I. The rest of Stage II checklist items shall be completed under Stage III.)			

Transmitter Location	YES	NO	Notes
Is the potential transmitter site free of significant vertical (25′ or higher) obstructions?	☐	☐	
Is power (115 volts, 60 Hz) and communication (telephone/wireless/owned wireline) service available at the site?	☐	☐	
Is there sufficient open ground (at least 40′ x 40′) for the cabinet and antenna installation?	☐	☐	
If there are adjacent HAR transmitters, has message synchronization been built into the design?	☐	☐	
Beacon Sign Location	**YES**	**NO**	**Notes**
Have MUTCD sign standards been followed?	☐	☐	
Are the signs visible and unobstructed?	☐	☐	
Is the sign placed such that a motorist is entering the proposed broadcast range of the HAR transmitter?	☐	☐	
Does the location of the sign permit the traveler to safely tune and then react to the message?	☐	☐	
Is it possible to co-locate the sign/beacon with an existing CCTV camera for the purpose of visual verification?	☐	☐	
Licensing and Permits	**YES**	**NO**	**Notes**
Has consideration been given to other HAR transmitters (not adjacent to the new site) along a particular route so that the same frequency can be used?	☐	☐	
ITS Enclosure (both transmitter location and beacon location)	**YES**	**NO**	**Notes**
Can the maintainer safely park a vehicle and safely access the enclosure?	☐	☐	
Is the enclosure location within 150 feet of the device?	☐	☐	
Does the location and orientation provide adequate protection for the enclosure?	☐	☐	
Control Cabinet Enclosure	**YES**	**NO**	**Notes**
Can personnel safely access the enclosure?	☐	☐	
Is the enclosure located within a reasonable distance of the sign?	☐	☐	
Is the sign face visible from the enclosure location?	☐	☐	

Does the location and orientation provide adequate protection for the enclosure? (I.E.-Protection from site environment, traffic, pedestrian, mischief, etc.)	☐	☐	
Power Requirements	**YES**	**NO**	**Notes**
Have the power requirements for the HAR and all of the subsystem components been determined?	☐	☐	
Power Availability	**YES**	**NO**	**Notes**
Have the power requirements for all of the subsystem components been determined?	☐	☐	
Has an appropriate power source been located and confirmed with the utility company within a reasonable distance from the site?	☐	☐	
Have Step-Up/Step-Down requirement calculations been performed where necessary?	☐	☐	
Have the metering options been determined?	☐	☐	
Power Conditioning	**YES**	**NO**	**Notes**
Do the standard grounding specifications meet the needs of the subsystem?	☐	☐	
Have the UPS and power back-up requirements been determined and accounted for?	☐	☐	
Communications	**YES**	**NO**	**Notes**
Have the communication requirements for the HAR been determined?	☐	☐	
For wired communication, has an appropriate source been located and confirmed within a reasonable proximity to the site?	☐	☐	
For cellular communication, has the required signal strength been verified at the site?	☐	☐	
If there are multiple communications options, have the pros/cons been studied?	☐	☐	
Environmental	**YES**	**NO**	**Notes**
Have all the necessary environmental, community, and cultural impact studies, processes and concerns been addressed?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has a list of all sole source items been developed?	☐	☐	
Technology Services Department	**YES**	**NO**	**Notes**

Has the Authority's Technology Services Department (TSD) reviewed and provided comments on the proposed communications, network integration, and software integration for the proposed equipment?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage II comments been addressed?	☐	☐	

13.8 Stage III Checklist (All ITS Subsystems)

Stage III			
Review Stage I and II	**YES**	**NO**	**Notes**
Has Stage I and II documentation been reviewed by designer?	☐	☐	
Verify that all Stage I and II checklists have been approved by PA.	☐	☐	
General	**YES**	**NO**	**Notes**
Have all necessary project permits been applied for?	☐	☐	
Are all required outside agency agreements complete?	☐	☐	
If equipment is located outside PA right-of-way, did Project Management send the drawings to the outside agency for review, and were those comments addressed?	☐	☐	
Has a list of net cost items been developed, cost estimate developed and approved by Estimating and Construction?	☐	☐	
Has the engineering estimate been submitted and approved?	☐	☐	
Do all the drawings conform to PA CAD standards?	☐	☐	
Has the final list of specifications, c-specifications, and marked-up appendix "A" been submitted?	☐	☐	
Sole Source	**YES**	**NO**	**Notes**
Has all Sole Source Documentation been submitted and approved?	☐	☐	
Review Comments	**YES**	**NO**	**Notes**
Have all 100% Stage III comments been addressed?	☐	☐	

