Engineering Department

PORT AUTHORITY NY NJ
AIR LAND RAIL SEA

Traffic Design Guidelines

For External Use
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1.0 TRAFFIC DISCIPLINE

1.1 OVERVIEW

These guidelines are provided as an overview of the Port Authority's design standards. Design details and associated documents outlined in these documents will be provided to the designer as required.

The Guidelines shall not replace professional design analyses, nor the Guidelines are 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 the design professional 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. The Traffic Engineering Discipline is part of the Engineering/Architecture Design Division (EADD) of the Engineering Department. As expanded upon below, the Traffic Engineering Discipline is organized into six functional groups: Traffic Planning and Priority Programs, Traffic Design, Traffic Operations, Traffic Safety, Transportation Technologies, and the Agency Operations Center. Roadway Access Management is a technical tool that is included within the first four of these functional groups.

1.1.1 TRAFFIC PRIORITY PROGRAMS

Perform transportation planning services and the functional planning of new infrastructure investments and improvements to existing vehicular and pedestrian facilities by performing surveys and developing and maintaining state-of-the-art traffic forecasting, simulation, and trip assignment computer models. Additionally, provide transportation planning and engineering services to major Redevelopment Programs and develop Transportation Management Plans to support construction.

1.1.2 TRAFFIC PLANNING AND PROJECT DELIVERY

Perform traffic engineering design services to support the Engineering Department's commitment to capital and operating major works programs by serving as a Project Engineer/Architect or in a support (Task Leader) capacity to other engineering disciplines.

Tasks include:

- ❒ Contract preparation.
- ❒ Stage IV construction coordination.
- ❒ Shop drawing reviews.
- ❒ Field support in auditing and implementing Maintenance of Traffic plans during construction.
- ❒ Traffic Signal turn-on and Final inspection checklist in coordination with the Construction Management Division (CMD) and Electrical Facility.
- ❒ TAA reviews.
- ❒ Transportation Management Plan (TMP) development.

1.1.3 TRAFFIC OPERATIONS AND CUSTOMER EXPERIENCE

Perform day-to-day traffic engineering services to provide a safe and reliable transportation system through the practice of Service Engineering. Work with facility staff to resolve traffic flow, control, capacity, levels of service, access, egress, and parking issues. Determine the design, type, size, and location of all traffic signs, signals, pavement markings, roadside appurtenances, and similar devices.

1.1.4 TRAFFIC SAFETY IMPROVEMENT PROGRAM

Perform traffic engineering services through a Traffic Safety Improvement Program to plan, implement, and evaluate traffic safety improvements to minimize the frequency, severity, and risk of vehicle crashes. Ensure due diligence on the part of the Port Authority of New York & New Jersey to provide a safe environment for vehicles and pedestrians.

1.1.5 TRANSPORTATION TECHNOLOGIES AND DATA

Manage the agency's ITS program in accordance with the implementation roadmap to help deliver the ITS Strategic Plan mission through the use of transportation technologies. Perform ITS planning, design, and construction and operational support services to improve operational efficiency and help optimize the use of available transportation system network capacity.

1.1.6 AGENCY OPERATIONS CENTER

The PA-Agency Operations Center (PA-AOC) is an Agency-wide transportation management center, operational 24/7. The AOC provides a single point of contact for real-time transportation information within the PA allowing the agency to speak as one voice with the State/City of New York and the State of New Jersey transportation management centers, as well as TRANSCOM. The PA-AOC enhances coordination with regional transportation partners to promote more efficient regional transportation systems management. Additionally, the PA-AOC has made partnering with third party technology companies a strategic priority. Collaboration with companies such as Google, Apple and Waze has increased capabilities in real-time transportation management, allowing the PA to reach a much larger number of customers.

2.0 TECHNICAL AND CODE STANDARDS/REGULATIONS

- Federal Highway Administration: Manual on Uniform Traffic Control Devices (MUTCD), latest edition
- American Association of State Highway and Transportation Officials (AASHTO): A Policy on Geometric Design of Highways and Streets – "AASHTO Green Book," latest edition
- Roadside Design Guide, 4th Edition, AASHTO, 2011
- Standard Highway Signs, FHWA, 2004
- Highway Capacity Manual (HCM), Transportation Research Board (TRB), 2010
- Public Right of Way Accessibility Guidelines (PROWAG), 2013
- Guide for the Planning, Design, and Operation of Pedestrian Facilities, AASHTO, 2004
- Americans with Disabilities Act Standards for Accessible Design
- Guide for the Development of Bicycle Facilities, AASHTO, 4th Edition, 2012
- Pedestrian Planning and Design, John Fruin, Ph.D., 1971
- NYC CEQR Technical Manual, NYC Mayor's Office of Environmental Coordination, 2014
- Station Planning and Design Guidelines, MTA New York City Transit, 2006
- Transit Capacity and Quality of Service Manual, 3rd Edition, Transportation Research Board (TRB), 2013

3.0 DESIGN CRITERIA AND SPECIAL REQUIREMENTS

3.1 PLANNING

3.1.1 TRAFFIC ANALYSIS

The design team should familiarize themselves with the material in the Port Authority Roadway Access Management Guidelines (Appendix A) prior to functional plan development. Of particular importance is chapter 2, "The Role of Roadway Access Management in Port Authority Business Practices."

3.1.1.1 FUNCTIONAL PLAN DEVELOPMENT

Generally produced in Stages I and II:

1. Determine design year (usually 20 years into future).
2. Determine design hourly volume (DHV).
3. On existing roads, obtain current traffic volume and apply growth factors that consider:
   - Local traffic
   - PA facility traffic
   - New facilities
   - Local planned developments
   - PA planned developments
4. For new facilities or roadways, determine trip generation volumes and assign them to the roadway network.
5. Select level of service for design (usually C or D).
6. Compare DHV to existing capacity (for not only the ultimate configuration but also for intermediate construction stages) at:
   - Tangent sections
   - Weaving areas
   - Ramps
   - Intersections
     - Signalized
     - Unsignalized
7. Develop conceptual plan to overcome capacity shortfall or operational deficiencies by:
   - Improving traffic management systems (improve existing conditions)
     - Rerouting traffic
     - Improved signing and striping
     - Traffic/parking restrictions
   - Widening
   - Signalization

- Revise existing
- New

- ❑ Roadway Access Management

8. Prepare functional plan in sufficient detail to show:
   - ❑ Existing major elements (curbs, barriers, signals, etc.) to remain, to be relocated, and to be revised
   - ❑ New design elements
   - ❑ Existing elements to be relocated
   - ❑ Pavement marking to clearly show number of traffic lanes
   - ❑ Roadway layout throughout the area of concern and where it meets existing
9. Finalize functional plan to include:
   - ❑ Traffic volumes (DHV)
   - ❑ Roadway and lane widths
   - ❑ Traffic signals
   - ❑ Traffic signs (regulatory, warning, directional)
   - ❑ North arrow

In general, before proceeding into the next phase of design development, secure Line Department/ Facility concurrence with functional plan.

3.2 DESIGN

3.2.1 CONSTRUCTION STAGING AND HOURS OF WORK

Construction should be staged to minimize traffic impacts while maintaining sufficient capacity to meet demand.

If possible, the existing number of lanes should be maintained. Where the number of lanes cannot be maintained, consideration should be given to off-peak or nighttime construction. Traffic Engineering assists the Facility and Line Department in determining the hours of work. Some routine lane closures may be performed during daytime hours, but other closures may only be performed during nighttime hours, which vary by facility. Traffic Engineering performs the traffic analyses to determine the hours of work that minimize delays and queueing.

3.2.2 MAINTENANCE OF TRAFFIC (MOT)

All construction and maintenance operations work within roadways shall be performed with approved MOT drawings. Every construction stage and substage where the traffic pattern changes requires a unique MOT scheme. Closures within parking areas also require MOT. All drawings must:

- Warn road users (motorists, pedestrians, and bicyclists) of work zones.
- Advise road users of the proper travel path through the work zone.
- Delineate areas where traffic should not operate.
- Separate and provide reasonable protection for both road users and workers.

3.2.2.1 Work Zone Traffic Control Layouts

A work zone is an area where road user conditions are changed by the use of temporary traffic control devices, flaggers, or other authorized personnel due to construction activity. Standards and guidelines for the maintenance and protection of traffic in work zones are found in Part 6 of the Manual on Uniform Traffic Control Devices (MUTCD).

3.2.2.2 Detours

Road closures should be avoided, but where necessary, detours should follow alternate routes close to, and generally parallel to the roadway being closed. The detour routes must have sufficient capacity and roadway width to carry the diverted traffic.

3.2.2.3 Intersections

When a lane closure is required on the far side of an intersection consideration should be given to closing the impacted lane in advance of the intersection. Proper taper lengths are required for the lane closure in advance of the intersection.

3.2.2.4 Ramps

Where work zones reduce the available acceleration lane distance, consideration should be given to closing the right lane in advance of the on-ramp to create a dedicated ramp entry lane using the closed right lane, where practical.

If advanced lane closures cannot be provided and adequate acceleration length to support a merge is not available, temporary traffic control of on-ramp traffic may, depending on mainline and ramp traffic volumes, consist of STOP (R1-1) or YIELD (R1-2) signs. Every attempt should be made to provide adequate acceleration length. The use of STOP or YIELD control contributes to a speed differential between mainline and entering traffic and should only be used where adequate acceleration length is not available or closing the ramp and detouring traffic is not practical.

In all cases, provide advance warning of the STOP or YIELD condition by using STOP AHEAD or YIELD AHEAD signs and VMS if appropriate. If space is available, install STOP and YIELD signs on both sides of the ramp.

3.2.2.5 Pedestrian and Bicycle Traffic

Pedestrian and/or bicycle traffic must be maintained through, or around work zones where pedestrians and/or bicyclists are not prohibited.

Pedestrian detour routes should be well marked, continuous, and easy to traverse. They must be maintained free of obstructions and hazards. The detour route shall maintain the same accessibility as existing.

3.2.2.6 Work Zone Traffic Control

Guidelines for the design, use, installation, and operation of traffic control devices in work zones are established by the MUTCD (PART 6, Temporary Traffic Control). Temporary traffic control devices include but are not limited to:

- Construction Signs
- Channelizing Devices
- Flashing Arrow Sign Units

- Portable Variable Message Signs
- Hand Signaling Devices
- Temporary Concrete Barrier
- Temporary Impact Attenuators
- Back-up Trucks
- Temporary Pavement Markings
- Temporary Traffic Signals

3.2.2.7 CONSTRUCTION SIGNS

Guidelines for the design, use, and installation of construction signs are established by the MUTCD. In addition, the following should be considered:

- Choose standard MUTCD signs that are appropriate and that accurately describe the roadway conditions.
- Choose the standard message signs according to what action the driver needs to take. Minimize the use of special messages.
- Use larger signs when greater visibility is desired. For example, high speeds or large volumes.
- Consider using smaller signs in narrow medians if larger signs will overhang the adjacent travel lane.

3.2.2.8 CONSTRUCTION SIGN PLACEMENT

A. Warning signs must be located to provide adequate visibility distance to drivers. They must not be blocked by foliage, roadway features, or other signs and traffic control devices nor interfere with other signs.

B. Actual distance from a warning sign to the condition should be close to the stated distance on the sign and in accordance with the MUTCD. However, positioning of the sign to enhance visibility and avoid conflicts with other traffic control devices and roadway features is more important than precise agreement with the stated distance.

3.2.2.9 CONSTRUCTION SIGN MOUNTING

A. The majority of construction signs are placed on X-Base sign supports and are offset 2 feet minimum from any travel lane. However, some signs are placed on Type III Breakaway Barricades, which include:

  - Arrow signs within tapers
  - ROAD/RAMP CLOSED signs at the closure point
  - Pedestrian detour/closure signs to physically block pedestrian paths

3.2.2.10 CHANNELIZING DEVICES

Channelizing devices guide motorists through the work zone. Channelizing devices are used to provide a physical separation between the travel lanes and the work area. Channelizing devices also provide for lane merges, lane shifts, diversions, detours, and narrowing of lanes. The predominantly used channelizing devices are drums and breakaway barricades but can include cones and tubular markers.

The type of channelizing devices used should be consistent throughout the work zone. In addition, the following should be considered:

- At locations where lane or shoulder closures are protected by temporary concrete barrier, a taper of channelizing devices is placed upstream of the end of the barrier where the closure begins.
- When used to close travel lanes where workers are exposed to traffic, the spacing of channelizing devices in tangent sections and tapers should be 20 feet.
- Where engineering judgement indicates a special need for closer device spacing, such as in tightly curved sections of the roadway, channelizing devices can be spaced 10 feet apart.
- Where driveways or intersecting streets or crossovers are located within the work zone, channelizing devices should be placed to adequately define their turning radii. A 5-foot spacing between channelizing devices should be adequate for most circumstances.
- Drums are to be used for all lane-closures except where work space is limited, and adequate lane widths cannot be provided through the use of drums but may be able to be provided by substituting cones.
- Type III barricades are used at all locations where a highway, bridge, ramp, or other segment of the roadway is closed to traffic, by placing them across the area that is closed.
- Place a minimum of 2 (preferably 3) Type III breakaway barricades with appropriate large arrow signs within the merging taper.

3.2.2.11 FLASHING ARROW SIGN UNITS

Flashing Arrow Sign Units (FASU) can be trailer-mounted or mounted on a back-up truck. The FASU can be set to display a Left Arrow, Right Arrow, Left and Right Arrow, and Caution pattern as stated below:

- Use a FASU for all lane closures, typically placed at the end of the taper with the appropriate arrow display.
- For shoulder closures and lane shifts the FASU displays a caution pattern, unless it is determined that an arrow display is more appropriate based on engineering judgement.
- Use a FASU for lane splits with a 2-sided arrow where both lanes provide equivalent destinations and purpose.

3.2.2.12 PORTABLE VARIABLE MESSAGE SIGNS

Portable variable message signs (PVMS) are to be used as supplemental, temporary work zone warning devices and for lane and roadway closures. PVMS may supplement signing in a work zone but cannot be used to replace regulatory or warning signs. They may also be used in lieu of or to supplement guide signs to display variable information, real-time traffic information, and for increased emphasis.

3.2.2.13 HAND SIGNALING DEVICES

Flaggers are used to stop traffic intermittently at work sites and to assign right of way, or to slow traffic as it passes the activity area to help protect the work crew. A flagger sign (W8-22) should be used to warn drivers that they are approaching a flagger station. Sight distance needs to be maximized for flagger locations, but as a minimum, approaching traffic must have sufficient distance to stop at the intended stopping point.

For projects in New York flagger services are the responsibility of the contractor. For projects in New Jersey flagger services are provided by the Authority (PAPD). When flagging services are required at a signalized intersection these services must be provided by the Authority (PAPD).

3.2.2.14 TEMPORARY TRAFFIC BARRIER

The use of traffic barriers (vehicle strong barriers) such as temporary concrete barrier or water-filled barrier should be used in the following conditions:

- When a drop-off of 6" or greater is present within 5 feet of the travel lane
- When the lane closure will be in place for an extended period of time.

Where temporary concrete barrier is used to close lanes or shoulders, the closure must first be formed using channelizing devices with the appropriate taper length. Recommended minimum flare rates for concrete barrier are shown in the AASHTO Roadside Design Guide. If possible, the approach ends should be started behind an existing barrier beyond its deflection distance. If approach ends cannot be carried beyond the clear zone, the ends must be suitably treated by impact attenuators or sand barrel arrays. A minimum length of 80 feet should be used for concrete barrier and 200 feet for water filled barrier (or per manufacturer's instructions, if greater).

Water-filled barriers shall not be used where the design speed exceeds 45 MPH.

Water filled barriers should only be used where there is a clear area behind the barrier as per the deflection characteristics provided by the manufacturer.

3.2.2.15 TEMPORARY IMPACT ATTENUATORS

Temporary impact attenuators shield concrete barrier end sections and other rigid objects located within the clear zone in construction zones. For design guidance refer to the AASHTO Roadside Design Guide.

3.2.2.16 BACK-UP TRUCKS

When the use of vehicle strong barrier is not feasible, a back-up truck should be used. A back-up truck is a vehicle equipped with a truck-mounted impact attenuator located a short distance upstream from a slowly moving lane or shoulder closure area or is parked a short distance upstream from a stationary lane or shoulder work area. Back up trucks must be used to protect motorists and workers in stationary work areas adjacent to the highway, except when the work area is protected by vehicle strong barriers.

Back up trucks should be located in each of the lane(s) and/or shoulder in which the work area is located. They should be positioned a sufficient distance (a minimum of 30 feet for speeds 45 mph and under) upstream of the workers and/or equipment being protected to allow for the distance they will roll ahead upon impact, but not so far that an errant vehicle can travel around the back-up truck and strike the workers/equipment.

3.2.2.17 TEMPORARY PAVEMENT MARKINGS

Temporary pavement markings are used to delineate a temporary traffic pattern or when it is necessary to open a roadway that is under construction and the contractor is unable to install final pavement markings. Temporary pavement markings must comply with the MUTCD.

3.2.2.18 TEMPORARY TRAFFIC SIGNALS

A temporary traffic signal installation is defined as a fully functional traffic control device comprised in part or wholly of temporary traffic signal components. All temporary traffic signal installations must be designed in accordance with the MUTCD. Temporary traffic signals should be used in the following situations:

- When any portion of a permanent traffic signal is disrupted by construction activities
- When temporary traffic patterns need to be accommodated at a traffic signal location
- To control traffic and optimize capacity during all stages of a construction project

3.2.3 Permanent Construction

3.2.3.1 Signing

All roadway signs shall be in accordance with the latest version of the MUTCD. Guide signing on airport roadway facilities shall be in accordance with the PA Airport Roadway Sign Design Manual (Appendix B).Lighting of Overhead Sign Panels shall be in accordance with the following guide:

<table>
<tr><th>Facility</th><th>Overhead Sign Lighting Criteria</th><th>Additional Notes</th></tr>
<tr><td>Airports, Bus Terminals, and Port Facilities</td><td>All signs shall require lighting unless otherwise noted or directed by the Chief Traffic Engineer.</td><td rowspan="2">Recommendations for permanent sign panel installations:
1. All signs shall be fabricated using Type XI sheeting.
2. All signs which have a VMS incorporated within, or positioned above or below, shall not have lighting.</td></tr>
<tr><td>Tunnels and Bridges</td><td>The need for lighting shall be evaluated in accordance with current AASHTO Roadway Lighting Guide Criteria.</td></tr>
</table>

All low clearance signing shall be in accordance with Low Clearance Signing Guidelines (Appendix C).

3.2.3.2 Pavement Markings

All pavement markings shall be in accordance with the Pavement Marking Design Guidelines (PA) (Appendix D).

3.2.3.3 Guiderail

All guiderail design shall be in accordance with the Roadside and Median Barrier Design Guide (PA) (Appendix E).

3.2.3.4 Barriers

Traffic barrier design shall be in accordance with the Roadside and Median Barrier Design Guide (PA) (Appendix E).

3.2.3.5 Delineation Devices and Markers

3.2.3.5.1 Delineator Spacing Guidelines

Delineators mounted on roadside or median barrier shall be spaced to allow the maximum benefit to the driver under all types of weather conditions. The following guide is recommended:

Side Mounted				
Straight Road	Left Curves	Right Curves	Verticals	Limited Visibility
75-100 Ft	40-50 Ft	75-100 Ft	40-50 Ft	40-50 Ft
Top Mounted				
Straight Road	Left Curves	Right Curves	Verticals	Limited Visibility
75-100 Ft	40-50 Ft	75-100 Ft	60-80 Ft	40-50 Ft

3.2.3.6 ITS

All ITS design shall be in accordance with the ITS Design Guidelines (PA) (Appendix F).

3.2.3.7 DYNAMIC MESSAGE SIGNS

All dynamic message signs shall be in accordance with the ITS Design Guidelines (PA) (Appendix F).

3.2.3.8 TRAFFIC SIGNALS

All traffic signal design shall be in accordance with the Traffic Signal Design Guidelines (PA) (Appendix G).

3.2.3.9 PEDESTRIAN AND BICYCLE ACCOMMODATIONS

All pedestrian and bicycle facilities design shall be in accordance with *the Guide for the Planning, Design, and Operation of Pedestrian Facilities, AASHTO,* and *Guide for the Development of Bicycle Facilities, AASHTO*

Pedestrian accommodations at signalized intersections shall be in accordance with the Traffic Signal Design Guidelines (PA).

3.2.3.10 ROADWAY ACCESS MANAGEMENT

All site design shall be in accordance with the Port Authority Roadway Access Management Guidelines (Appendix A).

4.0 DETAILS, NOTES, AND CUSTOM SPECIFICATIONS

4.1 DIVISION 1 MOT SPECIFICATION

Maintenance of Traffic and Work Area Protection Under “General Provisions” (Division 1) of the Specifications shall be included in all contracts requiring Maintenance of Traffic work. When utilized, the Division 1 MOT Specification (Appendix H) shall be edited to conform to project requirements. For work order contracts, the unedited Division 1 MOT Specification should be included in the parent work order contract and referenced in subsequent work orders.

4.2 STANDARD SPECIFICATIONS

The List of Specifications is as follows:

321723	THERMOPLASTIC REFLECTORIZED PAVEMENT MARKINGS
321728	PREFORMED REMOVABLE RETROREFLECTIVE PAVEMENT MARKING TAPE
321725	TRAFFIC PAINT PAVEMENT MARKINGS
347113	BOX BEAM GUIDE RAIL
347114	W-BEAM AND THRIE BEAM GUIDE RAIL
347115	TEMPORARY TRAFFIC BARRIERS
347117	TEMPORARY CONCRETE BARRIERS
347118	TEMPORARY TIMBER CURB
347121	TEMPORARY WATER FILLED BARRIER
344113	TEMPORARY TRAFFIC SIGNAL EQUIPMENT
347130	PLYWOOD SIGN PANELS AND WOOD SIGN POSTS
101423	ALUMINUM SIGN PANELS
260525	TRAFFIC SIGNAL CABLES
265522	VEHICULAR TRAFFIC SIGNAL HEADS AND MOUNTING HARDWARE
260547	TRAFFIC SIGNAL POLES, MAST ARMS, SPAN WIRE AND POLE FOUNDATIONS
344117	PEDESTRIAN TRAFFIC SIGNALS

344118 TRAFFIC SIGNAL CONTROLLER

262999 INDUCTIVE DETECTION CABLE AND DETECTOR SENSOR UNIT

344155 PREFORMED VEHICLE DETECTION LOOP

347155 VEHICLE DETECTION LOOP

261030 FIBEROPTIC CHANGEABLE MESSAGE SIGNS AND LANE CONTROL SIGNALS

5.0 APPENDICES

A. PA ROADWAY ACCESS MANAGEMENT GUIDELINES

B. PA AIRPORT ROADWAY DESIGN MANUAL

C. PA LOW CLEARANCE SIGNING GUIDELINES

D. PA PAVEMENT MARKING DESIGN GUIDELINES

E. PA ROADSIDE AND MEDIAN BARRIER DESIGN GUIDE

F. PA ITS DESIGN GUIDELINES

G. PA TRAFFIC SIGNAL DESIGN GUIDELINES

H. PA DIVISION 1 MAINTENANCE OF TRAFFIC SPECIFICATION

APPENDIX A

PA ROADWAY ACCESS MANAGEMENT GUIDELINES

Port Authority Roadway Access Management Guidelines

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THE PORT AUTHORITY OF NY & NJ

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PREAMBLE

Need for Roadway Access Management at Port Authority Facilities

The safe and efficient movement of people and goods at Port Authority facilities is critically important to the continued success and vitality of the Port Authority. Delays resulting from traffic congestion and crashes along Port Authority roadways increase both travel times and business costs for all users of these roadways, thereby undermining the operational efficiency of Port Authority facilities. Proper planning, design, and coordination help minimize such delays by promoting a safe and streamlined traveling environment, which helps to increase operational efficiency, maximize revenues, and reduce costs, liability, and crashes wherever operationally and financially feasible.

Many transportation agencies have recognized a need for increased *roadway access management* in response to these challenges. The purpose of roadway access management is to provide access to land development in a manner that preserves the safety and efficiency of the transportation system. As noted in the *Access Management Manual, Second Edition*, access management is defined as:

> *The coordinated planning, regulation, and design of access between roadways and land development. It involves the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway, as well as roadway design applications that affect access, such as median treatments and auxiliary lanes, and the appropriate separation of traffic signals*.[1]

One of the initiatives of the Chief Engineer is to develop an access management program for Port Authority facilities. To that end, these *Roadway Access Management Guidelines* were prepared to help incorporate access management concepts and methods into the agency's business practices in recognition of the agency's – and the region's – economic reliance on the efficient operation of Port Authority facilities. These *Guidelines* are consistent with the agency's Mission Statement:

> *To enhance the region's competitiveness and prosperity by providing transportation services that efficiently move people and goods within the region and facilitate access to the nation and the world.*

Access management has many dimensions at the Port Authority. It crosses organizational lines throughout the agency and involves staff from the line departments, Real Estate Services Department, Traffic Engineering, and other groups. It also affects consultants working on Port Authority projects, as well as tenants conducting day-to-day business on Port Authority property. Each of these groups has an important role in determining access outcomes and shaping the future vision for Port Authority facilities, whether through a lease negotiation with a tenant, the Tenant Construction and Alteration Process (TCAP), or a roadway improvement project initiated by the agency.

Because access management is multi-disciplinary and may influence the decisions of various individuals and groups, both within and outside of the Port Authority, it requires partnerships within the agency and a greater awareness of how the decisions of one group affect others. These individuals and groups must collaborate – both internally and externally – to manage access effectively and address potential problems proactively, preventing them from materializing later and, thereby, ensuring successful project outcomes.

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[1] *Access Management Manual, Second Edition*, Transportation Research Board, National Research Council, Washington D.C., 2014, p. 521.

Purpose of these Guidelines

Development activities and transportation improvement projects at Port Authority facilities often involve balancing traffic operations and safety with the needs of tenants. Access management provides the quantitative tools to successfully achieve this balance. In addition to providing detailed technical guidance, this document is intended to create synergy and promote successful project outcomes by providing an informed and structured approach to decision-making for use by and among the various organizational entities within the Port Authority. It is also intended to streamline the development process for tenants and their consultants by communicating the Port Authority's access management guidance, thereby improving the predictability of the development process and reducing the likelihood of tenant document revisions.

Because access management practices in the United States have been evolving based on research conducted over the past few decades, the concepts and methods set forth in this document represent the most recent research at a national level. This includes research published in the TRB *Access Management Manual*, as well as subsequent research efforts. Due to this evolution, some of the specific technical elements presented here may lead to different designs or decisions than previous experience would otherwise suggest. In all cases, however, this document tailors current national access management practices and strategies to specific applications at Port Authority facilities, while providing the Port Authority with an appropriate degree of flexibility needed both to accomplish its operational objectives and to accommodate future growth in a safe, efficient, and environmentally-sensitive manner.

Contents and Organization of these Guidelines

These *Roadway Access Management Guidelines* provide both general guidance for all Port Authority staff and detailed technical guidance for planning and engineering professionals. This includes Port Authority staff involved with TAA reviews, design of improvement projects, and day-to-day operations, as well as consultant engineering staff hired by tenants to prepare TAA design packages. This document was prepared to reflect the fact that its users have diverse backgrounds with a range of familiarity with access management principles, concepts, and techniques. For this reason, the specific technical guidelines presented in each chapter are preceded with an overview that provides background information, introduces basic concepts, and provides an educational framework for the technical guidelines that follow. This document provides:

1) An introduction to access management, including objectives, principles, and benefits;
2) A discussion of the role of access management in Port Authority business practices;
3) A description, and associated maps, of the roadway access classification system that has been established for Port Authority facilities;
4) Detailed engineering design guidance for the following areas:
   - Roadway cross-sectional elements
   - Unsignalized driveway spacing
   - Intersection corner clearance (spacing of driveways from intersections)
   - Traffic signal spacing
   - Access in the vicinity of interchanges
   - Driveway design

- Roadside buffers
- Intersection sight distance
- Auxiliary lanes, including exclusive left-turn and right-turn lanes

For each of the bulleted items above, the guidelines in the following chapters provide both Desirable and Minimum numerical values. The user is expected to meet or exceed the Desirable values. Where the user wants to use any value less than the Desirable value, a design exception is needed from the Chief Engineer for the applicable discipline.

5) A discussion of property access strategies and access management efficacy; and
6) General approval criteria and procedures for design exceptions when there is a perceived need to deviate from the established engineering design guidance described in this document, as indicated by the use of the verb "should."

Key words to apply these Guidelines

In these *Guidelines* the following terms are used:

- "Shall" – indicates a required or mandatory action.
- "Should" – indicates guidance of recommended practice, with deviations allowed by the Chief Engineer of the relevant discipline, using the design exception procedure.
- "May" – indicates a statement of practice that is a permissive condition.

Future Editions

This document is intended to be a "living document." As such, it will be revised periodically by the Port Authority to reflect new research and lessons learned through the course of its application.

CHAPTER 1: INTRODUCTION TO ROADWAY ACCESS MANAGEMENT

1.1 What is Roadway Access Management?

Roadway access management is defined as:

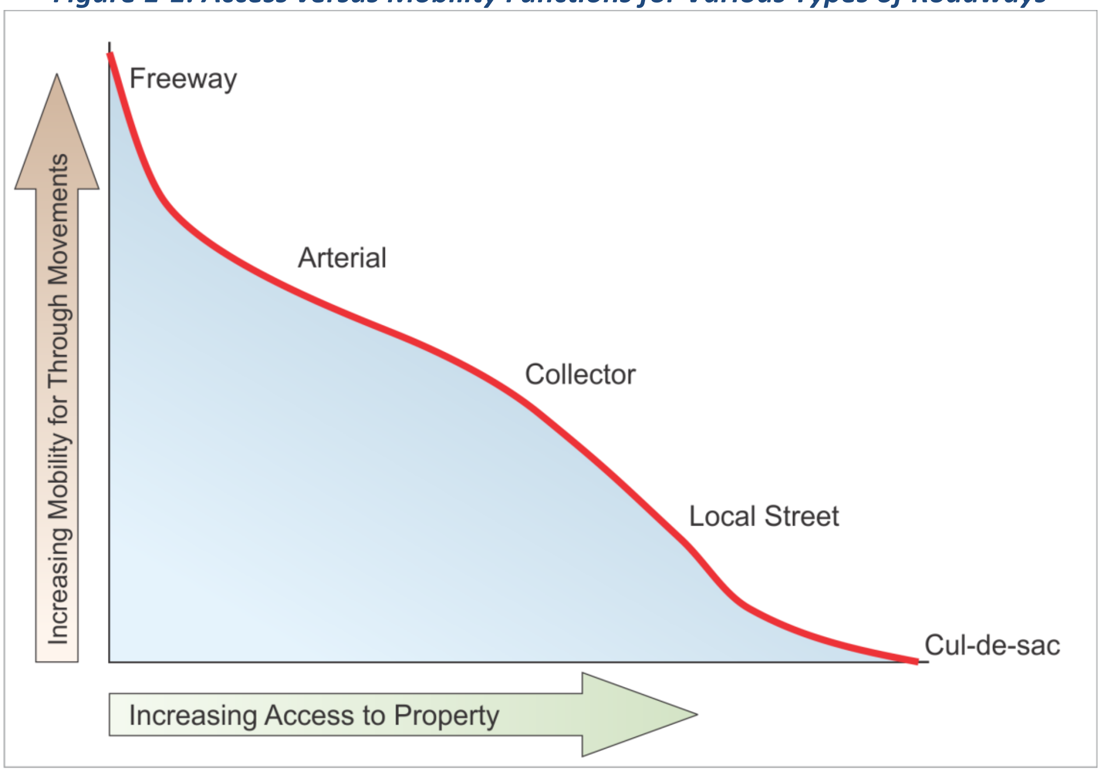
> *…the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. It also involves roadway design applications, such as median treatments and auxiliary lanes, and the appropriate spacing of traffic signals.*[2]

The purpose of roadway access management is to provide access to land development in a manner that preserves the safety and efficiency of the transportation system. The contemporary practice of access management extends the concept of access design and location to all roadways – not just limited-access highways or freeways.

Contemporary access management is a systematic way to implement the roadway functional hierarchy that is implicit in the structure of most surface transportation networks serving large areas of developed or developable land. As part of access management, roadways are classified by function on the basis of the priority given to land access versus through-traffic movement (see *Figure 1-1*).

As *Figure 1-1* shows, each roadway classification has a unique mix of mobility function and access function. At one end of the spectrum are freeways, which represent the highest classification of roadways in the transportation network. Freeways primarily serve a through-traffic mobility function and have the lowest property access function because access is typically limited to grade-separated interchanges with other freeways, arterials, and other higher classification roadways.

Figure 1-1: Access versus Mobility Functions for Various Types of Roadways



[2] Source: *Access Management Manual*, *First Edition*, Transportation Research Board, National Research Council, Washington D.C., *2003*.

At the other end of the spectrum are cul-de-sacs, which represent the lowest classification of roadways in the transportation network. Cul-de-sacs primarily exist to serve a direct property access function (to abutting residences or businesses) and – by virtue of their dead-end nature – accommodate no through traffic mobility function.

In between these two extremes (i.e., freeway and cul-de-sacs) are arterials, collectors, and local roads. These roadways serve both mobility and access functions, but in varying degrees as shown in *Figure 1-1*. Limiting access along arterials and other primary roads is extremely important. Drivers on these roads anticipate moving quickly with little or no congestion. Although these roadways may also need to accommodate access to adjacent properties, numerous closely-spaced driveways can result in traffic congestion and collisions. Access management is also necessary on lower-level roadways including collectors and local streets, where the roadway's mobility function is less important than on an arterial, but a greater degree of property access is required.

It is important to understand that the degree of access management varies not only with the functions and traffic characteristics of a roadway, but also with the character of the abutting land and the long-term planning objectives. More restrictive access management standards may be desirable on one arterial roadway, and less restrictive standards may be more appropriate on another. In addition, some major roadways may serve a mix of competing functions that are difficult to reconcile and that may require special design treatments or access management measures.

1.2 Access Management Objectives

To achieve the broad goal of accommodating access safely and efficiently, the Port Authority seeks to manage the location, design, and type of property access from its roadway facilities. Specific objectives of this effort include the following:

- Reduce traffic congestion
- Maintain traffic flow
- Reduce frequency and severity of crashes
- Reduce fuel consumption and vehicle emissions
- Preserve existing roadway capacity
- Accommodate pedestrians, bicyclists, and transit vehicles
- Support economic growth
- Provide access to businesses and tenant leaseholds
- Maintain or improve property values
- Preserve the Port Authority's investment in its transportation infrastructure

The key to achieving the Port Authority's objectives is the application of the following access management techniques, which are fully described in the subsequent chapters of these *Guidelines*:

- Consolidate and limit (where necessary) access along the Port Authority roadway system
- Promote development of an interconnected roadway system
- Promote sharing of property access to the roadway system

- Promote efficient circulation in Port Authority facilities

The primary goal is to create a system of interconnected roadways at each Port Authority facility that functions safely and efficiently for its useful life. Additionally, proper application of access management techniques helps promote safe and convenient access to land uses for businesses and travelers as well as more cost-efficiency in the Port Authority use of roadway funds.

1.3 Basic Access Management Principles

The application of basic access management principles can accomplish the objectives listed above. These principles are founded on an understanding of the different needs of the drivers using the roadway network, knowledge of which roadway elements cause the greatest conflicts, appreciation of the concerns of tenants and the Port Authority, and expertise in applying traffic engineering/access management techniques to these, at times, contradictory desires. Basic access management principles include the following:

1.3.1 Develop a Specialized Roadway Access Classification System

Because different types of roadways serve different functions relative to access and mobility, as described above, it is important to design and manage roadways according to their primary functions. In this way, proper balance can be achieved between traffic flow and access to abutting property, improving roadway operations.

1.3.2 Limit Direct Access to Major Roadways

Roadways that serve high volumes of through traffic, such as freeways and arterials, need a high level of access management to preserve their traffic movement function. On the other hand, frequent and direct property access is more compatible with the function of local and collector roadways. The underlying principle here is that direct access to a major roadway is not required when other access options are available.

1.3.3 Promote Roadway and Intersection Hierarchy

An efficient transportation network provides appropriate transitions from one classification of roadway to another. For example, freeways connect to arterials through an interchange that is designed appropriately for the transition. This concept also extends to surface streets, resulting in a series of intersection types that range from the junction of two principal arterial roadways to a tenant driveway connecting to a local street. The more important the mobility function of the roadway (i.e., the higher its classification), the higher the degree of access management that should be applied so that the roadway continues to perform according to its designed function.

1.3.4 Locate Signals in Accordance with Desired Signal Control Strategies

Along roadways where the progression of through traffic is the prevailing signal control strategy, long, uniform spacing of intersections and signals enhances the ability to coordinate signals and enables the continuous movement of traffic at the desired speed. Establishing a minimum bandwidth at coordinated traffic signals along a roadway helps to provide an orderly progression of through traffic from one intersection to the next. On the other hand, poor signal placement may lead to delays that cannot be overcome by signal timing or phasing changes. In addition, failure to carefully locate access connections or median openings that may later become signalized can cause substantial increases in arterial travel times.

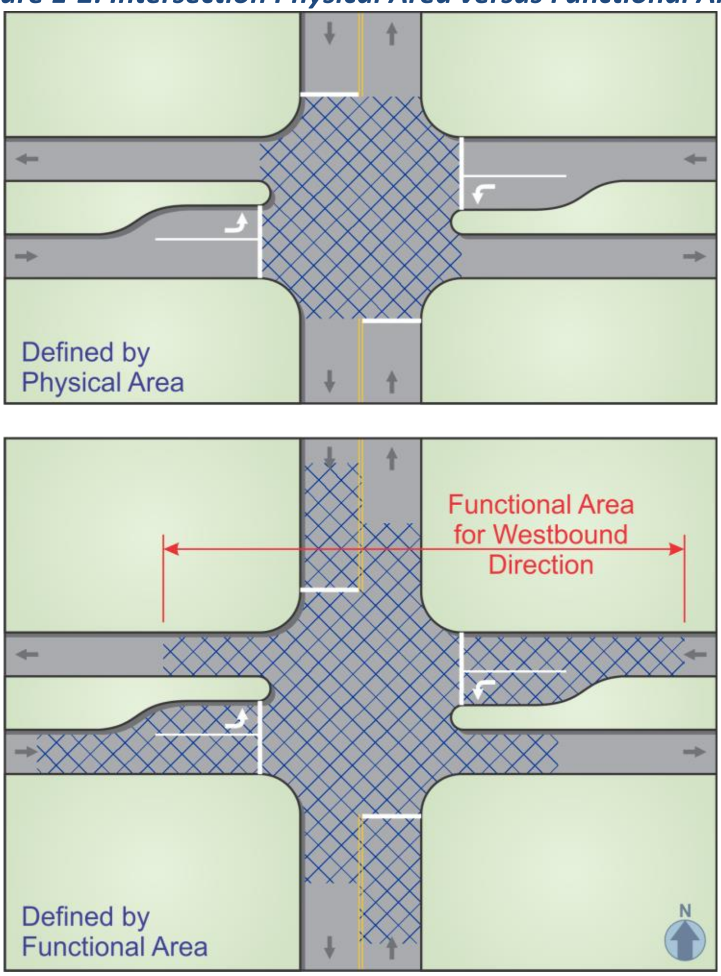
In cases where roadways already have existing traffic signals spaced relatively close to one another, the prevailing signal control strategy may be to manage the signal timing and phasing sequences so that vehicle queues do not spill back from one intersection to the next, obstructing the movement of traffic. Requests for new traffic signals under these circumstances must be analyzed considering this control strategy.

In yet another circumstance, the prevailing signal control strategy may be to accommodate high volumes of pedestrian movements – for example, across an airport terminal frontage roadway to an adjacent parking garage. In this situation, traffic signals must be located and operated with the priority given to the movement of pedestrians rather than the progression of through traffic.

1.3.5 Preserve the Functional Area of Intersections

To maximize the safe and efficient operation of an intersection, it is essential to preserve its functional area. The functional area extends beyond the physical junction of the intersecting roadways (see *Figure 1-2*). This functional area includes the approaches and vehicle departure areas where motorists are responding to the traffic control devices at the intersection by accelerating, decelerating, and maneuvering into the appropriate lane to stop or complete a turn. Access driveways located within these functional areas can cause motorist confusion and traffic conflicts that impair the function of the intersecting roadways.

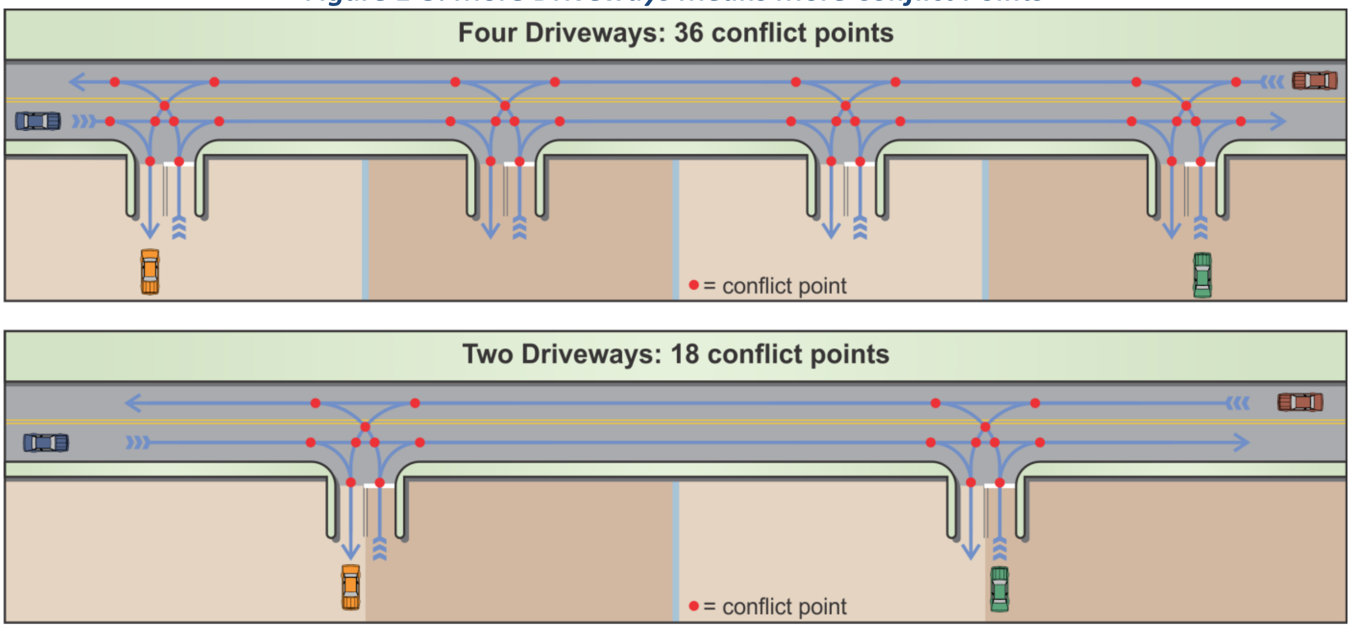
Figure 1-2: Intersection Physical Area versus Functional Area



1.3.6 Limit the Number of Driveways and Other Conflict Points

Drivers make more mistakes and are more likely to have collisions when they are presented with complex driving situations created by numerous conflicts. Simplifying the driving task, by limiting the number of driveways along a roadway – and the associated conflict points facing a motorist – contributes to improved traffic operations and fewer collisions. As shown in *Figure 1-3*, the roadway segment with four driveways has twice as many potential conflict points as the same roadway segment with only two driveways.

Figure 1-3: More Driveways Means More Conflict Points



Furthermore, the number of potential conflicts increases substantially when pedestrian and bicycle movements are considered as well. Therefore, a less complex driving environment is accomplished by limiting the number of driveways and the resultant number of conflict points between vehicles, vehicles and pedestrians, and vehicles and bicyclists.

1.3.7 Separate Driveways and Other Conflict Points

Drivers need sufficient time to address one set of conflicts before facing another. Thus, to provide drivers adequate perception and reaction time, the necessary spacing between conflict areas must increase as travel speeds increase. Separating conflict areas helps to simplify the driving task and contributes to improved traffic operations and lower crash frequency.

1.3.8 Remove Turning Vehicles from Through Traffic Lanes

Left-turn and right-turn lanes allow drivers to decelerate gradually out of the through lane and wait in a protected area for an opportunity to complete a turn, thereby reducing the severity and duration of conflicts between turning vehicles and through traffic. Similarly, adequate deceleration distances allow drivers to transition their travel speeds gradually when leaving the through traffic stream. The separation of turning and through traffic reduces crash frequency and improves efficiency.

1.3.9 Use Non-Traversable Medians to Manage Left-Turn Movements

Non-traversable medians channel left-turn turning movements to designated locations. Non-traversable medians that minimize left-turns or reduce the driver workload can be especially effective in reducing crash frequency. As shown in *Figure 1-4*, the four-leg intersection with all traffic movements allowed results in a total of 36 conflict points associated with the various crossing, merging, or diverging movements. On the other hand, as shown in *Figure 1-5*, a three-leg intersection with a non-traversable median limits the number of conflict points to only six when left-turns are allowed from the roadway to the driveway via a median opening and only two points when no left-turns are allowed (no median opening). Non-traversable medians also eliminate head-on collisions between traffic moving in opposite directions along a roadway. Full median openings – allowing left-turns from either direction on all approaches – must be analyzed on a case-by-case basis.

Figure 1-4: Conflicts at Four-Leg Full-Movement Intersection

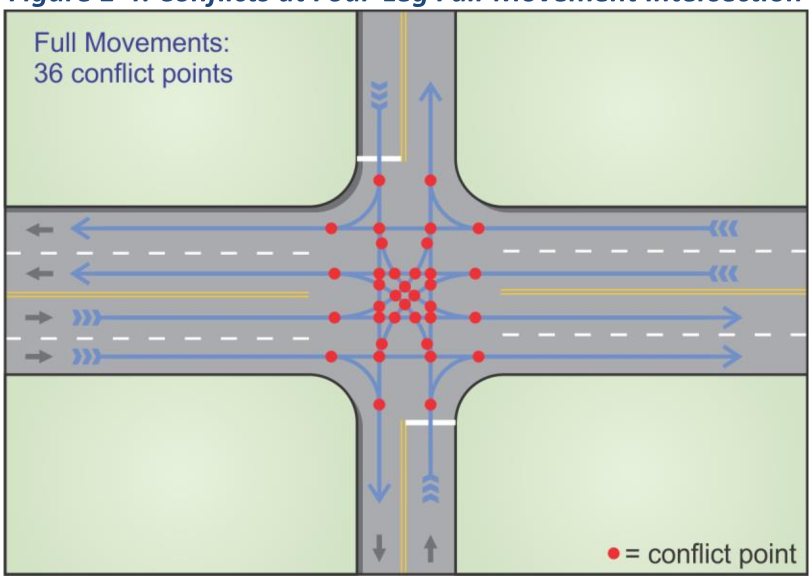
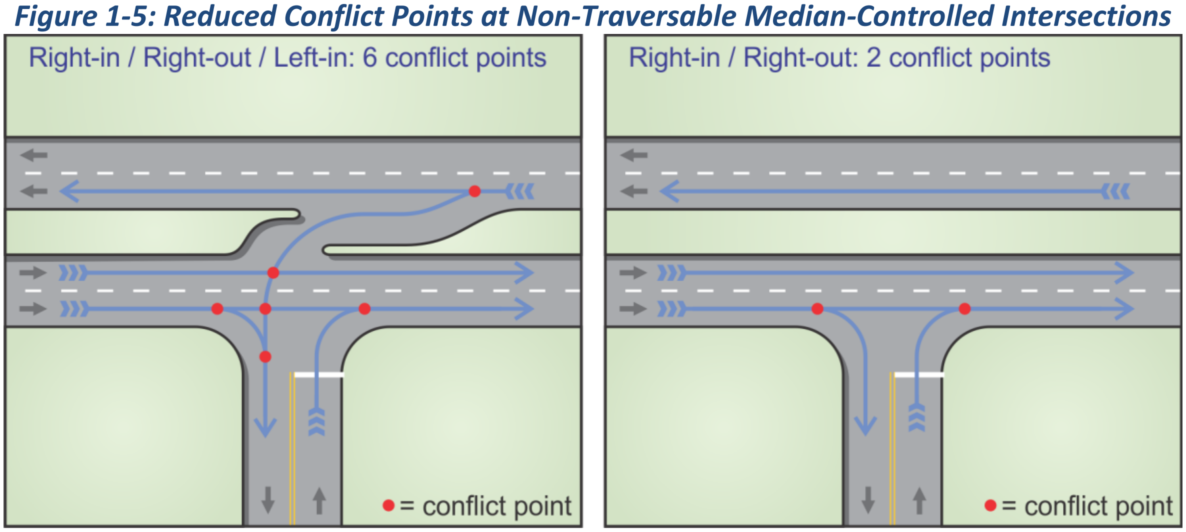


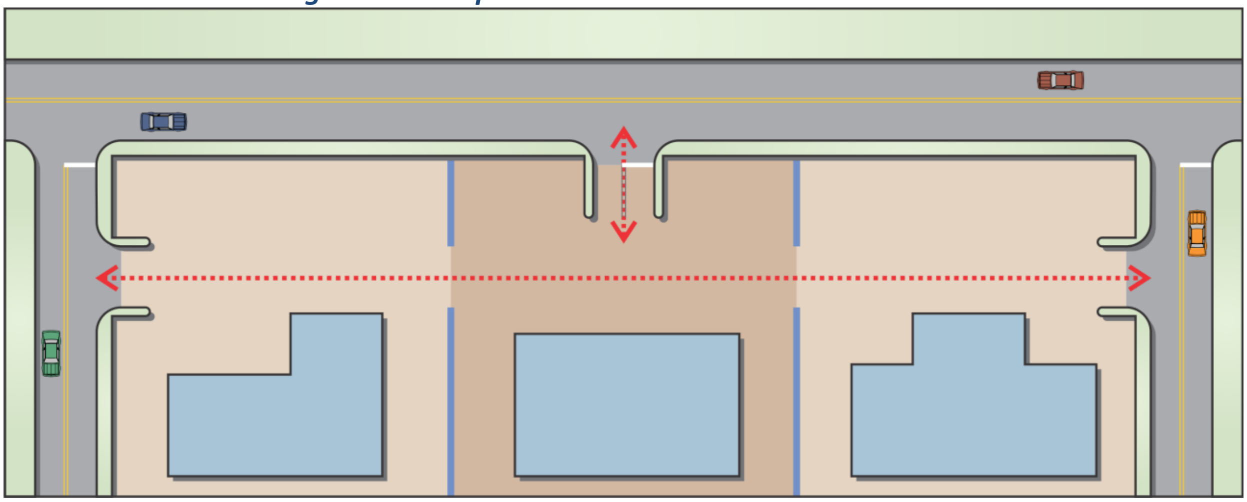
Figure 1-5: Reduced Conflict Points at Non-Traversable Median-Controlled Intersections



1.3.10 Provide a Supporting Street System and On-Site Circulation Systems

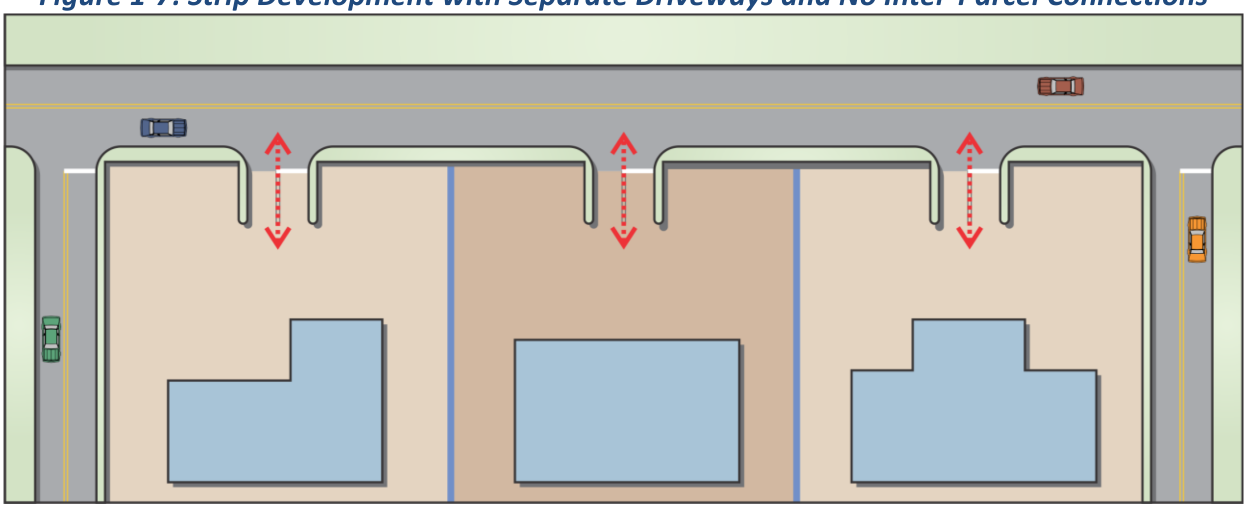
Access connections between adjacent parcels or leaseholds – as well as an interconnected network of supporting roadways – are beneficial in maintaining efficient traffic flow. A well-planned transportation system provides a supporting network of streets and direct inter-parcel connections (see *Figure 1-6*) to accommodate future development or redevelopment. Interconnected roadway networks and on-site circulation systems provide routes for motorists, pedestrians, and bicyclists that are alternatives to using the primary roadways.