14. Appendix B – List of Abbreviations

Acronym	Definition
AASHTO	American Association of State Highway and Transportation Officials
AM	Amplitude Modulation
AMR	Automatic Meter Reader
AP/RU	Access Points/Repeater Units
ATMS	Advanced Traffic Management System
C2C	Center to Center
C2F	Center to Field
CCTV	Closed-Circuit Television
Comm Desk	Communications Desk
ConOps	Concept of Operations
DMS	Dynamic Message Sign
ESS	Environmental Sensor Station
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
Gbps	Gigabits per second
GPS	Global Positioning System
HAR	Highway Advisory Radio
HDM	Highway Design Manual
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISO	International Organization for Standardization
ITS	Intelligent Transportation System
Kbps	Kilobits per second
LED	Light-Emitting Diode
LTE	Long Term Evolution
LUCS	Lane Use Control Signals
M2M	Machine to Machine
MAC	Media Access Control
Mbps	Megabits per second
MDC	Major Desired Capability
MDS	Magnetometer Detection System
MTA	Metropolitan Transportation Authority
MUTCD	Manual on Uniform Traffic Control Devices
NASA	National Aeronautics and Space Administration
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NJDOT	New Jersey Department of Transportation
NJTPA	North Jersey Transportation Planning Authority
NOAA	National Oceanic and Atmospheric Administration
NTCIP	National Transportation Communications for ITS Protocol
NWS	National Weather Service
NYCDOT	New York City Department of Transportation
NYCSRA	New York City Sub-Regional ITS Architecture
NYSDOT	New York State Department of Transportation
OCC	Operations Control Center
OD	Origin / Destination
OVDS	Over-height Vehicle Detection Systems
PA	Port Authority of New York and New Jersey
PIRF	Project Initiation Request Form
PMPP	Point to multi-point protocol
P/T	Pan/Tilt
RF	Radio Frequency
RFID	Radio-Frequency Identification
ROW	Right-of-Way
RPU	Remote Processing Unit
RWIS	Road Weather Information System
SE	Systems Engineering
TMC	Traffic Management Center
TRANSMIT	TRANSCOM's System for Managing Incidents and Traffic
TVSS	Transient-Voltage Surge Suppressor
UPS	Uninterruptible Power Supply
USDOT	United States Department of Transportation
VIDS	Video Imaging Detection System
WAN	Wide Area Network
WIM	Weigh-In-Motion
WiMAX	Worldwide Interoperability for Microwave Access
4G	Fourth Generation

15. Appendix C - Project Initiation Request Form (PIRF)

The agency has a mature and effective Project Lifecycle process that consists of the following stages:

- Stage 0 – Project Initiation
- Stage 1 – Conceptual Design
- Stage 2 – Preliminary Design
- Stage 3 – Final Design/Contract Award
- Stage 4 – Construction
- Stage 5 – Close-Out

All proposed capital projects must undergo a formal process to develop a high-level scope. This process constitutes the Project Initiation stage. The most important document to be completed during Project Initiation is the PIRF.[5] As noted in the aforementioned Handbook, all projects which are already on the Capital Plan as well as any "Added Starters" require a completed PIRF document. In effect, the PIRF serves as the cornerstone for capital projects at the agency because it focuses the formal scoping and definition effort and ensures that all stakeholders are aware of the appropriate project information so that they can make an informed decision to grant Stage 1 initiation.