Figure 1-6: Properties with Inter-Parcel Connections



Conversely, "strip development" (see *Figure 1-7*) with separate driveways for each business creates very short distances between access points on the roadway, impeding mobility and increasing crash frequency along that roadway.

Figure 1-7: Strip Development with Separate Driveways and No Inter-Parcel Connections



1.3.11 Match Driveway Design with Operational Needs

Driveways accommodate a wide range of vehicle types, traffic volumes, and vehicle turning speeds. For example, a short curb-return radius cannot efficiently accommodate the large trucks or the high-speed traffic expected on an arterial, but it may be an acceptable design treatment in lower-speed areas where only passenger cars and single-unit trucks are expected, or where there is a desire to shorten the pedestrian crossing distance. Consequently, driveway design should be tailored to meet the needs of all users of the driveway, considering trade-offs in the design features related to motorists, pedestrians, and bicyclists.

1.4 General Strategies for Implementing Access Management

Because independent implementation of access management by one person or group is impossible to achieve, coordination and collaboration are essential. Effective access management is never accomplished by one person or group independently. To optimize the benefits of access management, coordination and cooperation with appropriate stakeholders (including Port Authority staff, tenants and leaseholders, and consultants) is essential when initiating planning for a TAA project or undertaking a new roadway improvement. In addition, intra-agency coordination is critical when applying access management standards relative to a lease negotiation.

The effective application of access management is also greatly enhanced by on-going education and training activities to inform consultants, tenants, and staff from throughout the agency about the benefits of access management, the principles and techniques for successful application, and implementation activities.

Furthermore, the benefits of access management are realized most effectively when the techniques and strategies are considered early in the conceptual planning stages of a project, before key decisions about roadway alignments, building locations, access locations, and other aspects of a project are made. Once these key decisions are made, and a project has advanced beyond the planning stage (e.g., into design), it is more costly, time-consuming, and disruptive for everyone involved to go back and revise plans to incorporate recommended changes. Even worse, once a project is constructed, the costs to reconstruct a site or retrofit a roadway to make improvements in response to safety or operational issues that materialize after construction are quite often prohibitive.

1.5 Benefits of Access Management

Roadways are an important resource, costly to build, to maintain, to improve, and to replace. Because of this, it is simply not practical to allow roadways to deteriorate due to poor access management under the assumption that they will be replaced or reconstructed in the future. This is why effective management of the transportation system is essential.

By managing roadway access, the Port Authority can extend the life of its roadways, improve public safety, reduce traffic congestion, and improve the appearance and quality of its built environment. Access management not only preserves the transportation functions of roadways but also helps preserve long-term property value and the economic viability of abutting development. From an environmental perspective, improved traffic flow translates into greater fuel efficiency, reduced vehicular emissions, and a smaller carbon footprint.

Proper access management practices at Port Authority facilities will benefit many groups in several different ways. These include the following:

- The **Port Authority** benefits from a lower cost of delivering an efficient and safe transportation system, greater effectiveness in accomplishing transportation objectives, and reduced capital improvement costs associated with new or reconstructed roadways;
- **Tenants** are served by a more efficient roadway system that captures a broader market area, and they also benefit from stable property values due to a well-managed roadway network. In addition, they experience a more predictable and consistent development environment;
- **Freight carriers** benefit from reduced delay and crash frequency, resulting in lower transportation costs and shorter delivery times;

- **Motorists** face fewer decision points and traffic conflicts, simplifying the driving task, lessening congestion, and reducing crash frequency;
- **Pedestrians and cyclists** deal with fewer conflicts where motorists access the roadway, thereby improving the environment for walking and bicycling; and
- **Transit riders** experience reduced delay and reduced travel times.

Considerable research and experience from around the United States over the last several decades has demonstrated the traffic safety and operational benefits of access management. The benefits, however, extend beyond those to also include economic, environmental, system preservation, and aesthetic benefits. Results of national research are summarized in both the *Access Management Manual* and *NCHRP Report 420: Impacts of Access Management Techniques*.

CHAPTER 2: THE ROLE OF ROADWAY ACCESS MANAGEMENT IN PORT AUTHORITY BUSINESS PRACTICES

2.1 Overview of the Port Authority

The Port Authority plans, builds, operates, and maintains infrastructure critical to the New York / New Jersey region's trade and transportation network. These facilities include the nation's busiest airport system, marine terminals and ports, the Port Authority Trans-Hudson (PATH) rail transit system, six tunnels and bridges between New York and New Jersey, the Port Authority Bus Terminal in Manhattan, and the World Trade Center. Providing ingress to, egress from, and circulation within each facility is an extensive and complex roadway network, for which the Port Authority is also responsible. For more than eight decades, the Port Authority has worked to improve the quality of life for the more than 17 million people who live and work in New York and New Jersey.[3]

The agency's area of jurisdiction is called the Port District, a region within a radius of approximately 25 miles from the Statue of Liberty. The Port Authority was created to promote and protect the commerce of the Port District and to undertake port and regional improvements not likely to be financed by private enterprise, or that would not be attempted by either State alone. These include the development of major infrastructure: a modern port for the harbor shared by the two states, tunnel and bridge connections between the states, and, in general, trade and transportation projects that secure the region's economic well-being. The Port Authority's goal, as articulated in its mission statement, is "…to enhance the region's competitiveness and prosperity by providing transportation services that efficiently move people and goods within the region and facilitate access to the nation and the world."

2.2 Tenant Transportation and Access Needs at Port Authority Facilities

To help achieve the goals and objectives of its mission, the Port Authority leases portions of its property to tenants at the agency's various port and airport facilities. At port facilities, tenants typically move and store containers and large pieces of equipment, as well as process and move goods to, from, and within their leaseholds. The agency's airport facilities include airline, delivery service, and rental car tenants, and accommodate the movement of aircraft, allow for customer arrivals and departures, and provide adequate parking. These tenants are critical revenue-generating customers for the Port Authority.

Tenant activities and land uses also generate transportation needs and demands that must be accommodated. Both port and airport facilities must provide transportation infrastructure to meet the travel demands generated by tenants and customers who may choose to drive, walk, use public transportation, bicycle, or be dropped-off.

Furthermore, the need for access to and from specific tenant leaseholds must be balanced with the need for mobility for all users of the transportation network within a given Port Authority facility. At each facility, there are competing needs for space among various transportation modes and vehicle types: passenger cars, trucks, pedestrians, transit vehicles, and bicyclists. Most, if not all, of these user groups and vehicle types must be accommodated within the available right-of-way on many Port Authority roadways.

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[3] Source: Port Authority website, February 15, 2012: http://www.panynj.gov/about/facilities-services.html

- **Streamlined Business Operations** – All businesses are concerned with their own financial bottom line, which is based in part on how quickly and efficiently they can move their goods and satisfy the needs of their customers. Access management allows the Port Authority to help tenants to accomplish those goals.
- **Preserved Value of Port Authority's Investment in the Transportation System** – Access management helps maximize the value of capital improvements constructed by the Port Authority at its facilities by minimizing the probability that they might be needlessly consumed and degraded over time by inefficient operations. This enables the agency to maximize the value from its investment in the transportation system.
- **Reduced Environmental Impacts** – The traffic operational benefits of access management also help reduce vehicular emissions and pollution, reduce fuel consumption, and promote energy efficiency and sustainability. These actions help the agency move toward its carbon neutrality goals.

2.3 Including Access Management in the Transportation Planning Process

Implementing roadway access management at the Port Authority also involves including access management in the preparation of transportation master plans and/or sub-area plans. It may also involve conducting specific transportation studies at the request of Port Authority Engineering. The following sub-sections provide guidance with respect to each of these project types.

2.3.1 Preparing a Transportation Master Plan

A *transportation master plan* is a system-wide transportation plan for an entire Port Authority facility, prepared to accommodate projected changes in land development patterns and provide a supporting transportation system. Its purpose is to establish a strategy for providing reasonable access to all properties, while restoring or preserving the integrity of the transportation system, through careful consideration of access management principles. The primary benefit of having such a plan is that it lays the foundation for correcting existing access management problems and preventing others from occurring in the future. It also helps implement access management at a system-wide level and provide a framework for the consistent application of access management throughout the facility. *Table 2-2* illustrates a conceptual sequence for the preparation of a transportation master plan that reflects the needs of motorists, pedestrians, bicyclists, and transit users.

Even if a transportation master plan does not exist and circumstances do not allow for its creation, *Table 2-2* provides a framework or flow chart for applying the access management guidelines in this document.

Table 2-2: Framework for Preparing a Transportation Master Plan

Step No.	Task
1	Identify the Port Authority facility under consideration.
2	Identify the modes of transportation that will be accommodated at the facility in the master plan.
3	Identify existing and/or proposed freeways and interchanges that will be used to access this facility.
4	Identify existing and/or proposed arterial roadways that connect these interchanges with the facility.
5	Identify existing and/or proposed bicycle facilities and transit services that will be used to access the facility.
6	Identify desirable locations for signalized intersections on these arterial roadways.
7	Locate (or relocate) signalized intersections as close to the desirable locations as possible. [Note: Proper location and spacing of traffic signals is one of the most important decisions in access management due to the impact that signal location has on traffic progression along the corridor.]
8	Layout existing and proposed walkways, bicycle trails, and vehicular roadways as a supporting grid. A. Identify roadway classifications for each roadway. B. Plan access to land in the vicinity of interchanges. C. Identify walkway network for pedestrians, including missing links to be completed.
9	Determine existing and future roadway cross-sections to accommodate the applicable modes of travel. A. Even if traffic volumes are low and development densities are low, strongly consider non-traversable medians on principal arterial, arterial and collector roadways. B. Plan the site-access and circulation patterns based on roadway cross-sections, reflecting the needs

	of motorists, pedestrians, bicyclists, and transit users [Note: Having a cross-section with a non-traversable median is one of the most important decisions in access management. The installation of a non-traversable median precludes direct left-turns into and out of driveways. Left-turns are associated with 74 percent of driveway-related crashes.]
10	Provide the appropriate roadside buffer on all roadways based on future needs and volumes.
11	Identify desired driveway locations using guidelines.
12	Identify locations for left-turn and right-turn lanes.

2.3.2 Preparing a Sub-Area Plan

Although having a transportation master plan is desirable, circumstances may exist where one is not available and access management will need to be applied in the absence of such a plan. In these situations, the development and application of a *sub-area plan* is important. A sub-area plan is a transportation plan that addresses mobility and access needs, including pedestrian, bicycle, and transit accommodations and mobility for a specific area of a Port Authority facility. The sub-area may include one or more tenant leaseholds within a Port Authority facility and/or one or more roadways.

Like a transportation master plan, a sub-area plan provides a framework for the consistent application of access management to accommodate potential changes in land development patterns. A sub-area plan is useful for dealing with specific areas of a facility that are undeveloped or areas where redevelopment is possible. It may address the leaseholds occupied by one or more tenants, the adjacent roadways, and access to those roadways. It may also address areas within a Port Authority facility having roadways that are programmed for improvement or driveways that need to be consolidated or realigned. A sub-area plan may be prepared as an integral component of a transportation master plan or as an independent effort; in either case, it should incorporate provisions for coordination of future growth with improvement of the roadway network.

2.3.3 Scoping Transportation Studies

In some instances, Port Authority Engineering may request the preparation of a formal traffic or transportation study, requiring field data collection, crash history and/or operational analyses, and written documentation of findings. Although the specific scope of each traffic/transportation study should be tailored to the needs of the project, the following sub-section presents a broad listing of potential scope items that may need to be studied.

The following is a model scope of work for transportation studies needed as part of a site-specific development or a redevelopment program. It is intended as a reference to support a team conceptual planning meeting with Port Authority Engineering. The actual detailed scope of work would be a product of this meeting, and include any or all of the following work items:

- **Preliminary Transportation Assessment**
    - Identify project characteristics: land uses, sizes
    - Provide conceptual sketch of site layout, including potential location and configuration of:
        - Buildings
        - Access driveways to the subject property or properties, including traffic control devices (e.g., STOP signs, traffic signals, etc.) and allowable vehicle movements (e.g., left-turns, through movements, and right-turns).
        - Sidewalks
        - Drive aisles and parking spaces
        - Drive-through locations
        - Bicycle facilities and accommodations (e.g. bicycle parking)

        - Security booths
        - Other items
    - Define design vehicle and its parameters
    - Identify signing requirements
    - Identify potential transportation safety and operations issues, and recommended solutions, including those related to pedestrian and bicycle network connectivity

- **Transportation Operations Impact Analysis**
    - Scoping
        - Identify critical peak hours for study
        - Identify build (horizon) year(s)
        - Prepare trip generation estimate (mode split, person-trips, vehicle-trips)
        - Prepare trip distribution estimate
        - Prepare trip assignment
        - Identify interchange and/or intersection study locations
        - Identify crosswalk, sidewalk, and street-corner study locations
        - Identify Measures of Effectiveness (MOEs) for analysis
    - Existing Conditions Analysis
        - Identify existing conditions data needed
        - Conduct 24-hour Automatic Traffic Recorder (ATR) volume counts
        - Conduct intersection turning movement counts
        - Conduct pedestrian movement counts
        - Conduct bicycle movement counts
        - Prepare volume flow diagrams
        - Conduct operational analyses
        - Identify existing operations and crash history issues
    - Future Conditions No-Build Analysis
        - Identify soft sites and associated vehicle, pedestrian, and bicycle traffic volumes
        - Identify background traffic growth factor
        - Estimate future No-Build volumes
        - Conduct operational analyses
    - Future Conditions Build Analysis
        - Superimpose project-generated vehicle, pedestrian and bicycle traffic on future No-Build volumes
        - Conduct operational analyses
        - Identify potential project-related impacts
        - Identify, analyze, and recommend mitigation measures
    - Other Analyses
        - Transportation Crash History Analysis (see below)
        - Traffic Signal Warrant Analysis (see below)
        - Intersection sight distance analysis (see below)
        - Arterial operational analysis
        - Freeway weaving analysis
        - Assessment of vehicle turning paths and horizontal driveway profile
        - Assessment of vertical driveway profile
        - Assessment of connectivity of pedestrian facilities (e.g. sidewalks and pedestrian paths)
        - Assessment of bicycle access and connectivity to the local and regional roadway and bicycle networks

- **Crash History Analysis**
    - Summarize crash data for most recent 3- to 5-year period by:
        - Crash type (i.e., rear-end, left-turn, etc.)
        - Crash participants (i.e., motorist, pedestrian, bicyclist, etc.)

    - Crash severity (i.e., fatality, injury, property damage only), and
    - Prevailing conditions (i.e., pavement conditions, weather conditions, etc.)
  - Prepare collision diagrams
  - Identify key factors contributing to crashes
  - Recommend crash countermeasures / safety improvements

- **Traffic Signal Warrant Analysis**
  - Refer to guidance and procedures in the [Port Authority] *Intersection Signalization Procedures* for traffic signal warrant analyses

- **Other Transportation Analyses, Studies, and Surveys**
  - Intersection sight distance analysis
    - Field measurement of existing sight distance
    - Calculation of needed sight distance
  - Travel time survey
  - Vehicle speed survey
  - Origin-destination survey
  - Vehicle classification survey
  - Queuing analysis
    - Signalized and unsignalized intersections
    - Access driveways
    - Toll booths
    - Access gates (entry and exit)
  - Parking studies
    - Existing parking utilization
    - Existing parking duration and turnover
    - Future parking demand projections
  - Travel behavior surveys
    - Mode split survey
    - Origin-destination survey (verbal)
    - Pass-by trip rate or linked-trip rate surveys

2.4 Applying Roadway Access Management Guidelines at Port Authority Facilities

The Port Authority's facilities are constantly undergoing changes. These changes could be related to tenant alterations, roadway improvement projects, new development and redevelopment actions for specific sites and tenants, and large redevelopment programs for a facility. During the course of these projects, design decisions need to be made regarding the proper location and design for a driveway or intersection, as well as what type of traffic control (e.g., traffic signal, stop-control, etc.) is most suitable at the location. In addition, there are decisions regarding where channelization features and non-traversable medians should be installed, where breaks in non-traversable medians should be located, how much sight distance is needed, and what is the necessary width of the roadside buffer.

The roadway access management guidelines contained in the following chapters of this document have been established to help identify these options and develop the best solutions to a range of possible access management-related issues. The guidelines reflect the functional hierarchy (i.e., the level of importance) of the individual roadways at Port Authority facilities and are intended to be applied as the opportunities to make access-related changes at Port Authority facilities arise over time.

Table 2-3 presents an overview on how to apply sequentially the guidelines in this document at a Port Authority facility. The sequence shown in *Table 2-3* should be taken as development or redevelopment occurs in accordance with the decisions made at the team conceptual planning meeting.

Table 2-3: Process for Applying Roadway Access Management Guidelines

Step Number	Tasks
1	Consult and use the transportation master plan and/or the applicable sub-area plans, if available
2	Identify the access classification of existing and proposed roadways
3	Determine preliminary cross-sections and roadside buffers for existing and proposed roadways
4	Locate intersections and driveways at desired locations
5	Provide for proper intersection sight distance
6	Design driveways, including left-turn and right-turn lanes
7	Only as a last resort, consider requesting a design exception from these *Guidelines*

2.5 References to Guidelines in Other Port Authority Documents

These *Guidelines* have also been integrated into other Port Authority documents, by reference, to reinforce their application throughout the agency. *Table 2-4* identifies references to these *Guidelines* in other Port Authority documents.

Table 2-4: References to Other Port Authority Documents

Document
Tenant Construction and Alteration Process (TCAP) Manual
Tenant Construction Review Manual
Traffic Engineering Design Guidelines

CHAPTER 3: ROADWAY ACCESS CLASSIFICATION SYSTEM

3.1 Overview

A roadway *access classification system* (ACS) is typically used to establish the level of allowable access for roadways of varying levels of importance in the transportation system. An ACS is a hierarchy of access categories that forms the basis for the application of access management to all roadways.[4] Each access category has related criteria governing the access-related standards and characteristics for corresponding roadways. These access categories ultimately define where access can be allowed on the roadway system and abutting properties, and where it should be denied or discouraged. For purposes of applying access management to Port Authority facilities, an ACS was established. This chapter provides a description of the ACS and presents the associated access category assignments at Port Authority facilities.

3.2 Access Classification System for Port Authority Roadways

Table 3-1 provides an overview of the access classification system developed for Port Authority facilities. As shown in the table, the ACS establishes a tiered system of access categories based on the known functionality of individual roadways at Port Authority facilities. This first edition of the *Port Authority Roadway Access Management Guidelines* document provides detailed guidelines for General Roadway Access Classifications listed in *Table 3-1*. *Table 3-1* also identifies airport-specific roadway classifications, including airport terminal frontage roads, restricted vehicle service roads, and recirculation roads. These are special types of roadways at Port Authority facilities, serving unique functions and accommodating specific user-groups. Guidelines for these roadways will be addressed in a future edition of this document.

Because freeways – roadways that do not provide direct access to properties – are of the greatest level of importance in traffic mobility, they represent the highest category within the access classification system. Design criteria for freeways are established in sources such as AASHTO's *A Policy on Geometric Design of Highway and Streets* (i.e., the "Green Book").

The next tiers of the Port Authority ACS include "principal arterial" and "arterial" roadways at Port Authority facilities. On these roadways, the priority is given to serving through traffic, with direct property access a secondary function. Principal arterials are distinguished from arterials by their accommodation of high percentages of trucks in the traffic stream (i.e., percentages typically found at port facilities). Collector roadways provide both a mobility function – by accommodating through traffic traveling between local roads and arterials – as well as a property access function.

Local roads and private roads primarily provide direct access to abutting properties, but they may also accommodate relatively low volumes of through traffic. Whereas private roads are located within tenant leasehold areas and typically designed, operated, and maintained in accordance with negotiated tenant lease agreements, local roads are owned, operated, and maintained by the Port Authority. Local roads and private roads generally have lower posted speeds than higher classification roadways (i.e., principal arterial, arterial, and collector roadways).

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[4] An ACS is not a roadway design functional classification system such as found in AASHTO's "Green Book."

Table 3-1: Port Authority Roadway Access Classification System

Access Classification	Functional Description	Traffic Flow Characteristics	Vehicle Types	Operational Characteristics	Other Distinguishing Characteristics
General Roadway Access Classifications[1]					
Freeway (including mainline freeways and ramps)	Exclusively used for the movement of through traffic. Does not serve any property access function (no driveways).	Exclusively uninterrupted traffic flow.	Typical	N/A	N/A
Principal Arterial Road	Primarily used for the movement of through traffic; access to abutting land uses is subordinate to through traffic movement.	Interrupted traffic flow.	Serves a higher percentage of trucks compared to an arterial road.	N/A	Road is used as a major detour route on a routine basis. Installing non-traversable medians is desirable as part of redevelopment programs.
Arterial Road			Serves a lower percentage of trucks compared to a principal arterial.	N/A	N/A
Collector Road[2]	Provides both land access and traffic circulation functions, collects traffic to/from local streets and channels it to/from arterials.	Interrupted traffic flow.	Typical	N/A	N/A
Local Road[3]	Primarily provides direct access to abutting land uses, very low level of through traffic movement.	Interrupted traffic flow; low operating speed.	Typical	N/A	N/A
Private Road Open For Public Travel	Same as Local Road.	Same as Local Road.	Typical	N/A	A local road within a tenant leasehold area. Tenant has jurisdiction based on a negotiated lease agreement.
Airport-Specific Roadway Access Classifications					
Terminal Frontage Road	Serves as one of the designated passenger drop-off and pick-up locations at a terminal (e.g., airline terminal, bus terminal, or AirTrain station).	Uninterrupted or interrupted traffic flow.	No trucks.	Very low speed.	Little, if any, through traffic.
Restricted Vehicle Service Road (RVSR)	Local road, typically within the Aeronautical Operations Area (AOA). Restricted: special drivers and special vehicles with a unique identification and registration system. Service: Primary function is circulation of aircraft service vehicles within the AOA. Small percentage of through traffic. Similar to factory floor with forklifts moving to facilitate the manufacturing of products.	Interrupted traffic flow.	Unique vehicle types: baggage carts (Tugs), airplane fuel trucks, catering and other service trucks with vertical lift payloads. The most common vehicle is a tug pulling trailers of luggage.	Very low speed.	During certain times of the day, the volume of vehicles providing various services to planes at gates far exceeds the volume of through traffic. Unique security requirements associated with the identification system. All points of entry to the AOA are controlled by guard posts, whether they are vehicular or pedestrian access points.
Recirculation Road	Shortcut to allow vehicles to return to the terminal frontage(s).	Uninterrupted or interrupted traffic flow.	Almost exclusively passenger vehicles.	Same, or similar, speeds to adjacent road segments.	Partially-controlled access (no driveways).

1. The classification of a roadway must be consistent for the entire width of its cross-section at any point on the roadway. (Example: The frontages at EWR Terminals A, B, C are classified "Airport Terminal Frontage Road" across their entire cross-section even though the left most lane is a "through only" lane from which no stopping is permitted.)
2. The connecting roads (typically one-way ramps) upstream and downstream of an airport terminal frontage are typically considered to be collector roads. (Examples: The roads that lead to and from the frontages at EWR Terminals A, B, C are collector roads.)
3. When a connecting road only serves the frontage (i.e., there is no through traffic on the road), it is considered to be a local road. (Examples: The roads that lead to and from the frontages at EWR AirTrain Stations P2 and P4 are local roads.)

Table 3-2 presents some example roadways corresponding to each access classification from among selected Port Authority facilities. Readers who are familiar with the roadways at one or more Port Authority facilities will gain a better understanding of the roadway access classifications by considering the examples in *Table 3-2*.

Table 3-2: Example Roadway Classifications by Port Authority Facility

Access Classification	Newark Airport	JFK Airport	LaGuardia Airport	Teterboro Airport	Stewart Airport	Port Newark-Elizabeth Marine Terminal
General Roadway Access Classifications[1]						
Freeway (including mainline freeways and ramps)	I-78 Connector; Express Rd.	JFK Expressway; Van Wyck Expressway	Ramps to/from Grand Central Parkway	None	None	None
Principal Arterial Road	None	The sequence of roads: North Boundary Rd., 150th Ave., 147th St., and Cargo Service Rd. (which serve as the detour route when Van Wyck Expressway is closed).	None	None	None	McLester Street/Corbin Street, Lyle King St., Port St. from NJTPK to Doremus Ave.
Arterial Road	Brewster Rd; Earhart Dr., At-Grade Parking Roadway, Lindbergh Rd.	Lefferts Blvd.	Runway Dr., LaGuardia Rd.	None	Stewart Blvd.	None
Collector Road[2]	Conrad Rd.	Cargo Plaza Rd.	Central Terminal Dr., Bowery Bay Blvd., Marine Terminal Road	None	Bruenig Rd.	Port St. from Doremus Ave. to Craneway St.; Polaris St.
Local Road[3]	Carson Rd.	North Hangar Rd.	Fiorello Lane	Charles Lindbergh Rd.	First St.	Export St., Calcutta St.
Private Road Open For Public Travel	Airis Dr.	Access Road to Building 9	None	South end of Fred Wehran Drive	None	Panama Street
Airport-Specific Roadway Access Classifications						
Terminal Frontage Road	Frontage roadways at Terminal A, B, C. Frontage roadways at AirTrain stations P2 and P4.	Frontage roadways for Terminals 1 through 8.	Frontage roadways for Terminals A through D.	Frontages at Buildings 111, 112.	Terminal frontage roadway	None
Restricted Vehicle Service Road (RVSR)	Fuel Farm Road	RVSR	RVSR	RVSR	Perimeter Road	None
Recirculation Road	Recirculation Rd.	Typical recirculation roads	None	None	None	None

1. The classification of a roadway must be consistent for the entire width of its cross-section at any point on the roadway. (Example: The frontages at EWR Terminals A, B, C are classified "Airport Terminal Frontage" across their entire cross-section even though the left most lane is a "through only" lane from which no stopping is permitted.)
2. The connecting roads (typically one-way ramps) upstream and downstream of an airport terminal frontage are typically considered to be collector roads. (Examples: The roads that lead to and from the frontages at EWR Terminals A, B, C are collector roads.)
3. When a connecting road only serves the frontage (i.e., there is no through traffic on the road), it is considered to be a local road. (Examples: The roads that lead to and from the frontages at EWR AirTrain Stations P2 and P4 are local roads.)

CHAPTER 4: ROADWAY CROSS-SECTIONAL ELEMENTS

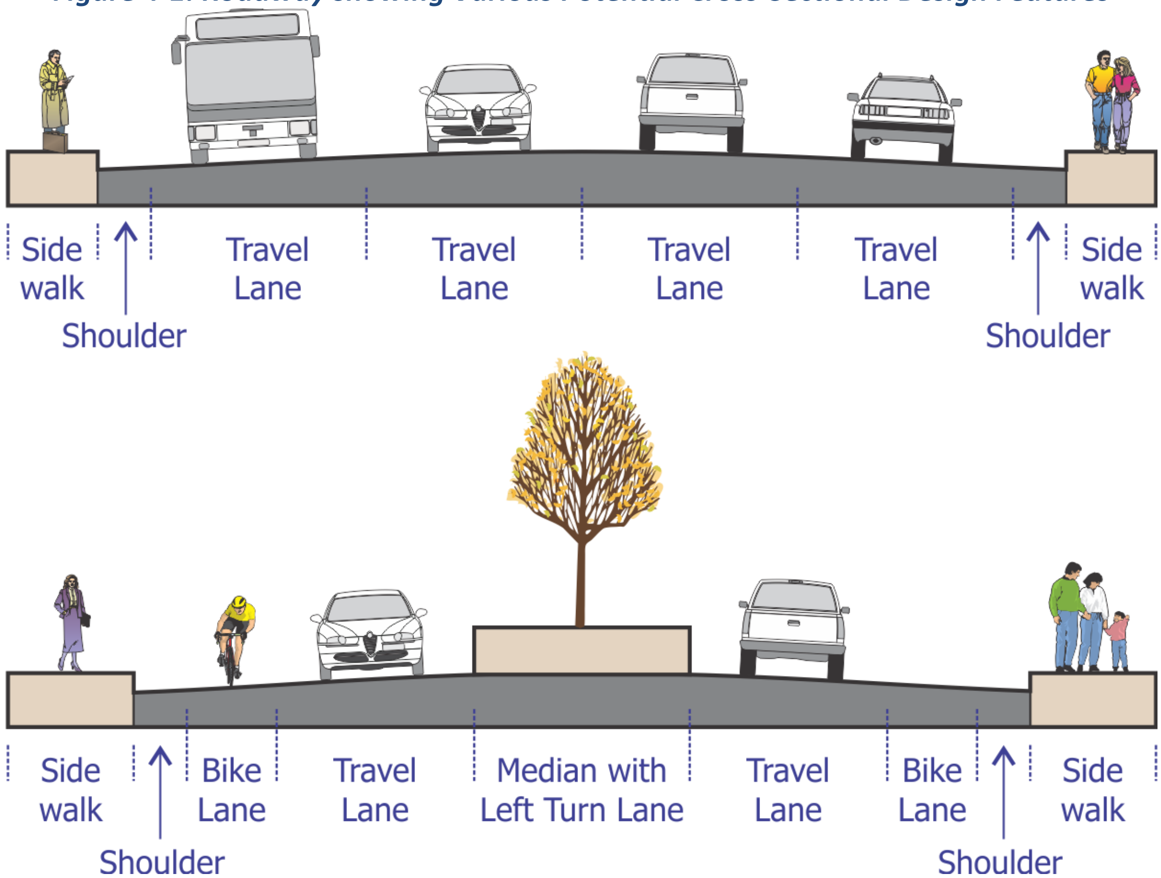
4.1 Overview

Roadways at Port Authority facilities differ from one another in their access classifications and intended functions, as described in *Chapter 3*. They also differ with respect to their specific design characteristics and the user groups they are intended to accommodate. Therefore, no “one size fits all” design solution applies to all situations. Moreover, constraints on the physical width of the roadway may preclude the provision of beneficial cross-sectional elements in a specific roadway design. Ultimately, applicable Port Authority policies and stakeholder input should drive the decision-making process as to which cross-sectional elements are most appropriate for a given roadway. To help inform that decision, this chapter provides general principles and guidance regarding a number of those elements for consideration in roadway planning or design projects at Port Authority facilities.

Within the given cross-sectional width of a roadway, vehicular traffic has to be accommodated. However, Port Authority roadways should, where appropriate, also include design features supporting other modes of travel — such as sidewalks for pedestrians, bike lanes for bicyclists, and bus pull-outs for transit. Additionally, cross-sectional elements such as non-traversable medians, auxiliary lanes, shoulders, and/or roadside buffers should be considered. Providing on-street parking may also be appropriate along some roadways. Having the space to accommodate all of these design treatments frequently would require roadway widening.

In practice, roadway widths are often limited by leasehold boundaries, existing buildings, environmental considerations, and other constraints that may rule out the possibility of widening the roadway. Therefore, each of the roadway design features noted above is in “competition” for physical space within the limited cross-section of the roadway. As a result, transportation practitioners often must consider trade-offs among these features in the design of the roadway cross-section, balancing the needs of the various users within the context of the surrounding area. The information in this chapter provides a general introduction to potential cross-sectional features and their benefits. *Figure 4-1* illustrates a roadway with different potential cross-sectional design features within the same roadway width. Note that the width necessitates choices be made between the different cross-sectional elements.

Figure 4-1: Roadway showing Various Potential Cross-Sectional Design Features



4.2 Complete Streets Concepts

4.2.1 What are Complete Streets?

According to the National Complete Streets Coalition[5], a *complete street* is one that is comfortable, convenient, and safe for travel by motorists, pedestrians, bicyclists, and transit users of all ages and abilities, as well as sensitive to the context of its surrounding land uses and environment. As such, complete streets are an important part of comprehensive solutions to transportation problems. For that reason, many transportation agencies have adopted a complete streets policy to advance the objective that roadways are planned, designed, and operated to accommodate all users safely as part of both new roadway construction projects and retrofit improvement projects. The goal of complete streets planning and design is to, over time, integrate the needs of multi-modal users as part of independent projects in order to ultimately create a complete, interconnected network of roadways that can safely and conveniently accommodate all travelers.

4.2.2 Why Make a Street "Complete"?

Complete streets allow travelers to choose between several safe, attractive, and convenient modal choices, rather than having to rely exclusively on the automobile for all travel. Roadways that include designated places for people to walk, cross lanes of moving traffic, catch a bus, and bicycle decrease the risk of crashes. On the other hand, "incomplete" streets — those designed only with motorized vehicles such as automobiles and trucks in

[5] http://www.completestreets.org/

mind[6] — can limit transportation choices and may make walking, bicycling, and using transit inconvenient and unattractive.

As such, complete streets benefit quality of life and the environment. Complete streets encourage walking and bicycling — particularly for short- and medium-distance trips — which contributes to a healthy and active lifestyle. Moreover, walking and bicycling require no gasoline, and fuel consumption per passenger for transit vehicles is more efficient than that of automobiles. In addition to reduced fuel consumption and the associated cost savings, the multi-modal travel opportunities provided by complete streets can also help reduce vehicle emissions.

4.2.3 Port Authority Policies that Support Complete Streets Concepts

The Port Authority embraces the complete streets philosophy. Two policies enacted by the Port Authority Board that have applicability to complete streets concepts are the *Environmental Sustainability Policy* and the *Bicycle Policy*. By promoting pedestrian and bicycle accommodations and transit mobility through complete streets planning and design efforts, the Port Authority is taking steps toward achieving the goals of the Port Authority's *Environmental Sustainability Policy*, which states, in part:

> *The Port Authority will continue to use its best efforts to reduce all greenhouse gas (GHG) emissions related to its facilities by 80% from 2006 levels, by 2050. The reduction of GHG emissions by 5% annually will be the central focus of the Port Authority's sustainability efforts. The majority of these reductions will come from improvements made through new capital investments and changes in operations.*
>
> *The Port Authority will encourage its customers, tenants, and partners to conduct their businesses in a more sustainable fashion, including reductions in their own GHG emissions, providing support for these efforts in all cases where it is practical to do so.*[7]

Additionally, complete streets are supportive of the Port Authority's *Bicycle Policy*, which states, in part:

> *In keeping with its mission to meet the critical transportation needs of the bi-state region, the Port Authority supports bicycling as an important and sustainable mode of travel. It seeks to provide its customers, tenants, visitors and employees with safe and convenient bicycle access and secure bicycle parking at its facilities, wherever operationally and financially feasible.*
>
> *Goals of this policy include:*
>
> - *Integrate improved bicycle access, safe bicycle lanes, and secure bicycle parking and storage into existing Port Authority buildings and facilities, owned or operated by the Port Authority.*
> - *Ensure that design guidelines for new construction and major renovations include sufficient bicycle access, storage, and related amenities to meet emerging demand.*
> - *Remove any unnecessary restrictions on bicycle access, and promote the safe coexistence of motor vehicles, bicycles and pedestrians at Port Authority facilities.*

[6] Excluding freeways and expressways, which are intended to be high-speed and exclusively accommodate motor vehicle travel.

[7] *Port Authority Environmental Sustainability Policy*, approved March 27, 2008.

- *Encourage tenants to expand bicycle access and accommodations.*
- *Coordinate bicycle facility improvements and intermodal connections with regional planning organizations, other regional transportation providers, and local governments to promote safe and seamless travel throughout the region.*[8]

4.2.4 Complete Streets Guidelines for the Port Authority

As part of the effort to develop these *Roadway Access Management Guidelines*, a need was identified for guidelines addressing pedestrian and bicycle connectivity at Port Authority facilities and guidelines for providing transit at Port Authority facilities. The Port Authority Bicycle Master Plan, as indicated in its "Purpose" statement, provides a long-range vision to institutionalize bicycle planning, practices, and policies within the agency to accommodate the growing modal share of bicycling within the New York-New Jersey metropolitan region. The Port Authority is committed to monitoring cycling demand at its facilities and to making improvements and investments where necessary and feasible. The Bicycle Master Plan proposes strategies and potential implementation measures to achieve this vision, but its recommendations are wholly independent of the funding and prioritization decisions outlined in the agency's Capital Plan. Many strategies identified in this Bicycle Master Plan would not require significant capital investment and could have a positive impact on cycling in the region. These strategies could be integrated into existing operations and maintenance budgets based on the priorities and available resources within each Port Authority department.

4.3 Non-Traversable Median Treatments

Installations of non-traversable (i.e., raised) medians — with provisions for median openings to accommodate left-turns and U-turns (see *Photo 4-1*) — have proven to be among the most effective techniques for reducing conflicts and improving traffic operations along roadways.

Photo 4-1: Port Authority Roadways with Non-Traversable Medians

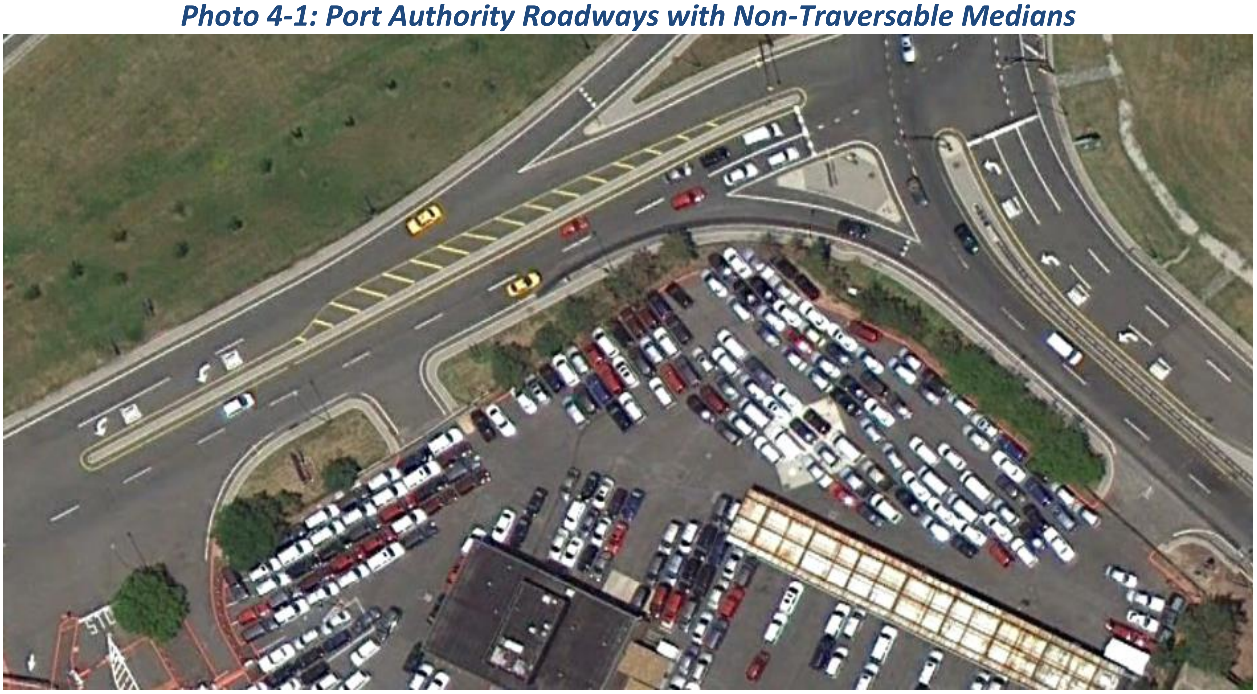


Photo source: Google Earth™ mapping service

[8] *Port Authority Bicycle Policy* issued by the Office of the Executive Director in Bulletin #10-05, dated March 29, 2010

Left-turning vehicles account for nearly three-quarters (74 percent) of all access-related crashes. Allowing unrestricted left-turn movements to and from all access driveways increases the number of vehicular conflict points with other vehicles, pedestrians, and bicyclists. Non-traversable medians — with designated median openings to allow for left-turn and U-turn movements — offer the following advantages over the other types of roadway cross-sections:

- Vehicles traveling in opposite directions are physically separated, eliminating the propensity for head-on crashes.
- When properly designed, the physical space provided for the deceleration and storage of left-turning and U-turning vehicles occurs outside of the through traffic lanes. The resulting reduction in speed differential between the turning and through vehicles improves traffic operations and reduces the potential for crashes.
- At a full median opening, the width of the non-traversable median provides a refuge area for passenger cars making a two-stage left-turn from a side-street (i.e., crossing traffic approaching from the left, and then turning left and merging with traffic approaching from the right)[9] or traveling straight across the roadway.
- The number of left-turn conflicts with vehicles, pedestrians, and bicyclists is reduced.
- The non-traversable median provides a refuge area for pedestrians crossing the roadway at intersections. In addition, mid-block pedestrian crossings can be provided and signalized without interfering with traffic progression (i.e., by stopping traffic approaching from the left first, and then stopping traffic from the right).
- Locations for making left-turns and U-turns are clearly identifiable to the driver, thus reducing driver workload.
- Non-traversable medians reduce the frequency and severity of crashes as compared to both undivided roadways and roadways with Two-Way Left-Turn Lanes (TWLTLs).

A non-traversable median should be considered on Port Authority roadways that fall under any of the following categories[10]:

- All new multi-lane principal arterial and arterial roadways
- Existing multi-lane principal arterial and arterial roadways with Average Daily Traffic (ADT) in excess of 24,000 vehicles per day
- Roadways where aesthetic considerations are a high priority
- Multi-lane roadways with high levels of pedestrian activity
- High-crash locations or areas where limiting left-turns is desirable

[9] The median may not be sufficiently wide to provide a safe refuge outside the traveled way for longer vehicles, such as trucks, making these movements.
[10] Source: 2003 *Access Management Manual*.

4.4 Auxiliary Lanes (Left-Turn and Right-Turn Lanes)

Auxiliary lanes (i.e., exclusive left-turn lanes and right-turn lanes) are an effective means of limiting the speed differential between a turning vehicle and through traffic behind it. The addition of auxiliary lanes has been shown to provide a variety of traffic safety and operational benefits including the following:

- Reducing the number of conflicts and crashes (particularly rear-end, angle, and sideswipe crashes)
- Physically separating turning traffic and queues from through traffic
- Decreasing vehicular delay and increasing intersection capacity
- Providing an area for turning vehicles to decelerate outside of the through traffic lane(s)
- Providing greater operational flexibility (e.g., additional traffic signal phasing opportunities)

Additional guidance regarding left-turn and right-turn lanes is provided in *Chapters 11* and *12*, respectively.

4.5 Roadside Buffers and Clear Zones

Establishing a roadside buffer is fundamental to roadway design. In addition to providing physical space along the roadside for the recovery of errant vehicles (i.e., a clear zone), the roadside buffer also provides a variety of benefits. First, it provides the unobstructed sight lines necessary for drivers to see oncoming traffic when they are waiting to turn from intersecting roadways and driveways. Second, the roadside buffer provides space for the location of roadside guide signs and for the placement and maintenance of utilities. In addition, the roadside buffer also provides space for sidewalks or pedestrian pathways and can be used for snow storage. Additional guidance regarding roadside buffers is provided in *Chapter 10*.

CHAPTER 5: UNSIGNALIZED DRIVEWAY SPACING

5.1 Overview

Driveways introduce conflicts and friction into the flow of traffic along a roadway. Vehicles entering and leaving the roadway often slow the movement of through traffic, and the difference in speeds between through traffic and turning traffic increases the potential for crashes. Before seeking a driveway on the primary roadway, the design team should consider the various property access strategies described in *Chapter 13* to provide for sufficient access. These strategies include providing access through use of the following:

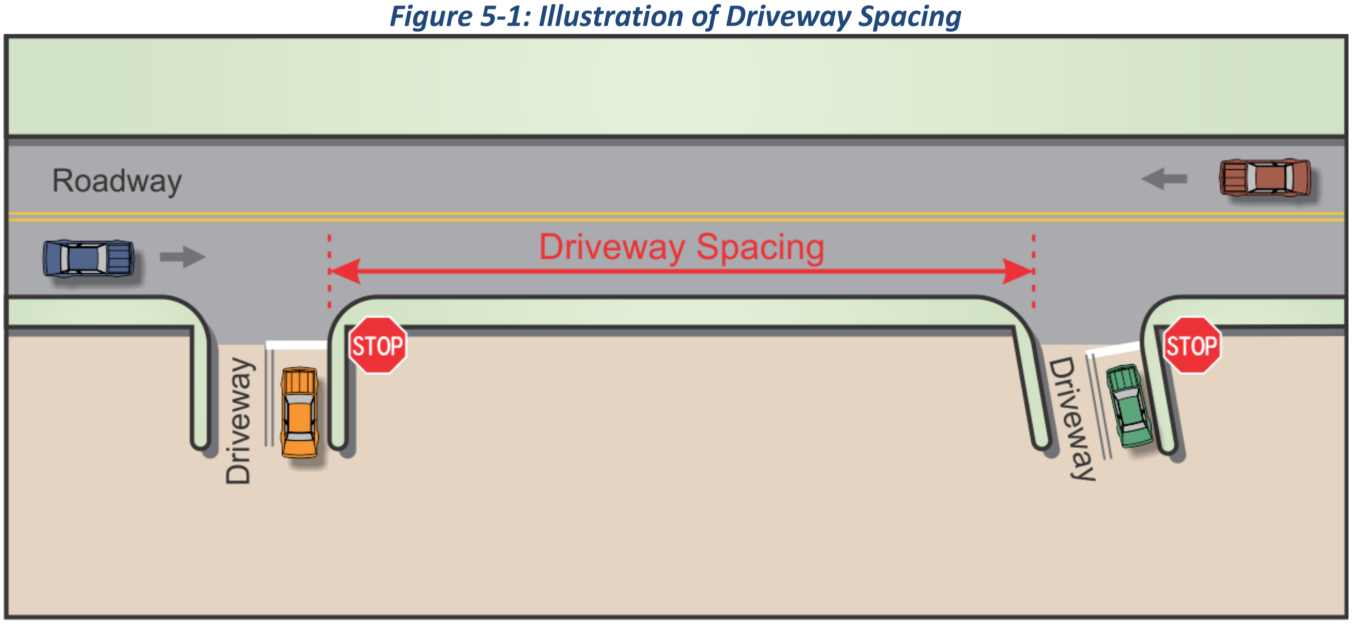
- Secondary roadways[11]
- Shared driveways and cross-access between leaseholds
- Frontage roads

Where a driveway is needed, its location should be selected to minimize its adverse effects on traffic flow and roadway safety. Increasing the spacing between the driveways – through proper planning of future driveways and closing or consolidating existing driveways – improves traffic flow and reduces the potential for crashes along the roadway by:

- Reducing the number of conflicts per mile
- Providing a greater distance for motorists to anticipate and recover from turning maneuvers
- Providing opportunities for the construction of acceleration lanes, deceleration lanes, or exclusive left-turn or right-turn lanes

As shown in *Figure 5-1*, driveway spacing is measured from the nearest edges of adjacent driveways.

Figure 5-1: Illustration of Driveway Spacing



[11] As defined in these *Guidelines*, a "secondary roadway" is one that has a lower access classification than the intersecting primary roadway (see *Chapter 3*, Table 3-1).

Each of these strategies is addressed in *Chapter 13* and should be considered. The intent of each strategy is to provide *reasonable access* for a particular property, or properties, such that the resulting access configuration conforms to the access management guidelines described in this document.

5.2 Guidelines

The spacing guidelines for unsignalized driveways vary by access classification. The spacing guidelines for principal arterial, arterial, and collector roadways are different than the spacing guidelines for local roads and private roads open for public travel. Both sets of guidelines are based on the posted speed of the street where the driveway would be located. The 85th percentile speed may be used in place of the posted speed if an engineering study that supports the use of the 85th percentile speed over the posted speed is completed and approved by Port Authority Traffic Engineering. In addition, if a roadway at a Port Authority facility does not have a posted speed, then the 85th percentile travel speed should be used.

The spacing guidelines presented below shall be applied using engineering judgment, with consideration given to site-specific features, which may result in the shifting of a driveway location to achieve safer and more efficient operations.

5.2.1 Principal Arterial, Arterial, and Collector Roads

The driveway spacing distances for principal arterial, arterial, and collector roadways are given in *Table 5-1*. The Desirable Driveway Spacing distances should be used. These distances are based on whether the roadway is divided (i.e., has a non-traversable median) or undivided (i.e., no median), as shown in *Figure 5-2*. Under constrained conditions, potential driveway locations may be limited by the existing physical features of the built and natural environments.

Where the Desirable Driveway Spacing distances shown in *Table 5-1* cannot be achieved, other access strategies or a design exception is needed.

Table 5-1: Unsignalized Driveway Spacing Distances for Principal Arterial, Arterial, and Collector Roadways

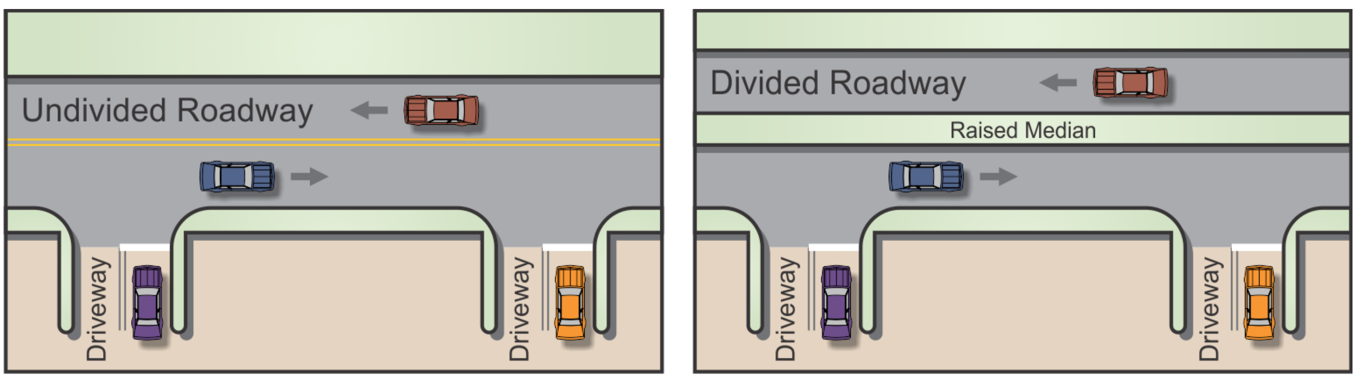
Posted Speed[1] (mph)	Desirable Driveway Spacing[2]		Minimum Driveway Spacing[3] (feet)
	Undivided Roadways (feet)	Divided Roadways (feet)	
20	260	245	115
25	370	340	155
30	500	450	200
35	640	570	250
40	790	700	305
45	950	835	360
50	1,140	995	425
55	1,340	1,165	495

1: The 85th percentile speed may be used in place of the posted speed if an engineering study that supports the use of the 85th percentile speed over the posted speed is completed and approved by Port Authority Traffic Engineering.

2: Desirable Driveway Spacing is based on superimposing the desirable corner clearance footprints for unsignalized intersections for the corresponding posted speed. Source: V. Stover and F. Koepke, *Transportation and Land Development, 2nd Edition*, 2002.

3: Minimum Driveway Spacing is based on AASHTO Stopping Sight Distance for the corresponding posted speed. Source: Adapted from Table 3-1, AASHTO, *A Policy on Geometric Design of Highways and Streets*, 2011, p. 3-4.

Figure 5-2: Comparison of Undivided and Divided Roadway Cross-Sections



5.2.2 Local Roads and Private Roads Open for Public Travel

The driveway spacing on local roads and private roads open for public travel are given in *Table 5-2*. The Desirable Driveway Spacing should be used. The Minimum Driveway Spacing distances are based on the Right-Turn Conflict Overlap (RTCO) concept[12].