Version 0.21of the PIRF, dated March 16, 2012, is reproduced on the following pages. Of special import is the newly approved inclusion of ITS considerations in Section 2 (Scope) of that document. Item 2f. (ITS Scope) mandates that it be indicated whether ITS scope has been considered, and if so, request that an outline of the ITS scope be provided. Traffic Engineering will review this portion of all PIRFs and, in consultation with the Working and Steering Committees, coordinate ITS-related activities as necessary.

Clearly, this formal consideration of ITS scope at the Project Initiation stage constitutes a major achievement in efforts to foster an enterprise approach to ITS planning and implementation.

[5] Project Initiation Handbook, The Port Authority of New York and New Jersey, Project Management Office, January, 2012.

Project Initiation Request Form (PIRF)

Version 0.21, March 16th 2012

0.1 Instructions

This document defines the project scope, schedule and cost at a high level and aligns the concurrence with necessary stakeholders to obtain a Stage 1 charge code. Upon completion, submit to the PMO@panynj.gov to start the Gate 0 Review process. This process formally initiates the project Stage 1 charge code release process.

Grey highlighted text is for guidance only and should be replaced with project-specific detail.

When this form is completed and agreed by Lead Engineering Principal and the Program Manager e-mail this form to the PMO at PMO@panynj.gov.

0.2 Version Control

Version	Date	Details of Changes
0.1	MM/DD/YYYY	Add a row detailing each change to the document and up-versioning to 0.2, 0.3, 0.4 etc.

0.3 PIRF Detail

Project Title	
Line Department	AVIATION
Project Facility	[INCLUDE UNIT NAME & NUMBER]
Project Manager	[OR POINT OF CONTACT]
Capital Project ID	(formerly INCAPS ID)

0.4 Approvals

PM must work with Lead Principal Engineer to Prepare PIRF and enter the Lead Eng. Principals Name on Line #2 below. The PM will also ensure the Program Manager is in agreement with the content of the PIRF (and will add –e-signatures in the approvals column) before sending it in to the PMO.

#	Name	Role	Approval
1	Filled out by PM	Line Dept. Program Manager	E-Signature *
2	Filled out by PM	Lead Engineering Principal	E-Signature *
3	To Be Filled out by PMO	Fixed Assets Representative	To be by email
4	To Be Filled out by PMO	MBD Representative	To be by email

*PMO will call Line Department Program Manager and Lead Principal Engineer to Confirm they concur with the content of the PIRF before sending it on Fixed Assets and MBD for their approvals

0.5 Outputs

PID	to be added after Gate Review 0
Stage 1 Charge Code (from PCS**)	to be added after Gate Review0
Contract Number (from Eng.**)	to be added after Gate Review 0 for projects recommended for Stage 3

**If available

1. Project Detail

Title	Description
1a. Project in Capital Plan? (Y/N)	Is the project in the current Capital Plan? Enter 'Yes/No'.
1b. Project Category	Select from: 'State of Good Repair', 'Mandatory', 'Security', 'System Enhancing', 'Revenue Producing', 'State and Regional'.
1c. Business Objective (seek input from Facility Ops)	Select from: Asset Management, Safety and Security, Access and Mobility, Customer Service
1d. Relevant Strategic Campaign	Select from: Transportation for a Competitive Export Economy, Transit-based economic growth, Efficient goods movement network, Seamless regional travel, Sound, secure, state-of-the-art infrastructure
1e. Region	Select from 'New York', 'New Jersey', 'Interstate'
1f. Is Project Part of a Program? (Y/N)	Yes/No if yes please add the program code#. Please list all projects included in the Program by In-Caps ID and include the program title.
1g. What type of asset is being created?	New Asset/ Improved Asset/ Asset Replacement/ Major Rehabilitation of an Existing Asset

2. Scope

Please note that the text boxes expand as you enter the detail.