Where the desirable driveway spacing distances shown in *Table 5-2* cannot be achieved, other access strategies or a design exception is needed.

Table 5-2: Unsignalized Driveway Spacing Distances for Local Roads and Private Roads Open for Public Travel

Posted Speed[1] (mph)	Desirable Driveway Spacing[2] (feet)	Minimum Driveway Spacing[3] (feet)
20	115	85
25	155	105
30	200	125
35	250	150
40	305	185
45	360	230

1: The 85th percentile speed may be used in place of the posted speed if an engineering study that supports the use of the 85th percentile speed over the posted speed is completed and approved by Port Authority Traffic Engineering.

2: Desirable Driveway Spacing is based on AASHTO Stopping Sight Distances. Source: Adapted from Table 3-1, AASHTO, *A Policy on Geometric Design of Highways and Streets*, 2011, p. 3-4.

3: Minimum Driveway Spacing is based on New Jersey Department of Transportation “Right-Turn Conflict Overlap”. Source: Adapted from NJDOT, *New Jersey Highway Access Management Code*, 1990, p. 19.

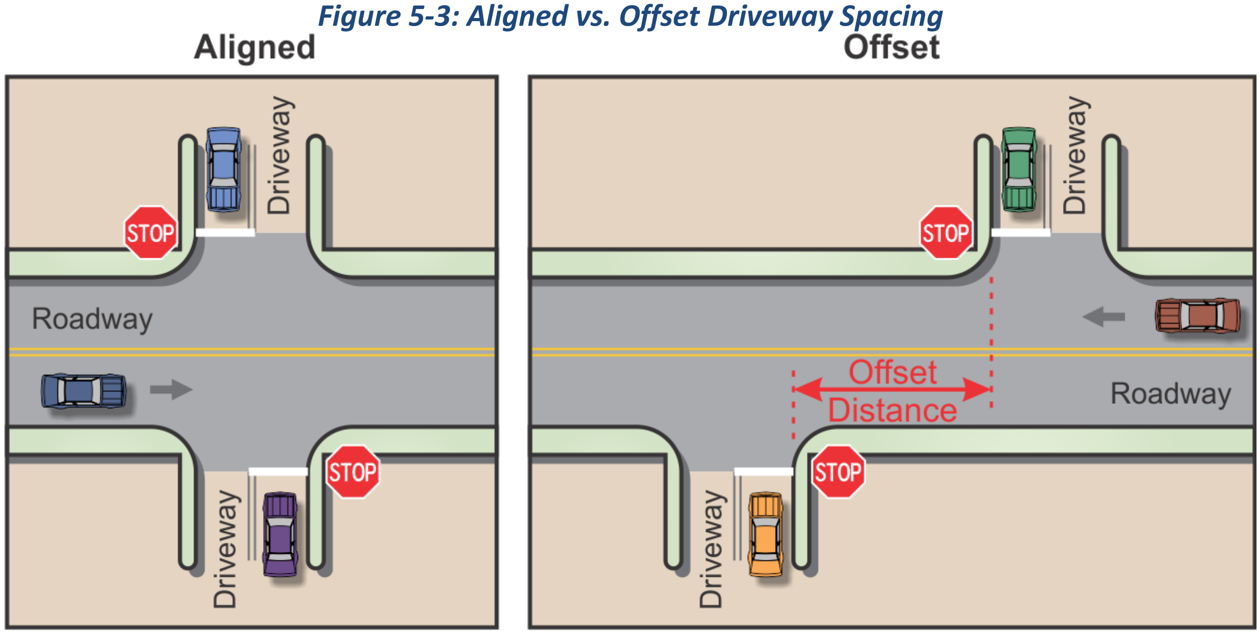
[12] The Right-Turn Conflict Overlap (RTCO) distance is based on a driver (Driver “A”) departing a driveway and accelerating away from another driver (Driver “B”) who is approaching that driveway in the same direction. Rather than coming to a complete stop, Driver “B” must only decelerate to avoid a collision with Driver “A”. The RTCO distance is the distance required to avoid this collision. However, if Driver “A” stalls upon exiting the driveway, a crash could occur due to insufficient stopping distance for Driver “B” (unless a shoulder or vacant adjacent lane exists to allow Driver “B” to change lanes and avoid a collision).

5.2.3 Additional Guidelines

The following additional guidelines apply to driveways on roadways of all access classifications:

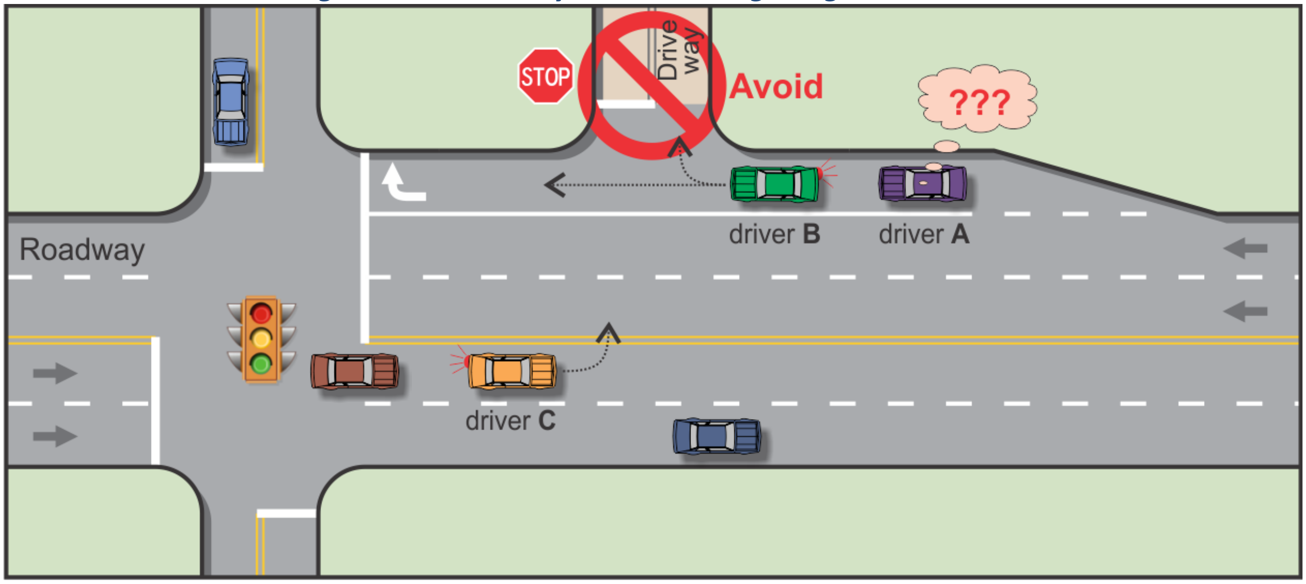
- On undivided highways, driveways on opposite sides of the roadway should be aligned. Where this is not possible, the driveways should be offset by at least 200 feet (see *Figure 5-3*). One purpose of the offset is to separate the conflict points associated with each driveway. This is particularly important for conflicts associated with opposing left-turn movements from the roadway into the driveways, where the queue from the left-turn movement at one driveway may block the opposing left-turn into the other driveway. Further, the offset spacing distance should be increased where operational analysis of the driveways reveals a need for greater spacing (e.g., due to a high percentage of trucks, high turning movement volumes at the driveways, length of queues, etc.).

Figure 5-3: Aligned vs. Offset Driveway Spacing



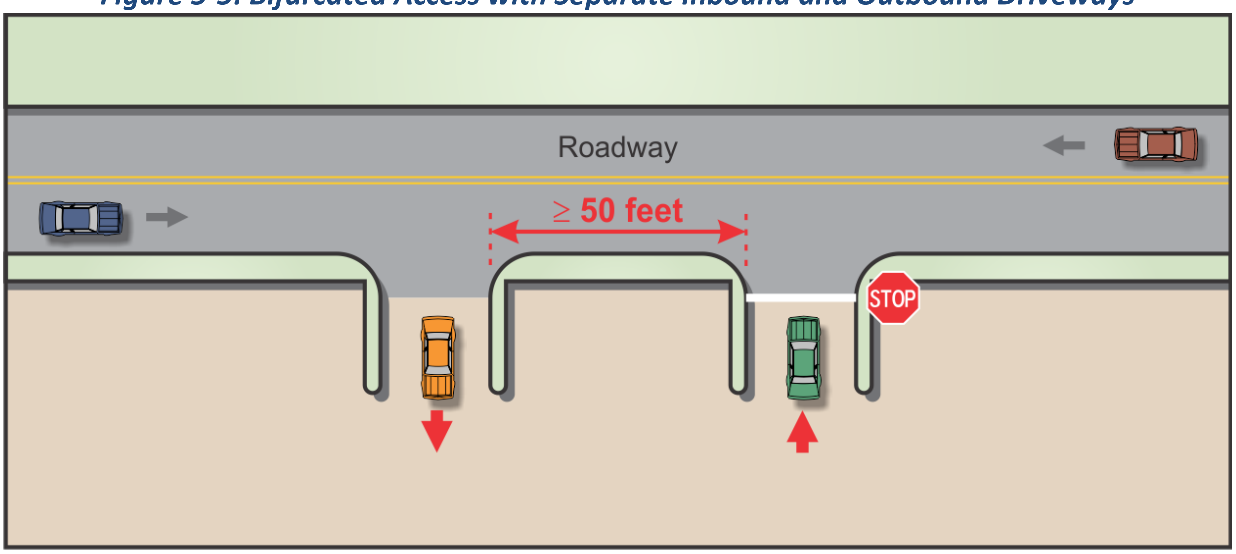
- Driveways should be avoided along an acceleration, deceleration, or exclusive right-turn or left-turn lane (see example in *Figure 5-4*). One purpose of this guideline is to avoid violating driver expectancy. As shown in *Figure 5-4*, Driver "A" is following Driver "B" who has a right-turn signal on. Driver "A" may expect Driver "B" to turn right at the signalized intersection, while Driver "B" may intend to make a right-turn into the driveway. This confusion increases the potential for a crash.
  In addition, avoiding driveways along right-turn lanes reduces the potential for a driver traveling in the opposite direction to make a left-turn into the driveway. A driver stopped and waiting to turn left into the driveway (through on-coming traffic in the opposite direction) often generates unexpected delays and queues that may back up through the signalized intersection. As shown in *Figure 5-4*, due to the proximity of the driveway to the signalized intersection, vehicles following Driver "C" will need to slow or stop unexpectedly while Driver "C" waits to turn left into the driveway. The resulting vehicle queues may spill back into the signalized intersection. This confusion also increases the potential for a crash. Similarly, a left-turn egress movement from the driveway onto the roadway may be blocked by a queue of vehicles waiting at the signal. These conflicting movements result in operational problems.

Figure 5-4: Driveway Located Along a Right-Turn Lane



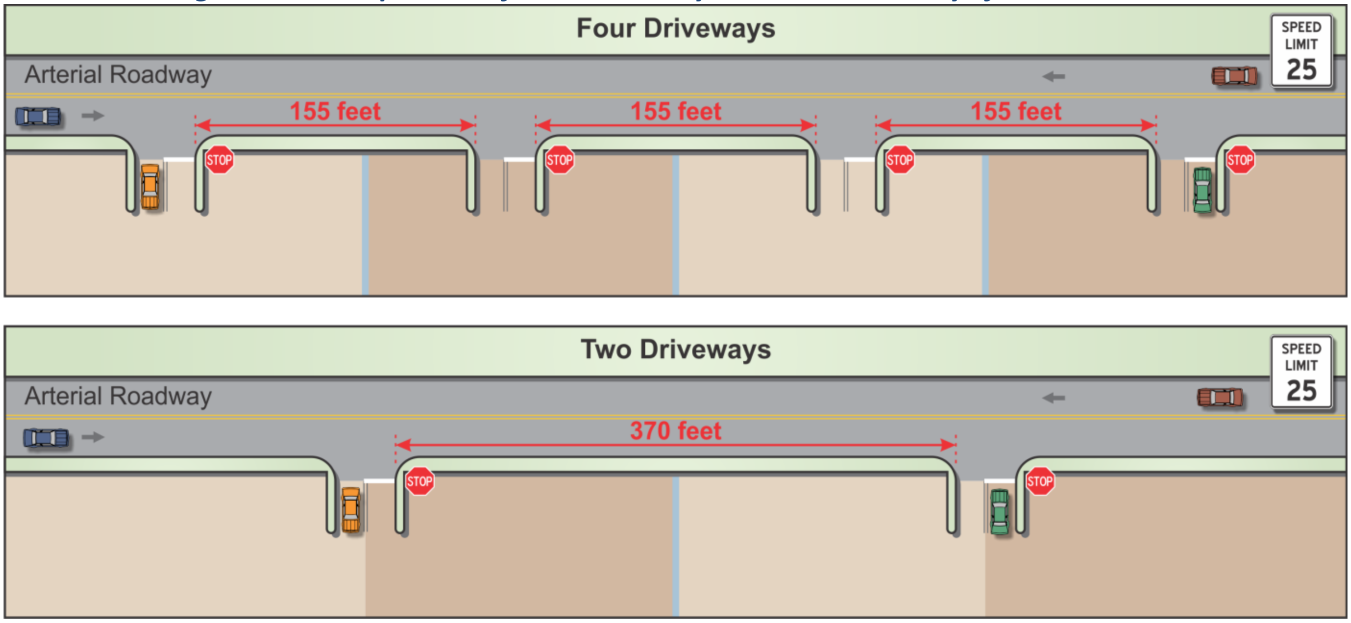
- An access may be bifurcated with separate driveways for ingress and egress, thereby separating the conflict points associated with the ingress and egress movements. Wherever possible, the distance between such driveways should be at least 50 feet (see *Figure 5-5*). The spacing distance should be increased where operational analysis of the driveways reveals a need for greater spacing (e.g., due to a high percentage of trucks, high turning movement volumes at the driveways, etc.).

Figure 5-5: Bifurcated Access with Separate Inbound and Outbound Driveways



- Even where sufficient frontage exists to provide multiple driveways and meet the spacing criteria shown in *Tables 5-1* and *5-2*, the number of driveways should be minimized. As illustrated in *Figure 5-6*, even though there is sufficient frontage for the four driveways shown, fewer may be adequate and more advantageous. Instead of each of the four sites having its own driveway, these sites may be accessed via two shared driveways, as long as each driveway is designed to provide enough capacity and safe access onto the abutting roadway.

Figure 5-6: Comparison of Two Driveways vs. Four Driveways for Site-Access



- Property access should be limited to designated driveways. Continuous unrestricted access along a property frontage (i.e., an open frontage as in *Photo 5-1*) should not be allowed. This guideline not only decreases the number of potential conflict points but also minimizes driver confusion and resulting accidents.

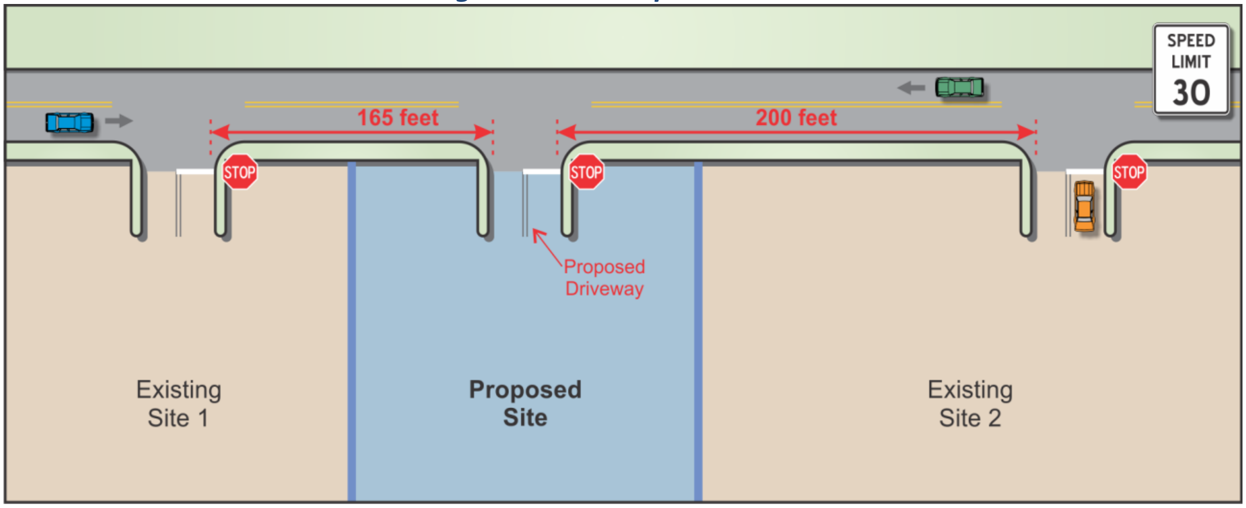
Photo 5-1: Continuous Access Along a Property Frontage

Source: J.L. Gattis

5.3 Example Calculation

Given: An undivided arterial roadway has a posted speed of 30 mph (see *Figure 5-7*). A site is proposed for development between two existing sites. The distances from the proposed driveway to each of the two existing driveways are shown in *Figure 5-7*.

Figure 5-7: Example Problem



Problem: Identify whether the unsignalized driveway spacing guidelines can be met for a driveway that is planned to serve the proposed site shown in *Figure 5-7*.

Solution: For an arterial roadway, refer to *Table 5-1* and identify the Desirable Driveway Spacing corresponding to an undivided roadway with a posted speed of 30 mph, as shown below.

Posted Speed (mph)	Desirable Driveway Spacing		Minimum Driveway Spacing (feet)
	Undivided Roadways (feet)	Divided Roadways (feet)	
20	260	245	115
25	370	340	155
30	**500**	450	200
35	640	570	250

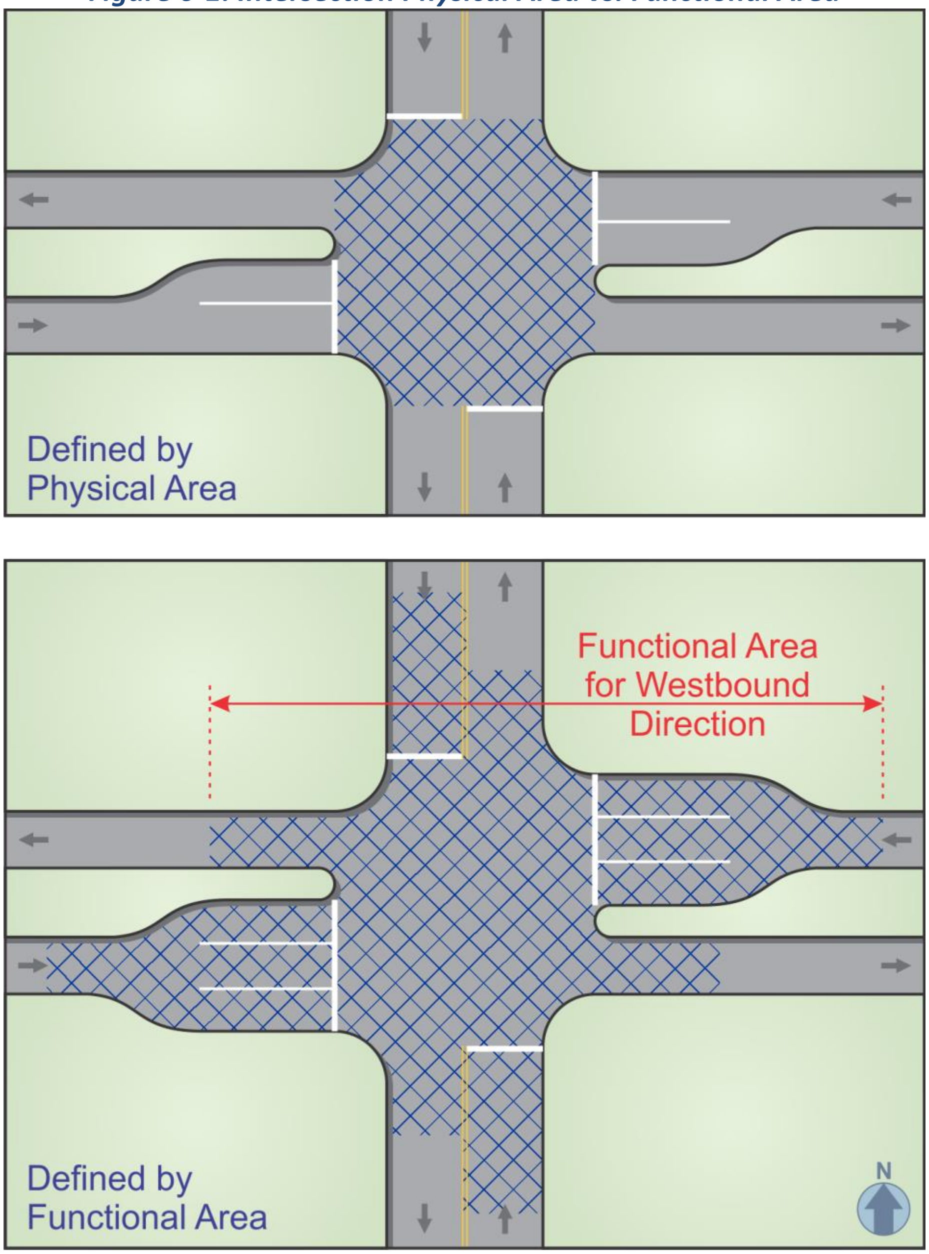
As shown in Table 5-1, the Desirable Driveway Spacing is 500 feet. However, as shown in *Figure 5-7*, this spacing cannot be achieved given the existing spacing to the two driveways serving the adjacent properties. Therefore, other property access strategies or a design exception is needed for the proposed driveway location.

CHAPTER 6: INTERSECTION CORNER CLEARANCE

6.1 Overview

Protecting the functional integrity of intersections along Port Authority roadways is extremely important, including intersections with both other Port Authority roadways and roadways under the jurisdiction of the state, county, or local municipality. One strategy to help accomplish this is to locate driveways outside of the *functional area* of an intersection. As shown in *Figure 6-1* and described previously, the functional area extends beyond the physical intersection of the two roadways to include the upstream approaches where deceleration, maneuvering and queuing take place, as well as the downstream departure area beyond the intersection where driveways could introduce conflicts and generate queues backing up through the intersection.

Figure 6-1: Intersection Physical Area vs. Functional Area



Source: Adapted from Figure 9-1, AASHTO, *A Policy on Geometric Design of Highways and Streets*, 2011, p. 9-3.

The functional area of an intersection is defined by clearance distances on both the upstream approach and the downstream departure leg in the vicinity of the physical intersection. Driveways should be located beyond the Upstream Clearance Distance (UCD), shown in *Figure 6-2*, and the Downstream Clearance Distance (DCD), shown in *Figure 6-3*. These distances shall be computed using the procedures described in this chapter.