Title	Description
2a. Project Background	State the project location, context, origin, existing conditions, aims and business objectives. Why is the project required at this time? What are the key project business objectives? Start Year: Completion Year:
2b. Assumptions	State any key project assumptions
2c. Scope of Work	Describe the project scope. How will the project address the business aims/objectives? Include any known quantities such as number of units, linear feet, or area, etc., that would help pinpoint the scope of work and cost.
2d. Key Deliverables	State any known project deliverables (Engineering deliverables should not be listed at this point)
2e. Exclusions	Note any explicit exclusions from the delivery of the project (e.g. the project will not deliver the following areas as they are deemed out-of-scope
2f. ITS Scope	Indicate if Intelligent Transportation System (ITS) scope has been considered. If so outline the scope of work required from ITS. Require liaison with Traffic Engineering.
2g. Constraints	State the constraints within which the project must operate. Note any known restrictions affecting any aspect the project (e.g. budgetary, schedule, quality, resourcing etc.)
2h. Interfaces (input may be required from Facility Ops)	Describe any relationships or dependencies with interrelated projects/programs/activities (internal or external to Port Authority). State whether the project will be a standalone effort or part of a larger program
2i. Consequences of Not Undertaking	Briefly describe the consequences and outcomes of not undertaking the project. What would occur in the short/med/long term? Include savings/benefits resulting from the project.
2j. Design Expectations (seek input from Engineering)	Design expectations to provide Engineering with additional information to input to project Proposal System. E.g. field surveys required, environmental assessments, studies, alternatives analysis, life cycle cost analysis, interim submissions. You should not include typical design expectations.
2k. Concept/Impact of Operations	Briefly describe the concept of operation. Estimate the impact of the project operation. (The benefit described may be measured after the asset is put in service.)

3. Project Cost

Title	Descriptions
3a. Estimated Total Project Cost (TPC)	Enter a TPC estimate. Provide unit measure and number of units, if applicable.
3b. Financial Contribution	Enter the level of financial contribution afforded to the project from: "<1", ">=1&<1.3", ">=1.3", "NONE"
3c. Funding Sources	Select one or more from: Dept. of Homeland Security, Dept. of Justice, Federal Aviation Administration, FAA/AIP, FEMA, Federal Highway Administration, Flight Fees, Federal Transit Administration, I-95 Corridor Coalition, NJ Dept. of Transportation, PA Investment, NY State Emergency Management Office, Passenger Facility Charges, Transportation Security Admin/DHS
3d. Grant Funding	Does this project include grant funding? If so provide a brief description of the amount and source
3e. Project Stages	List the proposed stages the project is planning to pass through (i.e. if any stages will not be undertaken). State whether a Pre-Stage 1 effort has been executed.
3f. Stage 1 Project Budget	Estimate the budget required for Stage 1- Conceptual Design. This is the budget required to complete Stage 1 of the project.
3g. Service Life Value (PM to seek this information from Engineering)	Enter the life expectancy for the major asset being created

4. Project Schedule

Project Stage	Start Date	End Date
4a. Stage 1 – Conceptual Design	Estimated stage start date	Estimated stage end date
4b. Stage 2 – Preliminary Design	Estimated stage start date	Estimated stage end date
4c. Stage 3 – Final Design/Contract Award	Estimated stage start date	Estimated stage end date
4d. Stage 4 – Construction	Estimated stage start date	Estimated stage end date

5. Project Risks

#	Risk Description	Risk Severity	Proposed Actions
5.1	<Include a brief description of the risk and the specific vulnerability to the project>	<What are the likely consequences of the risk occurring, what level of impact will it have on the project?>	<Description of the proposed mitigation to prevent the risk occurring>
5.2			

6. Project Stakeholders

#	Stakeholder Group	Support to project	Engagement Strategy
6.1	<List stakeholders/stakeholder groups>	<L/M/H>	<Outline the strategy for engaging with stakeholders to gain their concurrence with objectives/approach>
6.2			

7. Other Comments

Use this space to enter any further relevant comments about the project.

PLEASE SELECT A **NEED CODE**:

NEED CODE	DESCRIPTION
0	Annual
1	Structural Integrity
2	Safety
3	Security
4	Regulations
5	Physical Plant SGR
6	Customer Service
7	Enhancements
8	System Maintenance
9	Traffic Studies

The illustration below indicates where the PIRF process fits into the future Project Gate Review Process and is for information only.