Figure 6-2: Upstream Clearance Distance (UCD) for Westbound Direction

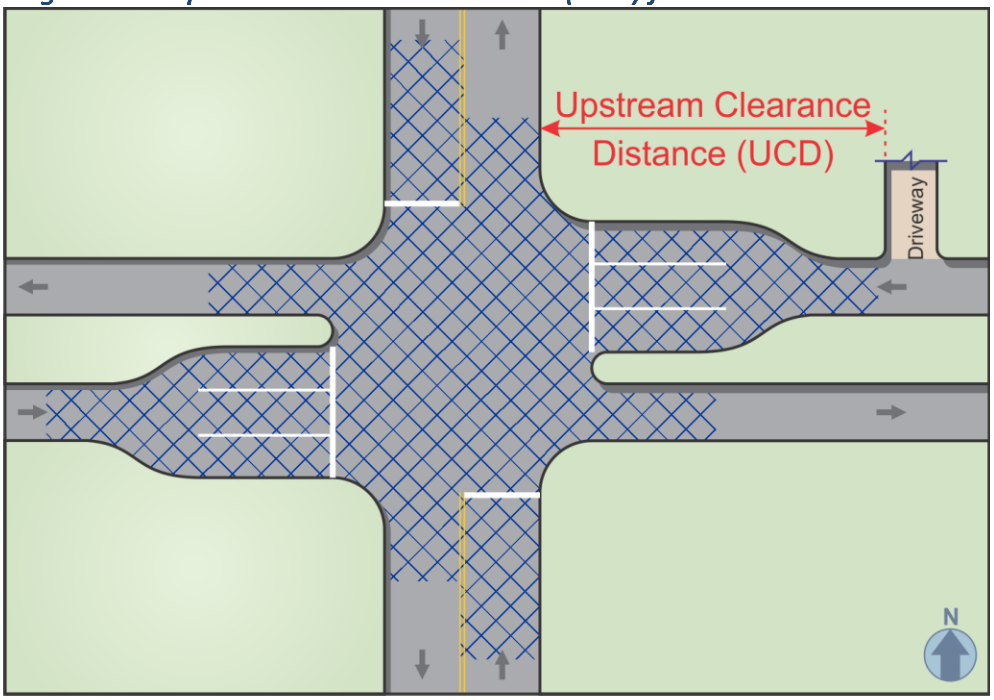
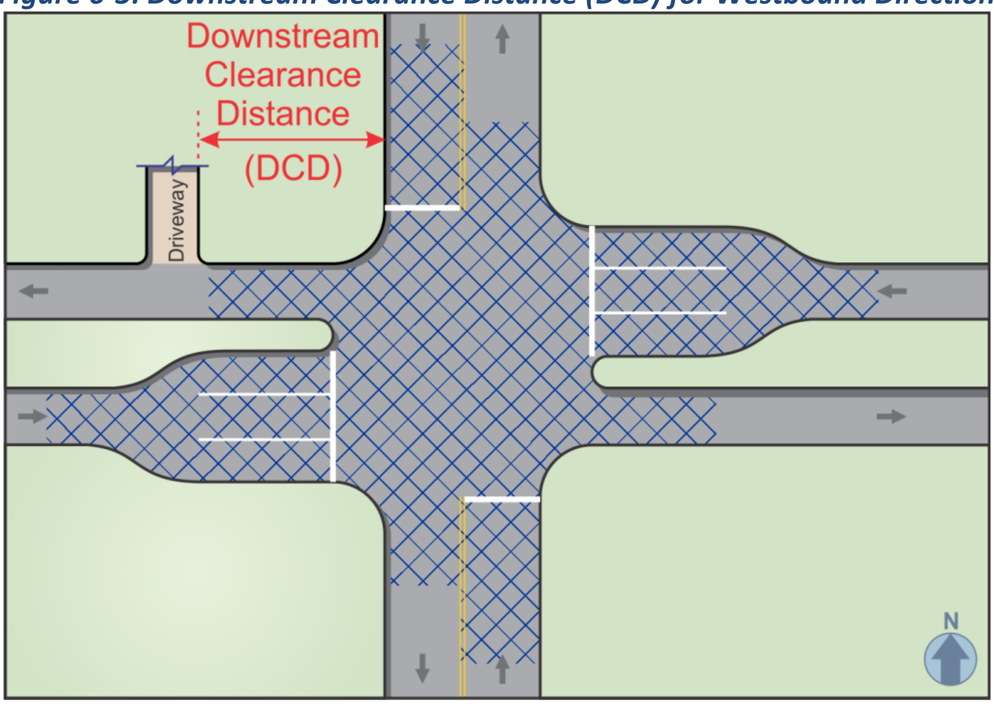


Figure 6-3: Downstream Clearance Distance (DCD) for Westbound Direction



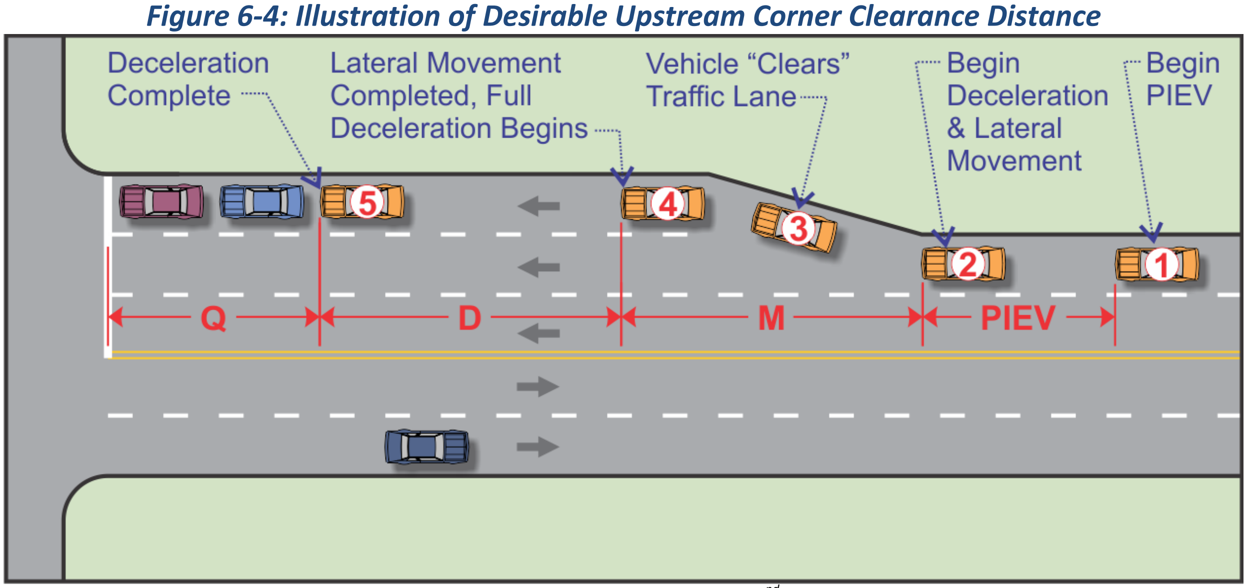
6.2 Guidelines

6.2.1 Principal Arterial, Arterial, and Collector Roads

Principal arterial, arterial, and collector roads have different corner clearance criteria than local roads and private roads open for public travel. The calculation of the desirable UCD for principal arterial, arterial, and collector roadways is the sum of the distances shown in *Figure 6-4*. The figure illustrates the movements necessary for a driver traveling along a roadway (from right to left) to recognize and prepare to turn at an upcoming intersection. The four stages required for the driver to be prepared to turn are depicted in terms of distances needed for each action. They include the following:

- **Perception, Identification, Evaluation, and Volition (PIEV) distance** – This is the total distance a driver needs to recognize and react to traffic activity at an upcoming intersection. The PIEV distance is also commonly referred to as the "perception-reaction" distance.
- **Maneuver (M) distance** – This is the distance required for a driver to maneuver laterally into the desired lane and begin decelerating.
- **Deceleration (D) distance** – This is the distance required for a driver to decelerate to the back of a standing queue.
- **Queue (Q) distance** – This distance is the length of the vehicle queue on the intersection approach. The length of the queue should be calculated using standard intersection capacity analysis software (e.g., Highway Capacity Software) based on the type of intersection traffic control (signalized, all-way stop-control, two-way stop-control, or roundabout) and the future traffic volumes from the project's forecast year of full build-out[13].

Figure 6-4: Illustration of Desirable Upstream Corner Clearance Distance



Source: Adapted from Stover, V., and F. Koepke, *Transportation and Land Development, 2nd Edition*, 2002, p. 5-42.

The sum of these distances (i.e., PIEV + M + D + Q) is the desirable UCD for principal arterial, arterial, and collector roadways. *Table 6-1* identifies the combined distances for "PIEV + M + D" for the corresponding posted speed. The queue distance (Q) is calculated based on site-specific conditions and added to the "PIEV + M + D" distance.

[13] A horizon year beyond the year of full build-out may be used based on engineering judgment and with approval from a Port Authority Traffic Engineering Principal.

Table 6-1: PIEV + M + D + Q Distances

Posted Speed[1] (mph)	PIEV + M + D Distance (feet)	Q Distance (feet)
20	130	Calculate based on site-specific conditions.
25	185	
30	250	
35	320	
40	395	
45	475	
50	570	

1: The 85th percentile speed may be used in place of the posted speed if an engineering study that supports the use of the 85th percentile speed over the posted speed is completed and approved by Port Authority Traffic Engineering.

Driveways on principal arterials, arterials, and collectors should be located outside of the functional area of intersections, as defined by the UCD and the DCD. These distances are determined by following the guidance provided in *Table 6-2*. The criteria for these roadways are also specified relative to whether the driveway is located upstream or downstream of the intersection, and whether the roadway has a non-traversable median.

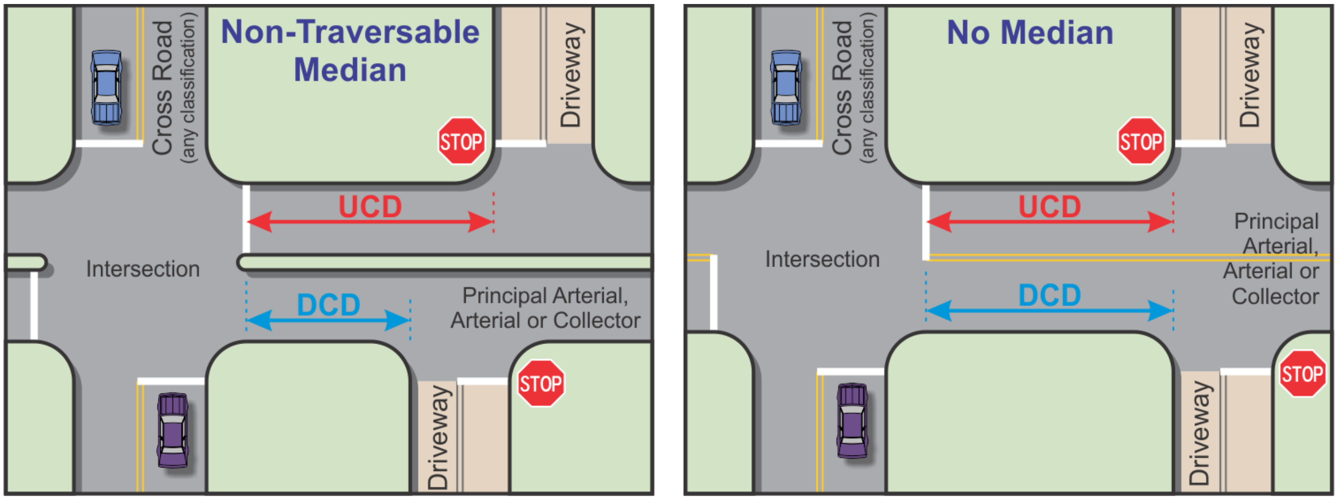
Table 6-2: Port Authority Corner Clearance Guidelines for Principal Arterial, Arterial, and Collectors Roads

Median Control?	Upstream Clearance Distance (UCD)		Downstream Clearance Distance (DCD)	
	Desirable[1]	Minimum[3]	Desirable	Minimum
Non-traversable median	PIEV + M + D distance + 85th percentile queue length on approach[2] (See ***Table 6-1*** for "PIEV + M + D" distances, based on posted speed.)	See ***Table 5-1:*** Use **minimum** unsignalized driveway spacing distance	See ***Table 5-1:*** Use **desirable** unsignalized driveway spacing distance	See ***Table 5-1:*** Use **minimum** unsignalized driveway spacing distance
No median, or traversable median			DCD equals the UCD for traffic traveling in the opposite direction on the same leg of the intersection	

1. The *desirable UCD* is measured between the nearest edge of the driveway and the stop bar on the intersection approach (see *Figure 6-6*).
2. The 85th percentile queue length represents the distance that would not be exceeded by a queue of vehicles 85 percent of the time during the analysis period. For major street approaches to two-way stop-controlled intersections where only the intersecting minor street is stop-controlled, queue length=0.
3. The *minimum UCD* is measured from the nearest edge of the driveway to the edge of the cross road, in accordance with the measurement for the unsignalized driveway spacing guidelines (see *Figure 6-6*).

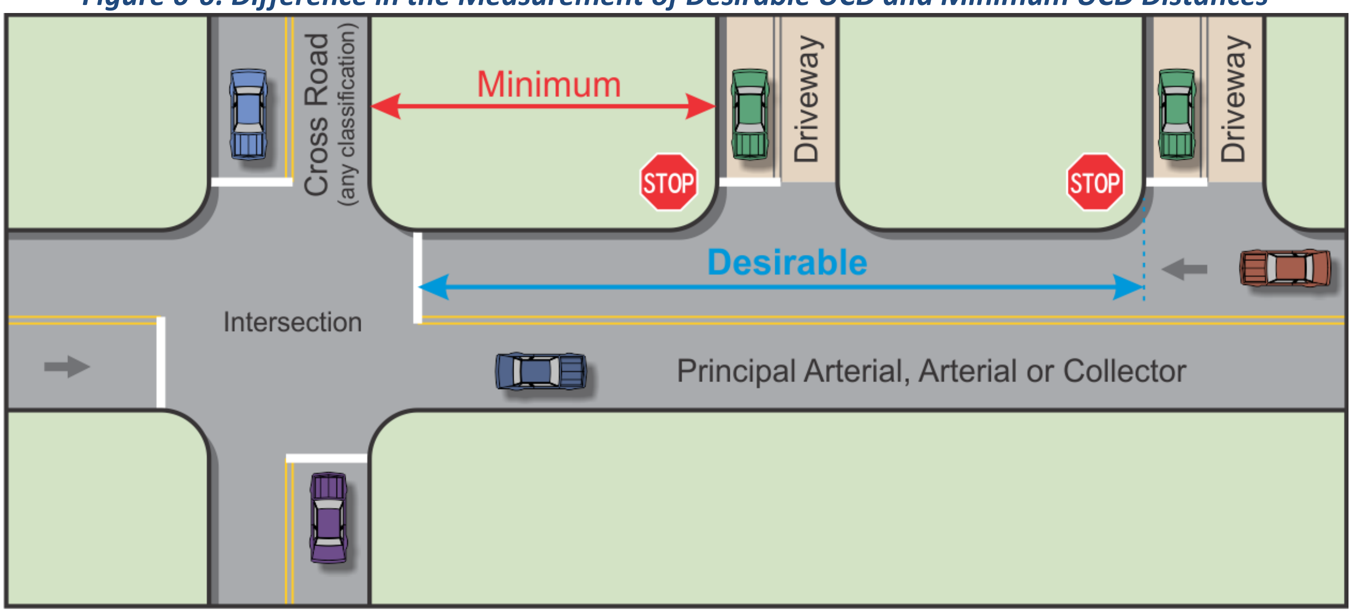
Figure 6-5 illustrates the difference in the desirable Upstream Clearance Distances and desirable Downstream Clearance Distances for roadways with, and without, a non-traversable median. As shown in *Figure 6-5*, for the "no median" case, the desirable DCD equals the desirable UCD for traffic traveling in the opposite direction. In contrast, for the median case, the desirable DCD is less than the desirable UCD. This is because left-turn conflicts at the driveways have been eliminated by the presence of the non-traversable median.

Figure 6-5: Comparison of Desirable UCD and DCD for Roadways With, and Without, a Non-Traversable Median



Furthermore, as noted in *Table 6-2*, and illustrated in *Figure 6-6*, the *desirable UCD* is measured from the nearest edge of the driveway *to the stop-bar on the intersection approach*. In contrast, the *minimum UCD* is measured from the nearest edge of the driveway *to the edge of the cross road*, in accordance with the measurement for the unsignalized driveway spacing guidelines described in *Figure 5-1*.

Figure 6-6: Difference in the Measurement of Desirable UCD and Minimum UCD Distances

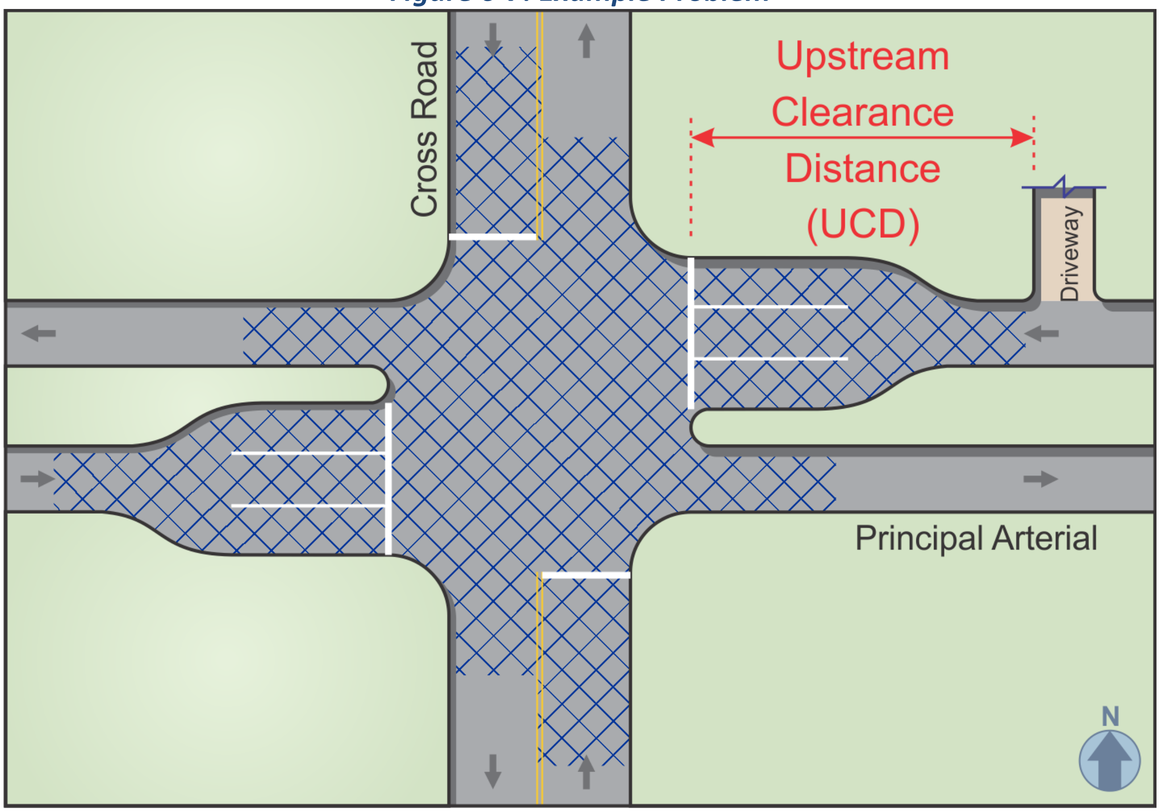


6.2.2 Example Calculation: Upstream Clearance Distance for Arterial Roadway

Given:

- A principal arterial roadway with a non-traversable median and a posted speed of 40 mph (see *Figure 6-7*).
- The principal arterial is intersected by a cross road. The intersection operates under traffic signal control. The 85th percentile queue length on the westbound approach to the cross road intersection is 175 feet (calculated using Highway Capacity Software).

Figure 6-7: Example Problem



Problem: Given the parameters above, calculate the desirable UCD for a site-access driveway planned to be located on the westbound approach of the principal arterial, east of the intersection with the cross road.

Solution:

1) See guidance in *Table 6-2* for a principal arterial roadway with a non-traversable median: **Desirable UCD** = (PIEV + M + D distance) + 85th percentile queue length on approach

2) Refer to *Table 6-1* for PIEV + M + D distance at 40 mph, as shown below

Posted Speed (mph)	PIEV + M + D Distance (feet)	Q Distance (feet)
35	320	Calculate based on site-specific conditions.
40	**395**	
45	475	

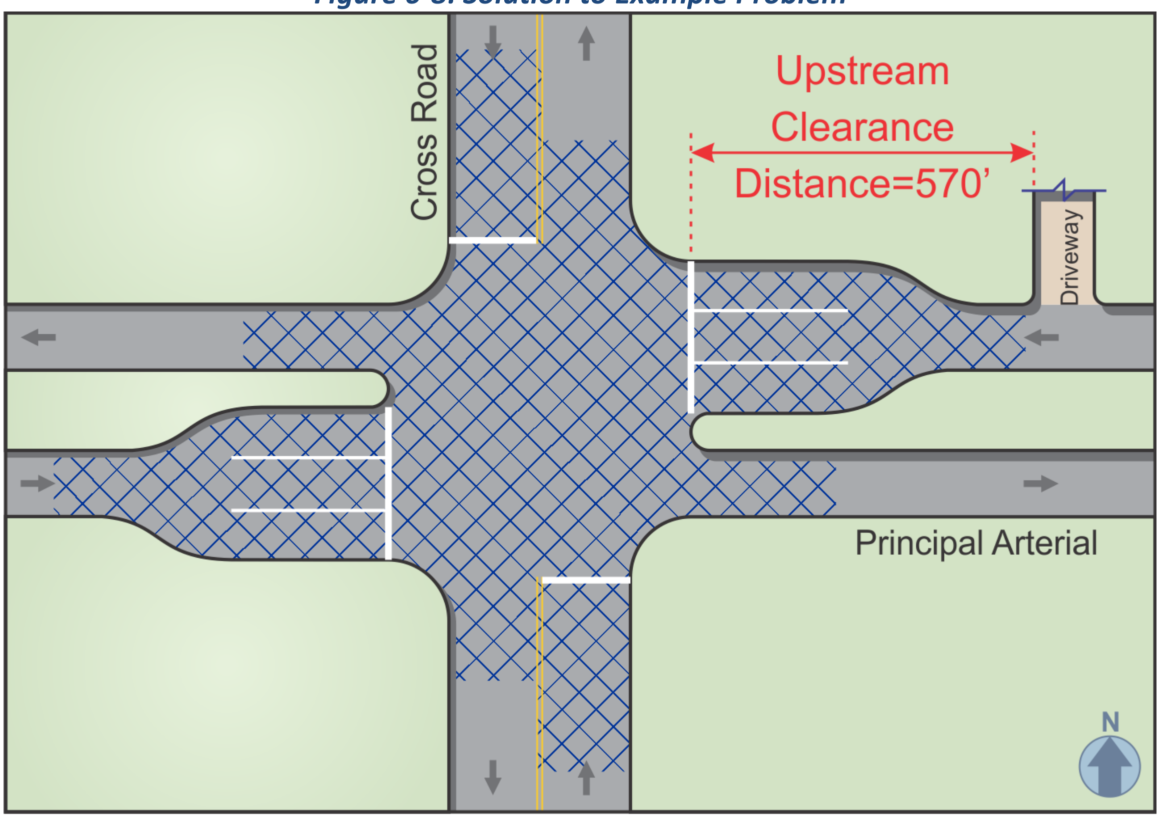
3) PIEV + M + D distance = 395 feet

4) 85th percentile queue length = 175 feet (given)

5) **Desirable UCD** = 395 feet + 175 feet = 570 feet (as measured from the nearest edge of driveway to the stop bar)

Therefore, the driveway should be located no less than 570 feet east of the stop bar on the westbound approach to the intersection, as shown in *Figure 6-8*.

Figure 6-8: Solution to Example Problem



6.2.3 Local Roads and Private Roads Open for Public Travel

Driveways on local roads and private roads open for public travel should be located outside the functional area of intersections, as defined by the UCD and DCD. In these cases, the desirable UCD and DCD distances are determined following the guidance provided in *Table 6-3*.

Table 6-3: Port Authority Corner Clearance Guidelines for Local Roads and Private Roads Open to Public Travel

Upstream Clearance Distance (UCD)		Downstream Clearance Distance (DCD)	
Desirable[1]	Minimum[3]	Desirable	Minimum
Greater of: 1) **Desirable** unsignalized driveway spacing distance (see *Table 5-2*) *or* 2) **95th percentile queue length**[2]	See ***Table 5-2:*** Use **minimum** unsignalized driveway spacing distance	See ***Table 5-2:*** Use **desirable** unsignalized driveway spacing distance	See ***Table 5-2:*** Use **minimum** unsignalized driveway spacing distance

1. The *desirable UCD* is measured between the nearest edge of the driveway and the stop bar on the intersection approach.
2. The 95th percentile queue length represents the distance that would not be exceeded by a queue of vehicles 95 percent of the time during the analysis period. For major street approaches to two-way stop-controlled intersections where only the intersecting minor street is stop-controlled, queue length=0.
3. The *minimum UCD* is measured from the nearest edge of the driveway to the edge of the cross road, in accordance with the measurement for the unsignalized driveway spacing guidelines.

6.2.4 Additional Guidance

In certain cases, limited frontage for the subject property may prevent the desirable corner clearance distances shown in *Tables 6-2* and *6-3* from being achieved. In these cases, the property access strategies should be considered, or the proposed leasehold boundaries should be redrawn. If these options are not feasible, the spacing of the property's driveway from the intersection should be maximized, and a design exception is needed.

CHAPTER 7: TRAFFIC SIGNAL SPACING

7.1 Overview

The proper spacing of traffic signals – in terms of frequency[14] and uniformity[15] – is one of the most important and basic access management techniques because of the effects traffic signals have on the traveling public. Properly-spaced traffic signals allow for the efficient progression of motor vehicle and pedestrian traffic, as well as providing an agency with greater flexibility in developing signal timing plans that can most effectively accommodate varying travel conditions (for example, fluctuations in volume during peak and off-peak periods).

Despite the benefits that traffic signals provide, the installation of a traffic signal is not always the best solution to the operational or safety issues at every intersection or driveway along a roadway. Closely-spaced or improperly-spaced traffic signals can result in frequent stops and unnecessary delays for motorists and pedestrians, as well as increased crash rates, increased fuel consumption, and excessive vehicular emissions.

Given the traffic operations, safety, and environmental implications related to the signalization of intersections, the decision to install a new traffic signal should involve a comprehensive examination of the land use and transportation context of the surrounding area from both planning and engineering perspectives, including such factors as:

- The Port Authority's desired traffic signal control strategy for the roadway or area
- The considerations outlined in the *Port Authority Intersection Signalization Procedures* document, specifically including whether or not the subject intersection meets the traffic signal warrants established in the *Manual on Uniform Traffic Control Devices* (*MUTCD*)
- The existing level of development on, as well as the build-out potential of, nearby properties
- The presence (or absence) of other traffic signals in the area
- The potential need for installation of traffic signals at nearby intersections in the future

7.2 Guidance – A Framework for Traffic Signal Installations at Port Authority Facilities

The guidance framework for determining the appropriate traffic signal spacing guideline to use for projects at Port Authority facilities incorporates:

- Procedures from the *Port Authority Intersection Signalization Procedures* document
- The scope and type of the Port Authority project (e.g., redevelopment program, TAA, etc.)
- An understanding of the Port Authority's desired signal control strategy for the location in question

Each of these parameters is included as part of a "decision tree" to help guide practitioners to the appropriate traffic signal spacing guideline for a particular project, if a traffic signal is warranted. Some background regarding these parameters is provided in the following sub-sections.

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[14] "Frequency" refers to the number of traffic signals for a given length of roadway and is sometimes referred to as "signal density." It is typically expressed as the number of signals per mile.

[15] "Uniformity" refers to the variation in the distances between individual traffic signals along a given length of roadway. It is desirable to minimize this variation and space the traffic signals at uniform distances. For example, suppose a two-mile segment of roadway requires four traffic signals (i.e., a signal density of two signals per mile). All things being equal, it is more desirable to space the signals at a uniform distance along the roadway (e.g., every ½ mile), rather than space them irregularly (e.g., 1 mile, ¼ mile, ½ mile, and ¼ mile).

7.2.1 Port Authority Intersection Signalization Procedures

The *Port Authority Intersection Signalization Procedures* is a Port Authority document describing the processes to be followed for the installation, modification, and removal of traffic signals, based on whether the requested action is initiated by the Port Authority, another public agency, or a private entity. The traffic signal spacing guidelines presented in this chapter incorporate, by reference, and build upon the procedures described in that document.

7.2.2 Scope and Type of Port Authority Projects

Each project within a Port Authority facility is unique in terms of its size and scope. For example, a Port Authority safety improvement project may focus on improvements to reduce crashes at a single intersection or driveway. At a broader scale, Tenant Alteration Applications are focused on the access and transportation needs for a specific site, with a scope that may include several adjacent roadways and intersections, abutting tenant leaseholds, and the immediate environs of the site. Further, large roadway improvement projects at Port Authority facilities may encompass improvements to dozens of individual intersections and driveways. At the highest level, Port Authority redevelopment projects involve broad planning-level efforts to reexamine the access and transportation needs of an entire facility, or large portion thereof. The traffic signal spacing guidelines presented in this chapter address these considerations.

The request for a traffic signal installation (or modification) shall be submitted to the Port Authority. Port Authority Traffic Engineering will review the request.

7.2.3 Port Authority Traffic Signal Control Strategies

The guidelines described in this chapter have been established in recognition that the Port Authority typically installs, maintains, and operates traffic signals in accordance with one of the following three primary signal control strategies[16]:

- Signal Control Strategy #1: Optimizing Vehicle Progression
- Signal Control Strategy #2: Managing Vehicle Queue Lengths to Prevent Spillback
- Signal Control Strategy #3: Managing Pedestrian Flow

Each of these signal control strategies applies a unique set of guidelines for the location of traffic signals at Port Authority facilities. The appropriate signal control strategy to be used in a particular area is determined by the Port Authority's Chief Traffic Engineer. Following a decision regarding the appropriate signal control strategy, the first step in determining the applicable traffic signal spacing guidelines is to use the decision tree in *Figure 7-1*.

The decision tree begins with a determination as to whether the subject location is part of a *Port Authority redevelopment program*. Under a redevelopment program, an entire Port Authority facility – or a significant portion thereof – is being considered for redevelopment. As such, the land uses, roadway alignments, and/or intersection locations at that facility are generally subject to major changes. As a result, there is typically a greater level of flexibility with respect to potential traffic signal locations and more opportunity to space traffic signals in accordance with the desired signal control strategy.

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[16] There may be other special signal control strategies used in particular locations at Port Authority facilities to address unique, site-specific operational or safety considerations.

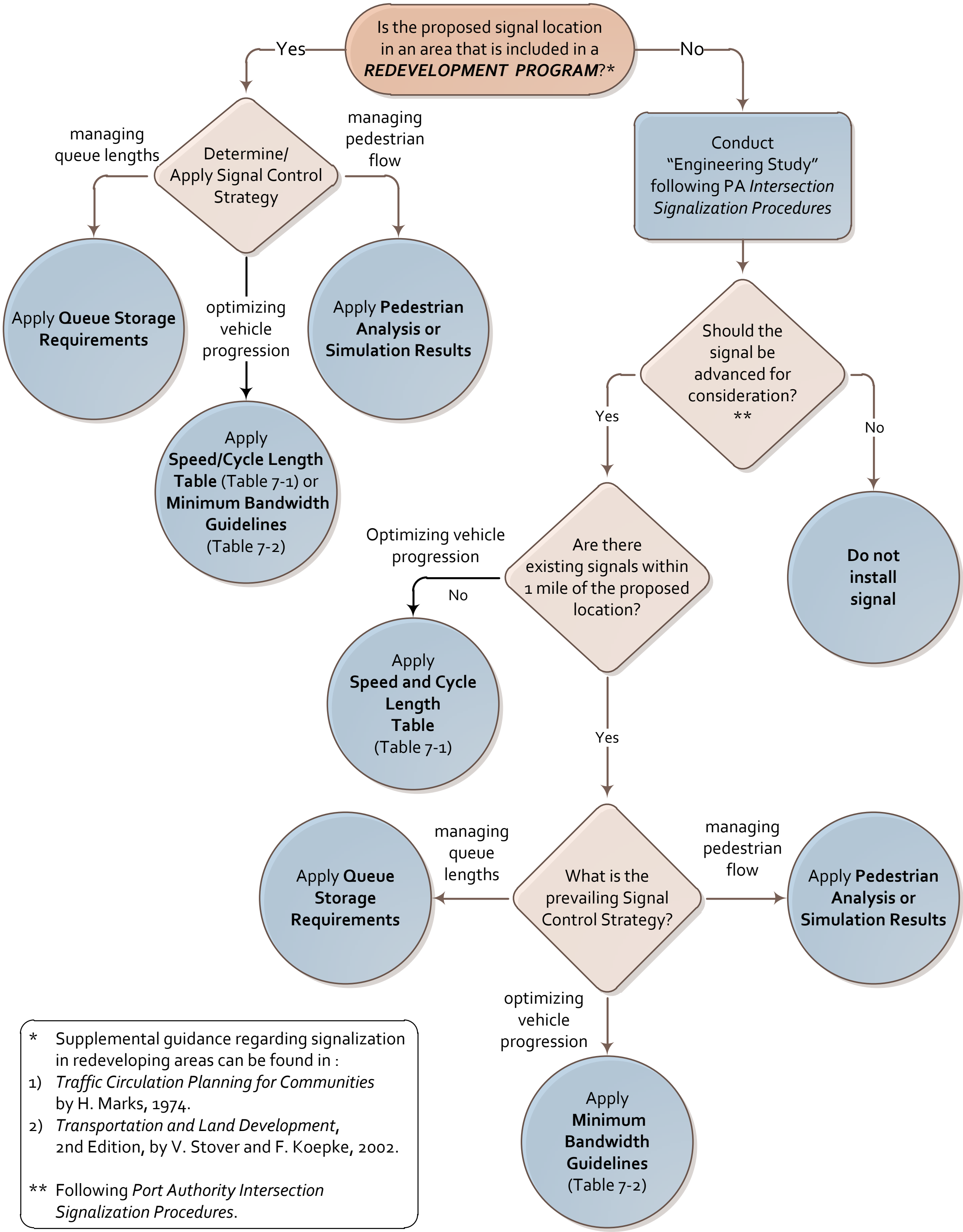
Conversely, many other Port Authority projects where traffic signal installations are considered – such as Tenant Alteration Applications and roadway improvement projects – are located in developed areas where properties already have been developed and roadway alignments and intersection locations already have been established. Under these circumstances, there is often less flexibility with respect to locating new traffic signals. Nevertheless, new traffic signals may still be installed, provided opportunities exist to change the operation of the existing traffic signals along the corridor (e.g., phasing sequences, timing patterns, and/or offsets) to provide for efficient traffic progression.

As shown in the decision tree, with non-redevelopment program projects, the "engineering study" described in the *Port Authority Intersection Signalization Procedures* should be applied first to determine whether a traffic signal is warranted. This engineering study involves a comprehensive examination of traffic safety and operations at the subject location, based on traffic volumes for peak and off-peak time periods, pedestrian activity, crash history, and other factors. The engineering study also includes a detailed analysis of the need for a traffic signal relative to the standard traffic signal warrants published in the *MUTCD*.

If the engineering study concludes that a traffic signal installation should be progressed, the spacing to other existing (or planned future) traffic signals along the intersecting corridors is then determined. Different traffic signal spacing guidelines will apply depending on whether existing traffic signals are located within one mile of the subject intersection.

In summary, the decision tree presents a framework for determining which traffic signal spacing guidelines are most appropriate, based on the type of project, the transportation and land use context of the project, and the Port Authority's desired signal control strategy. The specific traffic signal spacing guidelines are discussed below.

Figure 7-1: Traffic Signal Spacing Decision Tree



7.3 Traffic Signal Spacing Guidelines

The following sub-sections detail the Port Authority guidelines for traffic signal spacing based on the three signal control strategies outlined above.

7.3.1 Guidelines for Signal Control Strategy #1: Optimizing Vehicle Progression

When the efficient progression of vehicular traffic along a corridor is the desired traffic signal control strategy, the land use context of the abutting roadside development is first taken into consideration. Separate traffic signal spacing guidelines have been established for:

1) Undeveloped and developing areas

2) Developed areas

Each of these areas is discussed below along with its associated guidelines to achieve vehicle progression when a new traffic signal is proposed.

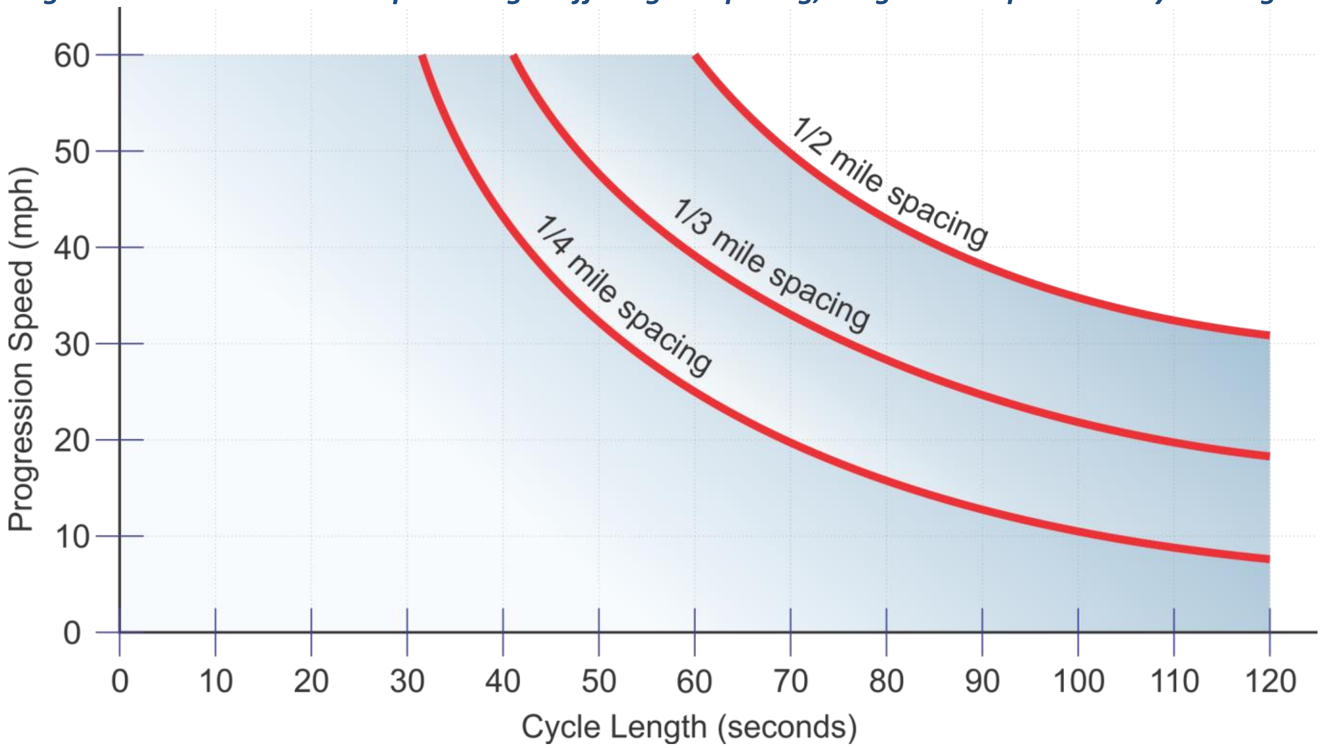
7.3.1.1 Guidelines for Undeveloped or Developing Areas

In both undeveloped and developing areas, there is typically greater flexibility for spacing traffic signals (relative to developed areas) because the spacing of intersections and driveways along a particular corridor has not yet been fully established. *Undeveloped areas* are characterized by: a) little to no roadside development, b) few (if any) intersecting driveways and roadways, c) right-of-way available for roadway improvements, and/or d) little to no pedestrian activity. *Developing areas* are those that are (or will be) undergoing changes related to roadside development activity. These areas are typically characterized by one or more of the following features: a) roadside development planned, imminent, or already taking place, b) a growing number of driveways and intersecting roadways, c) increasing pedestrian activity, and/or d) a need to consider transit. Under such conditions, it is generally easier to achieve ideal traffic signal spacing distances, as described below.

The progression speed for a corridor is primarily a function of both the traffic signal spacing along the corridor and the cycle length of the traffic signals along that corridor[17]. The fundamental relationships among traffic signal spacing, progression speed, and cycle length – which dictate the operation and performance of corridors with multiple signalized intersections – are illustrated in *Figure 7-2*. As the curves in *Figure 7-2* show, for a given cycle length, higher vehicle progression speeds can be achieved by increasing the distance between signals. Similarly, for a given cycle length, reducing the spacing between signals results in a reduction in the progression speed.

[17] Progression speed is also influenced by traffic volumes, traffic signal phasing parameters, and the vertical and horizontal alignments of the roadway. Therefore, the practitioner should consider these other factors when selecting the desired progression speed.

Figure 7-2: Basic Relationships among Traffic Signal Spacing, Progression Speed and Cycle Length



Source: Marks, H. *Traffic Circulation Planning for Communities*, p. 270.

Table 7-1 presents these same relationships – among progression speed, traffic signal spacing, and cycle length – in a tabular format. For a particular cycle length, the table shows the traffic signal spacing distances necessary to achieve various progression speeds. For example, at a cycle length of 80 seconds, spacing signals at 2,350 feet would result in a progression speed of 40 mph; however, reducing the spacing to 1,760 feet reduces the progression speed to 30 mph.

The signal spacing distances in *Table 7-1* range from a minimum of 1,100 feet (i.e., approximately 1/4 mile) at a 60-second cycle and a 25 mph progression speed, to a maximum of 2,640 feet (i.e., 1/2 mile). Note that 2,640 feet represents a practical maximum for the spacing of traffic signals at combinations of higher progression speeds and longer cycle lengths. On roadways where traffic signals are spaced more than ½ mile apart, variations in the travel speeds of individual vehicles begin to disperse the platoons, resulting in a loss of progression efficiency along the corridor.

The spacing distances shown in *Table 7-1* are intended to be used for spacing new traffic signals in areas where the desired signal control strategy is to optimize vehicle progression and where few traffic signals exist. Therefore, the traffic signal spacing distances shown in *Table 7-1* should be used in:

- Undeveloped areas, or
- Developing areas (e.g., areas that are part of a Port Authority redevelopment program), or
- Locations where existing signal spacing distances are one mile or more.

Table 7-1: Speed and Cycle Length Table

Cycle Length (seconds)	Progression Speed (mph)						
	25	30	35	40	45	50	55
	Signal Spacing (feet)[b]						
60	1,100	1,320	1,540	1,760	1,980	2,200	2,420
70	1,280	1,540	1,800	2,050	2,310	2,570	2,640
80	1,470	1,760	2,050	2,350	2,640	2,640	2,640
90	1,630	1,980	2,310	2,640	2,640	2,640	2,640
120[a]	2,200	2,640	2,640	2,640	2,640	2,640	2,640

a. Longest recommended cycle length.

b. A signalized intersection within 300 feet of the ideal location is generally acceptable. Where minimum traffic signal spacing distances are impractical, minimum bandwidth guidelines apply (see Table 7-2).

Source: *New Jersey State Highway Access Management Code*, Appendix "D", New Jersey Department of Transportation.

7.3.1.2 Guidelines for Developed Areas

As noted previously, many Port Authority projects are located in *developed areas*, which are urbanized and characterized by one or more of the following features: a) dense roadside development, b) substantial number of existing intersecting roadways, c) limited right-of-way available for roadway improvements, d) existing environmental and/or topographic constraints, and/or e) significant pedestrian or transit considerations. Under these conditions, signal spacing along a corridor is often already limited by irregular street patterns, natural or topographical constraints, or existing tenant leasehold boundaries. In these cases, different guidelines from those for undeveloped areas apply. Vehicle progression can still be maintained by ensuring that a specific percentage of the cycle length is devoted to progressing through traffic along the corridor. In other words, the objective is to guarantee that major street through traffic is allocated no less than a specified minimum length of green time along the length of the corridor. (It should be noted that this results in a comparable decrease in the green time allocation to intersecting side streets). This objective is achieved by applying *minimum bandwidth guidelines* to major street through traffic at all signals located in the corridor's signal system. Applying the minimum bandwidth guidelines requires constructing a time-space diagram[18] for the subject corridor and determining the bandwidth for a specific timing plan. This section introduces and illustrates the components of a time-space diagram before presenting the minimum bandwidth guidelines for Port Authority roadways.

Bandwidth is the time available (expressed in seconds or as a percentage of the cycle length) for vehicles to travel through a traffic signal system at a specific progression speed. As such, bandwidth is a quantitative measurement of the through traffic capacity of a signal progression system: the greater the bandwidth, the higher the capacity for progressing through traffic along the corridor. The *through band* (or *green band*) is the time-space path whereby a motorist would encounter a green light indication at all signals in the system.

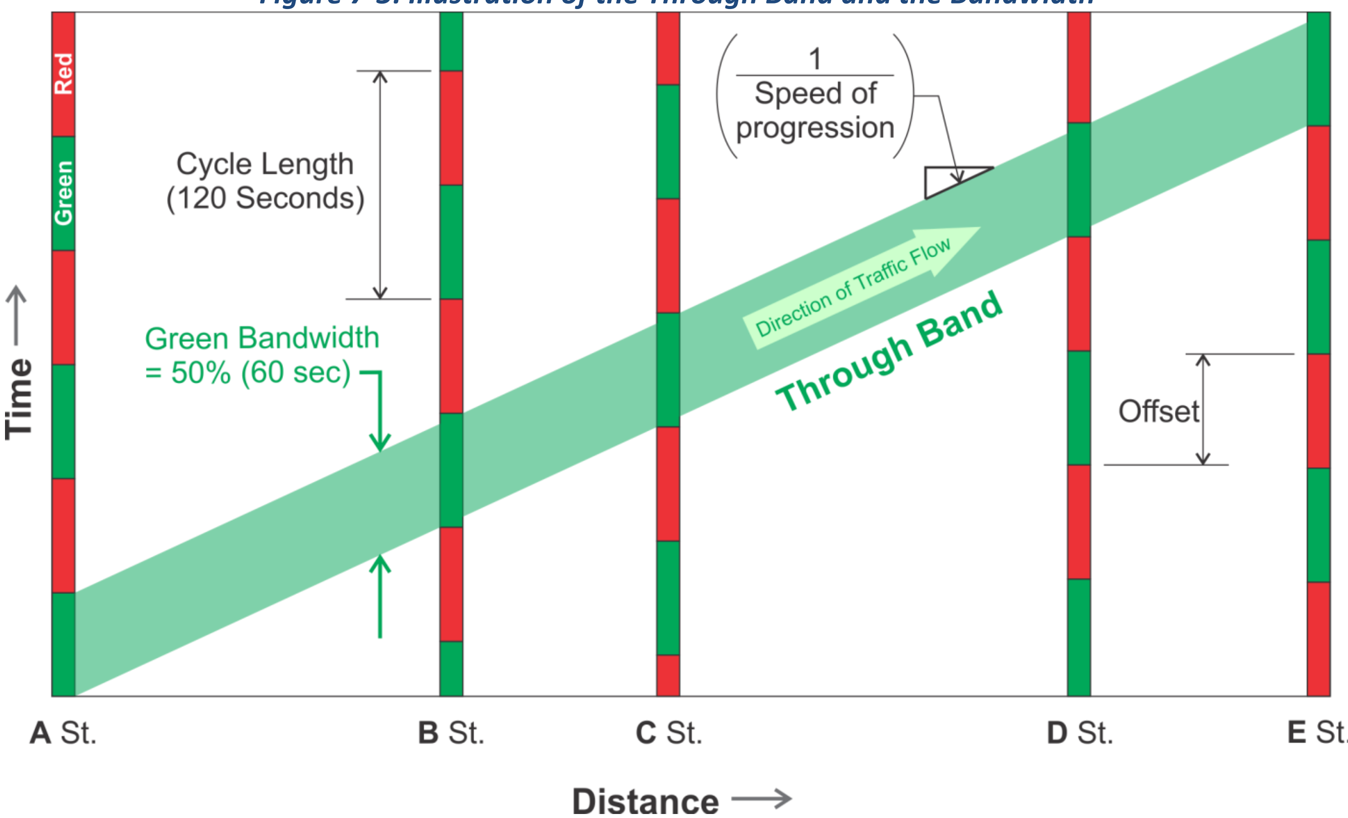
Figure 7-3 presents a time-space diagram showing an illustration of the through band and the bandwidth for traffic traveling in one direction along a corridor with five traffic signal-controlled intersections (i.e., "A Street"

[18] A *time-space diagram* is a graph on which the distance between signals and signal timing is plotted against time, and indicating the bandwidth and speed of traffic.

through "E Street") that are spaced at irregular distances along the length of the corridor. (*Figure 7-4* presents the same time-space diagram, but with "distance" on the vertical axis and "time" on the horizontal access, for readers more accustomed to this orientation.[19])

As shown in *Figures 7-3* and *7-4*, the alternating red-green timing at the intersections – coupled with the traffic signal offsets between adjacent intersections – allows for a continuous through band for the progression of major-street traffic through all five intersections in the signal system. This through band allows vehicles to travel, without stopping, through all five intersections at the progression speed. The duration of the bandwidth is the time elapsed between the passing of the first vehicle and the last possible vehicle moving without impedance through the traffic signal system at the progression speed. The vertical dimension of the through band in *Figure 7-3* (and the horizontal dimension of the through band in *Figure 7-4*) represents the bandwidth, which is shown to be 60 seconds, or 50 percent of the cycle length for the corridor. In practice, the bandwidth for a series of traffic signals along a corridor can be calculated either by preparing a time-space diagram manually or using a software program (e.g., SYNCHRO).

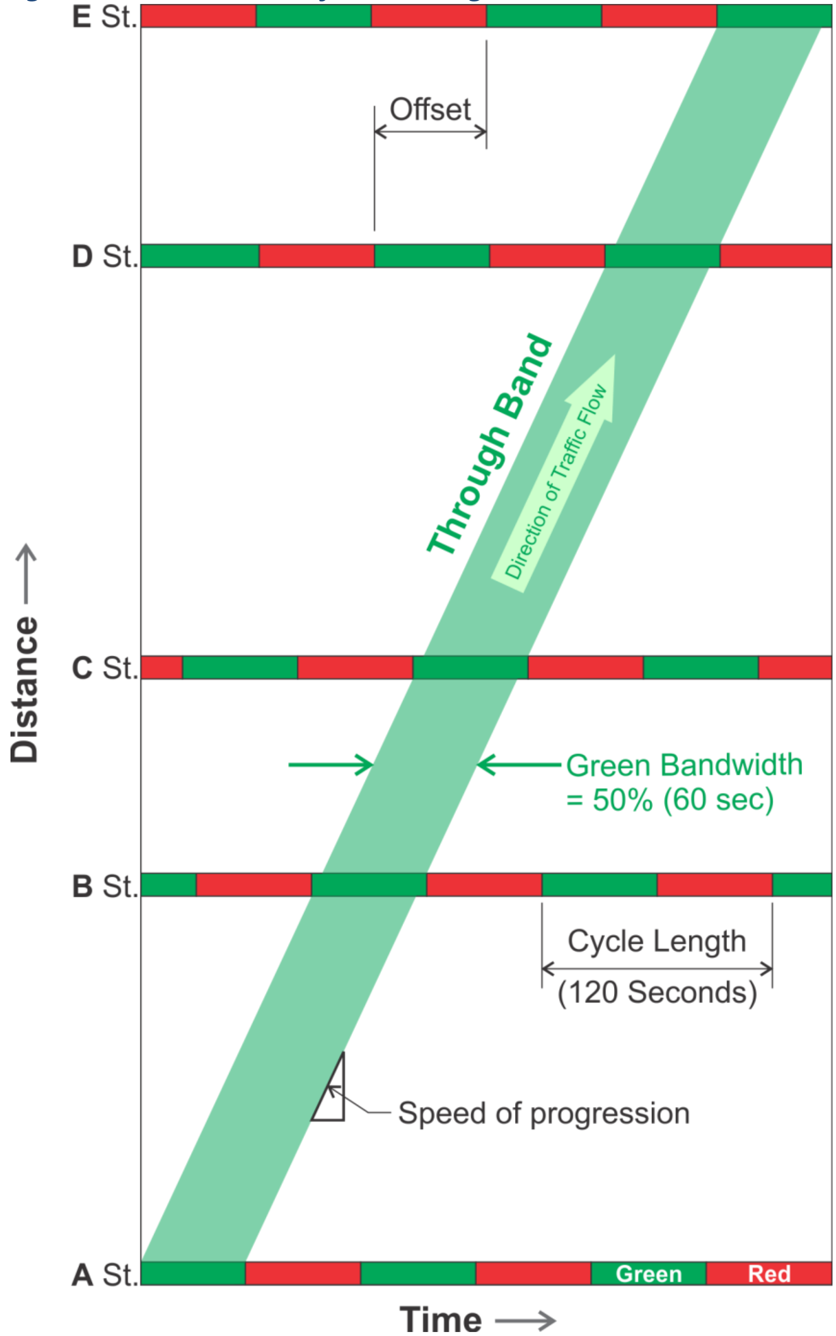
Figure 7-3: Illustration of the Through Band and the Bandwidth



Note: Figure 7-3 presents a time-space diagram with "distance" on the horizontal axis and "time" on the vertical axis. In contrast, Figure 7-4 presents "time" on the horizontal axis and "distance" on the vertical axis.
Source: Adapted from Banks, J.H., *Introduction to Transportation Engineering, 2nd Edition*, 2002, p. 308.

[19] Some readers may be accustomed to seeing a time-space diagram with "distance" on the horizontal axis and "time" on the vertical axis, as shown in Figure 7-3. Other readers may be accustomed to seeing "time" on the horizontal axis and "distance" on the vertical axis, as shown in Figure 7-4. Both versions are presented here.

Figure 7-4: Illustration of the Through Band and the Bandwidth



Note: Figure 7-4 presents a time-space diagram with "time" on the horizontal axis and "distance" on the vertical axis. In contrast, Figure 7-3 presents "time" on the vertical axis and "distance" on the horizontal axis.
Source: Adapted from Banks, J.H., *Introduction to Transportation Engineering, 2nd Edition*, 2002, p. 308.

Because of the higher traffic volumes typically found on principal arterials and arterials, wider bandwidths are desirable on these higher classification roadways. On the other hand, narrower bandwidths are acceptable on roadways of lower classification, such as collectors, because of the lower volumes, shorter trips served, and reduced driver expectations. Along local roads and other lower classification roadways, bandwidth is not a major consideration because the progression of through traffic is usually subordinate to the property access function of these roadways.

For developed areas where optimizing vehicle progression is the desired signal control strategy, the Port Authority's signal spacing guidelines are based on ensuring a minimum bandwidth is maintained along the corridor (requiring preparation of a time-space diagram as described above). The *Table 7-2* presents the minimum bandwidth guidelines for Port Authority facilities.

Table 7-2: Minimum Bandwidth Guidelines

Roadway Classification	Minimum Bandwidth[1]	
	Peak Periods	Off-Peak Periods[2]
Principal Arterial	45%	40%
Arterial	40%	35%
Collector	35%	30%
Local/Private Road	Progression not a criterion	

1. Where signalization already exists, and the bandwidth is less than the values shown in the table, an additional traffic signal may be permitted if it would not result in a reduction in the existing bandwidth.
2. Minimum bandwidth for off-peak periods applies where the peak hour of site-generated traffic would not coincide with the peak hour of traffic on the roadway network.

When optimizing vehicle progression is the desired signal control strategy, the minimum bandwidth guidelines shown in *Table 7-2* should be applied at all Port Authority facilities where:

- The project is located in a developed area, or
- The spacing of existing traffic signals is less than one mile.

Under these conditions, it is acceptable to install a new traffic signal provided that warrants are met and, with the new traffic signal in place, the traffic signal system along the corridor can meet the guidelines for minimum bandwidth shown in *Table 7-2*. If these minimum bandwidth criteria cannot be met, other traffic control devices should be considered, and other access strategies may be needed to serve the property (see *Chapter 13*). If none of these options provides a feasible solution, a design exception is needed (see *Chapter 14*).

7.3.2 Guidelines for Signal Control Strategy #2: Managing Queue Lengths to Prevent Spillback

On some roadways, existing signalized intersections may already be located in close proximity to one another. Due to the close spacing, vehicle queues may spill back from one intersection to the next, particularly during peak periods when volumes are high. Queue spillback from one signalized intersection into another can disrupt traffic operations at the upstream intersection as vehicles at the back of the queue block the turning paths of other vehicles, resulting in increased delays and reduced capacity. In addition, the congested conditions affect the safety performance of the roadway by increasing the potential for crashes. In some locations, gridlock can result.

Queue spillback may occur from different causes. In some cases, the close spacing of traffic signals may result from inconsistent planning practices. In other cases, traffic volumes have increased so much over time that what was once an acceptable condition has now become a problem. In either case, relocating one or both signals to meet any of the spacing guidelines described previously in this chapter (*Table 7-1* or *Table 7-2*) may be infeasible or cost-prohibitive.

Under these conditions, the Port Authority's desired signal control strategy may be to manage the lengths of the vehicle queues to prevent (or reduce the propensity for) spillback of queues from one intersection into the next. Queue spillback at existing closely-spaced intersections may be reduced or eliminated using a variety of operations, design, and traffic management strategies, including:

Less Costly / Easier to Implement Strategies:

- Modifying the timing and/or phasing parameters at one or both traffic signals, including:
  - Adjustments to phase lengths (timing)
  - Adjustments to phasing sequences
  - Adjustments to the offsets between the signals
- Metering the approaching (upstream) demand
- Prohibiting certain turning movements by time-of-day (or at all times)
- Signing and striping (e.g., "Don't Block The Box" or "Do Not Block Intersection" signs, cross-hatched striping inside the physical junction of the intersecting roadways, see *Photo 7-1*)

More Costly / More Difficult to Implement Strategies:

- Adding capacity to one or both intersections using any of the following design techniques:
  - Restriping approaches to the intersections to provide a lane configuration that is more suitable for prevailing traffic conditions
  - Widening one or more of the intersecting roadways to provide additional lanes
  - Channelizing right-turn movements (i.e., moving them outside of the intersection where they do not need to operate under signal control)
- Implementing alternative left-turn treatments

In locations where the Port Authority's prevailing signal control strategy is to manage queue lengths to prevent spillback, the strategies listed above – and combinations thereof – should be examined and tested as part of a comprehensive study, recognizing that each project is different and should be assessed individually. In all cases, however, the 95th percentile queue length[20], commonly-used for design purposes, should be applied where the desired signal control strategy is to manage queue lengths to prevent spillback.

It should be noted that most traffic engineering software packages (e.g., HCS, SYNCHRO) calculate queue lengths as one of their output parameters and should be used for testing many of the strategies identified above. Carefully calibrated simulation models may be applied to determine the impacts that various strategies have on the resulting queue lengths.

[20] The 95th-percentile queue length represents the distance that would not be exceeded by a queue of vehicles 95 percent of the time during the analysis period.

Photo 7-1: "Do Not Block Intersection" Sign and Cross-Hatched Striping at Intersection

Photo source: Port Authority archives (looking west on 14th Street from Manila Avenue on the New Jersey exit from the Holland Tunnel).

7.3.3 Guidelines for Signal Control Strategy #3: Optimizing Pedestrian Flow

In some locations, traffic signals are installed primarily to provide efficient pedestrian crossings, optimizing pedestrian flow across a roadway, rather than to accommodate vehicular traffic movements. One example of this is a series of pedestrian crosswalks that span the inner and outer lanes of an airport terminal frontage road to connect the airport terminal to a nearby parking facility.

Where the Port Authority's prevailing signal control strategy is to optimize pedestrian flow, a tenant may be asked to perform a comprehensive engineering study. The engineering study shall be conducted by a professional traffic engineer and should examine the relationships among the spacing, location, design features, and operation of existing and proposed traffic signals. The engineering study should include analysis and/or simulation of conditions involving both pedestrian crossings and intersecting motor vehicle traffic. At the team conceptual planning meeting with Port Authority Traffic Engineering, a detailed scope of work for the study will be developed and may include an examination of the following parameters:

- Crosswalk locations and relevant traffic control devices
- Pedestrian crossing volumes by time-of-day (i.e., peak and off-peak volumes)
- Pedestrian walking speeds and platooning characteristics
- Types of pedestrians crossing the roads (e.g., visitors versus employees, families with children, patrons with luggage)
- Delay for pedestrian crossings by time-of-day
- Motor vehicle volumes by time-of-day
- Delays for motor vehicle traffic
- Approach speeds for motor vehicle traffic
- Sight lines and available sight distances between pedestrians and drivers
- Expectations of drivers and motorists
- Illumination levels and visual clutter

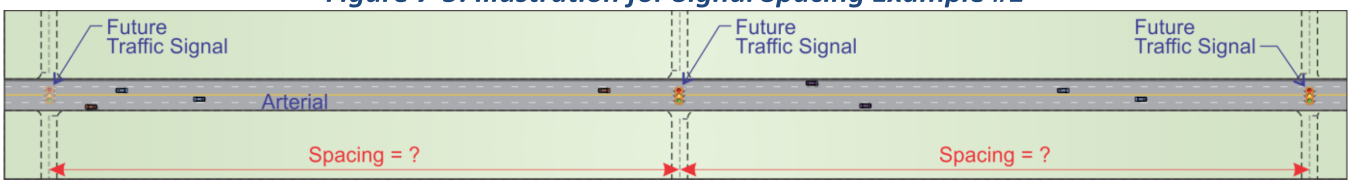
7.4 Example Calculations

7.4.1 Example #1: Signal Spacing in a Developing Area – Strategy: Optimize Vehicle Progression

Given:

- An arterial roadway is located in a developing area with no existing traffic signals and no intersecting cross-streets.
- A Port Authority redevelopment program is being undertaken that is projected to result in new development along the arterial with the potential to require several future traffic signal installations (provided warrants in the *Manual on Uniform Traffic Control Devices* are met). See *Figure 7-5*.
- The desired signal control strategy along the roadway is the optimization of vehicle progression.
- The desired progression speed is 35 mph, and the cycle length for new traffic signals along the roadway is 90 seconds.

Figure 7-5: Illustration for Signal Spacing Example #1



Problem: Find the spacing for new traffic signal installations along the arterial roadway.

Solution:

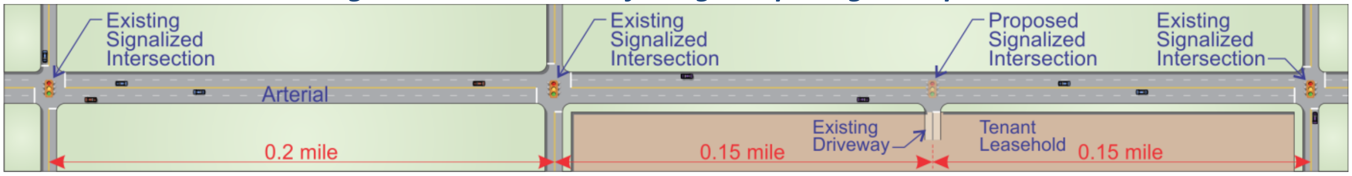
- Refer to *Figure 7-1* for guidance on determining the traffic signal spacing guidelines to be applied. Because the project is a Port Authority redevelopment program and the signal control strategy is to optimize vehicle progression, either the speed and cycle length table (*Table 7-1*) or minimum bandwidth guidelines could be used. However, because there are no existing traffic signals along the roadway (to potentially constrain the green bandwidth), the speed and cycle length table should be used in this case.
- Referring to *Table 7-1*, the signal spacing corresponding to a progression speed of 35 mph and a cycle length of 90 seconds is 2,310 feet. Because no intersecting cross-streets currently exist along the arterial roadway, there are no pre-established locations for potential future traffic signal installations. Therefore, to achieve the desired signal control strategy of optimizing vehicular progression, all new traffic signal installations along the arterial should be spaced approximately 2,310 feet apart.
- In addition, given that the area is newly developing, it is also desirable to proactively establish a supporting street network as well as potential future signal locations, to reduce reliance on the arterial roadway as the sole means for property access (see *Chapter 13*).

7.4.2 Example #2: Signal Spacing in a Developed Area – Strategy: Optimize Vehicle Progression

Given:

- To accommodate a change in business operations, a Port Authority tenant desires a new traffic signal at an existing driveway serving its leasehold, as shown in *Figure 7-6*.
- The driveway where the signal is desired is located along a Port Authority roadway that is classified as an arterial and has several existing traffic signals spaced as shown in *Figure 7-6*. The desired progression speed along the arterial is 30 mph.
- Discussion with Port Authority Engineering at the team conceptual planning meeting indicates that the applicable signal control strategy is to maintain vehicular progression along the arterial and not reduce the green bandwidth during peak periods.
- The existing cycle length for all existing traffic signals located along the arterial is 60 seconds.
- Existing green bandwidths are:
  - 36 percent during peak periods (below the minimum bandwidth threshold of 40 percent for arterials noted in *Table 7-2*)
  - 45 percent during off-peak periods (exceeding the minimum bandwidth threshold of 35 percent for arterials noted in *Table 7-2*)
- An engineering study, prepared following the *Port Authority Intersection Signalization Procedures*[21], indicates that a new traffic signal would meet *MUTCD* traffic signal warrants under projected future traffic conditions.

Figure 7-6: Illustration for Signal Spacing Example #2



Problem: Determine if the tenant's driveway along the arterial can be signalized as desired, given the parameters above.

Solution:

- Refer to *Figure 7-1* for guidance on determining the traffic signal spacing guidelines to be applied. The project is not part of a redevelopment program and the engineering study suggests that the signal should be progressed for consideration based on meeting MUTCD warrants.
- Because there are existing signals located within one mile of the desired location and Port Authority Engineering indicates that the applicable signal control strategy is to maintain vehicular progression along

[21] Step 2 of Process B: "Procedures for Installation of a New Traffic Signal Requested by Private Entities."

the arterial and not reduce the green bandwidth during peak periods, the minimum bandwidth guidelines shown in *Table 7-2* apply.

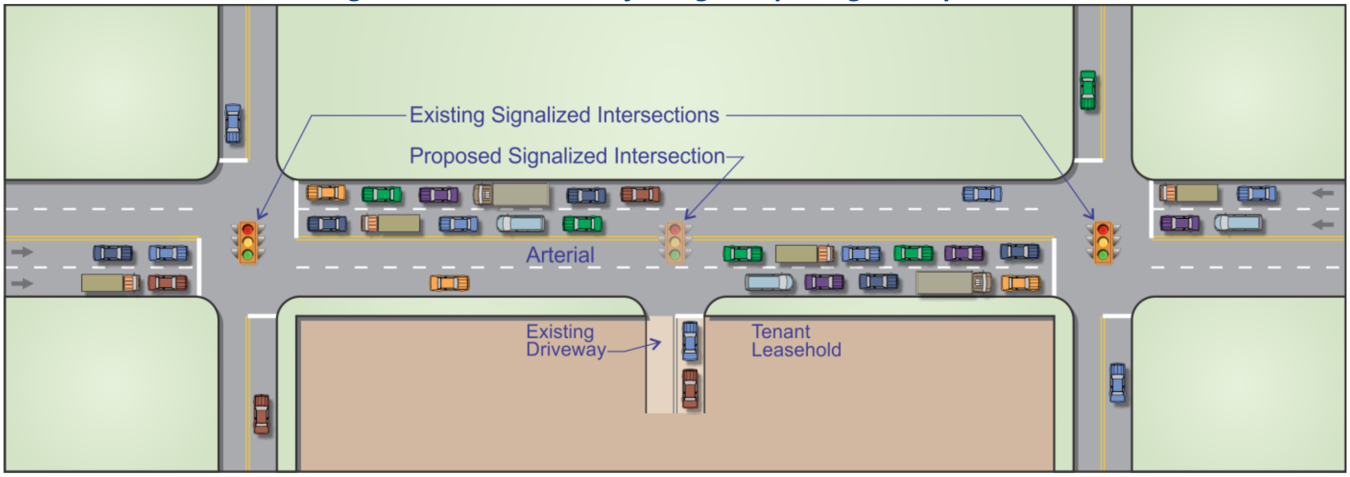
- A corridor-level traffic signal progression analysis, involving preparation of a time-space diagram (not shown here), is then needed to determine the bandwidth that can be achieved along the arterial with the new traffic signal in place. As noted above, the existing green bandwidths are:
    - 36 percent during peak periods (currently *below* the minimum bandwidth threshold of 40 percent) and
    - 45 percent during off-peak periods (currently *exceeding* the minimum bandwidth threshold of 35 percent)
- The progression analysis indicates that – with the proposed traffic signal in place – the projected bandwidth during off-peak periods would be reduced from 45 percent to 42 percent under future conditions. The projected 42 percent bandwidth under future conditions is still above the minimum bandwidth threshold of 35 percent specified in *Table 7-2*.
- However, the progression analysis also indicates that – with the proposed traffic signal in place – the projected bandwidth during peak periods would be reduced from 36 percent to 33 percent under future conditions. The projected 33 percent bandwidth under future conditions is not only below the minimum threshold specified in *Table 7-2*, but also below the existing 36 percent bandwidth.
- Therefore, if operational, design, or traffic management measures cannot maintain the existing bandwidth during peak periods, then the driveway should not be signalized and other access management strategies should be pursued to accommodate tenant's needs (see *Chapter 13*) or a design exception is needed for the proposed traffic signal location (see *Chapter 14*).

7.4.3 Example #3: Signal Spacing in a Developed Area – Strategy: Manage Queue Lengths

Given:

- An arterial roadway has two existing signalized intersections spaced as shown in *Figure 7-7*.
- To accommodate a change in business operations, a Port Authority tenant abutting the arterial between the two existing traffic signals desires a new traffic signal at an existing driveway serving its property.
- Discussions with Port Authority Engineering at the team conceptual planning meeting indicate that the applicable signal control strategy along the arterial is to manage queue lengths to prevent vehicle spillback between intersections.

Figure 7-7: Illustration for Signal Spacing Example #3



Problem: Determine if the tenant's driveway along the arterial can be signalized as desired, given the parameters above.

Solution: The steps for determining the solution to this problem are outlined below (a numerical solution is not provided):

- Because Port Authority's signal control strategy is to manage queue lengths, the primary objective is to prevent spillback of vehicle queues between the intersections. Traffic operations analysis of the two existing signalized intersections – as well as the signalized intersection proposed by the tenant – under projected future traffic conditions is needed to determine the 95th percentile queue lengths between all three intersections.

- The 95th percentile queuing results of the future conditions traffic operations analysis should be examined. If the projected future 95th percentile vehicle queues from adjacent intersections along the arterial do not spillback into each other, the tenant's proposed traffic signal may be allowed, provided a warrant analysis determines that a signal is warranted at this location.

- If the future conditions traffic analysis reveals that 95th percentile queues along the arterial extend back into adjacent intersections, the strategies presented in *Section 7.3.2* should be tested to identify what improvement measures — or combinations of measures — may result in vehicle queues along the arterial that do not spillback into adjacent intersections. If no solutions are identified, the signal should not be allowed. However, the tenant may request a design exception for the proposed traffic signal location, subject to approval from the Port Authority.

CHAPTER 8: ACCESS IN THE VICINITY OF INTERCHANGES

8.1 Overview

Freeway interchanges, important focal points of activity, provide the means of moving traffic between freeways and intersecting cross roads. Although direct property access is prohibited on the freeway itself, operational problems can arise when driveways and intersections along the cross road are spaced too close to the interchange ramp termini, resulting in heavy weaving volumes, complex traffic signal operations, frequent crashes, and recurrent congestion. In addition, driveways and median breaks that are provided for direct access to properties along the cross road compound these problems.

Managing access on cross roads in the vicinity of interchanges protects the longevity of both the interchange and the intersecting cross road by minimizing congestion, reducing crash rates, and simplifying driving tasks. Improperly managing access on the cross road near the interchange may cause congestion and potential crashes, thereby shortening the life cycle of the interchange. In addition, it may cause significant impairment of cross road and freeway mainline safety and operations. For these reasons, access management should be applied to interchange cross roads such that access points – including both driveways and intersections – are sufficiently separated from freeway interchange ramp terminals[22].

8.2 Guidelines

The guidelines for the spacing of access points in the vicinity of interchanges vary depending on the existing (or anticipated future) traffic control devices at the intersection between the freeway ramp terminal and the cross road. Separate guidelines exist for locations where the ramp operates:

A) under either STOP sign or traffic signal control, or

B) as a free-flow merge or under yield-control

The guidelines associated with each of these traffic control conditions are described below.

8.2.1 Spacing Guidelines for Stop-Controlled or Signal-Controlled Ramp Terminals

Where the intersection between a freeway ramp terminal and a cross road operates under STOP sign or traffic signal control (see *Figure 8-1*), the dynamics of traffic movements from the freeway to the cross road – and along the cross road – are similar to other roadways that involve STOP-controlled and traffic signal controlled driveways and intersections. Under these circumstances, the spacing guidelines to be applied on the cross road shall be in accordance with the applicable guidance presented previously in *Chapter 5* (Unsignalized Driveway Spacing), *Chapter 6* (Intersection Corner Clearance) and *Chapter 7* (Traffic Signal Spacing).

[22] A "ramp terminal" is the intersection of a freeway ramp (entrance or exit ramp) and a surface street.

Figure 8-1: Stop or Signal Control at Interchange Ramp

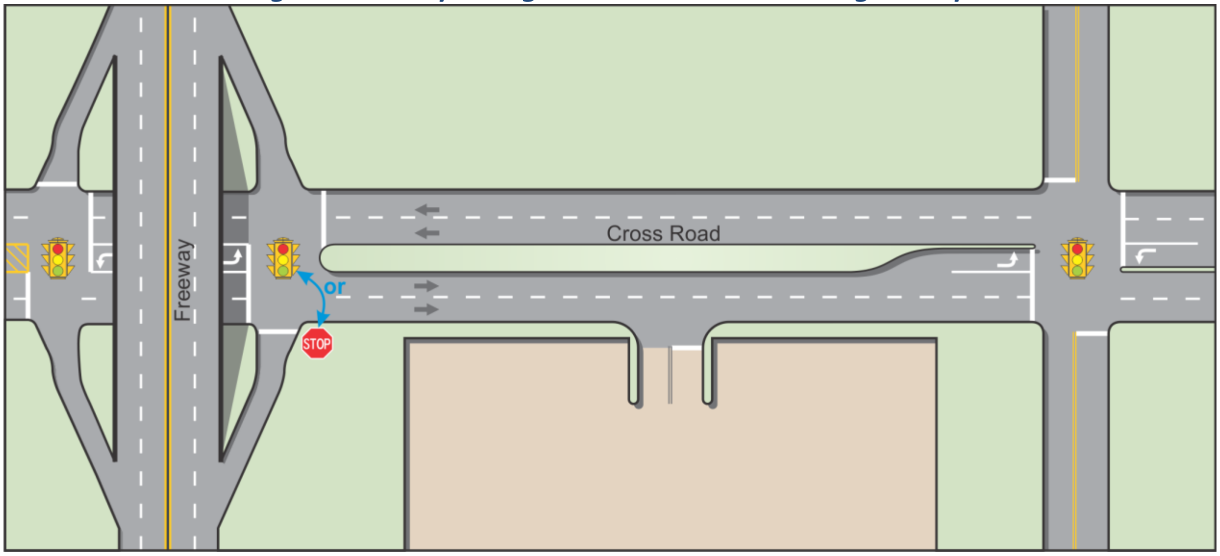
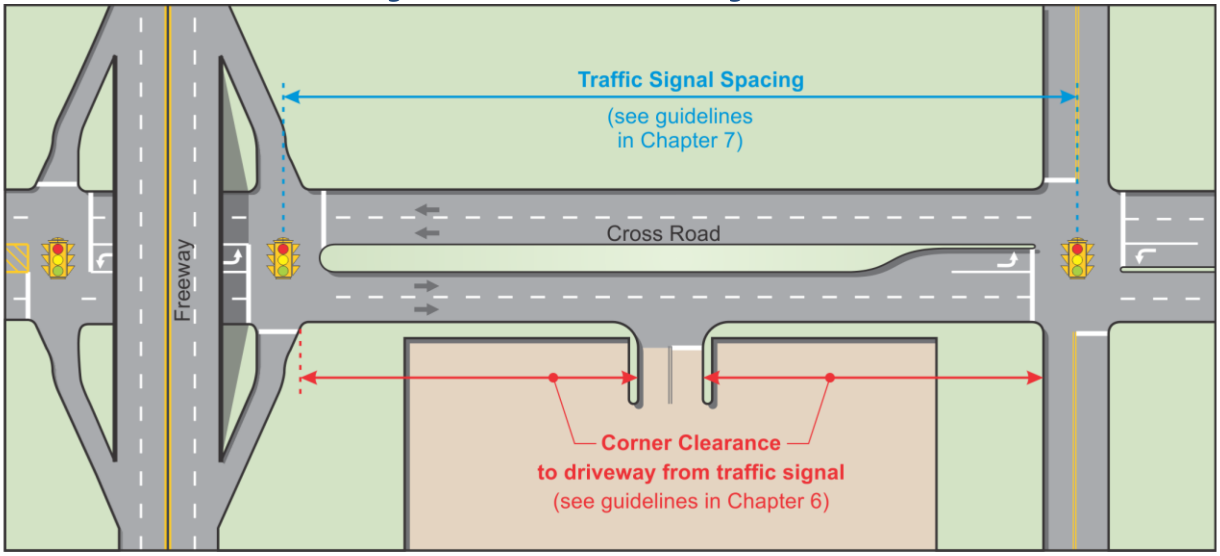


Figure 8-2 illustrates how the guidelines from *Chapters 6* and *Chapter 7* would be applied to determine:

1) The corner clearance between a signalized interchange ramp terminal and a STOP-controlled driveway on the cross road (*Chapter 6*)

2) The spacing between a signalized interchange ramp terminal and a signalized intersection on the cross road (*Chapter 7*)

Figure 8-2: Application of Traffic Signal Spacing and Corner Clearance Guidelines to a Signal-Controlled Interchange Cross Road

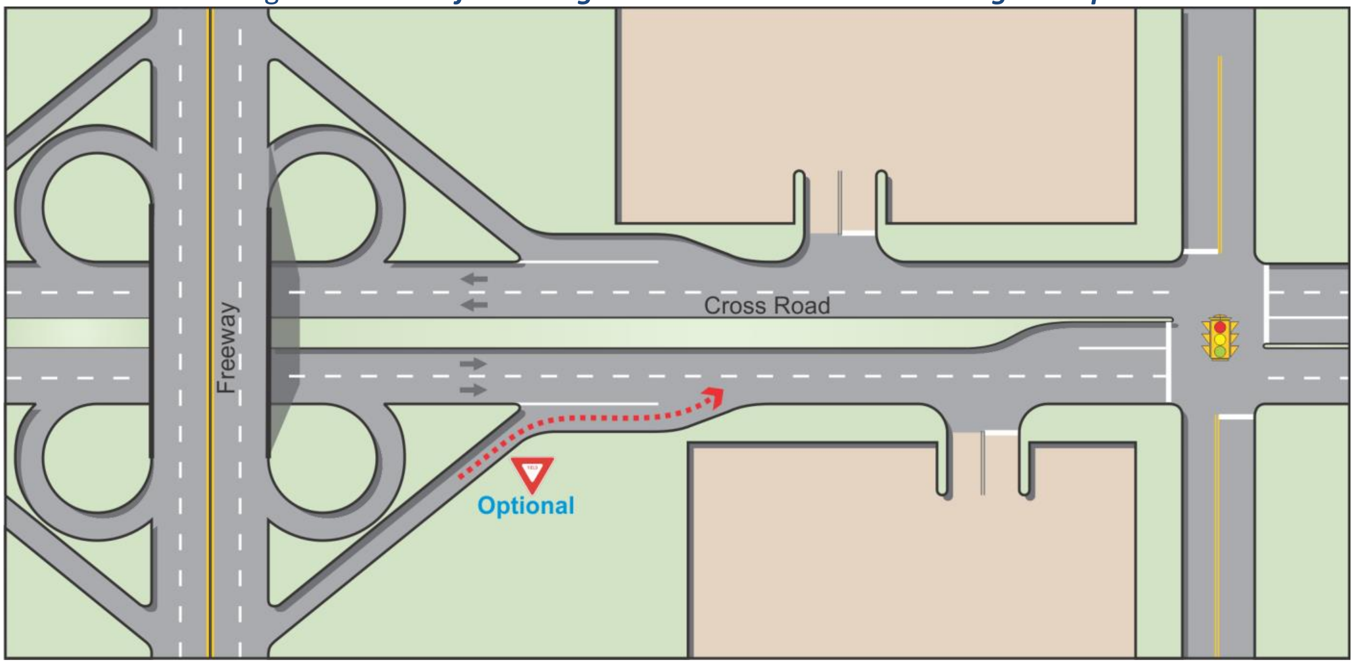


At intersections where the ramp terminal is STOP-controlled at the cross road, consideration should be given to the possibility that this intersection may become signalized in the future as a result of traffic volumes increasing over time. Under these circumstances, where traffic signal control at the ramp terminal is anticipated in the future, the traffic signal spacing guidelines and corner clearance guidelines should be applied rather than the unsignalized driveway spacing guidelines; application of the unsignalized spacing guidelines might not provide sufficient spacing of driveways and intersections along the cross road under future conditions.

8.2.2 Spacing Guidelines for Free-Flow Merge or Yield-Controlled Ramp Terminals

In locations where the ramp terminal connects to the intersecting cross road via a free-flow merge (see *Figure 8-3*), drivers exiting the freeway via the ramp do not need to stop, but rather merge with traffic traveling on the cross road. Similar traffic flow dynamics exist in locations where the ramp terminal is yield-controlled at the cross road.

Figure 8-3***: Free-flow Merge or Yield Control at Interchange Ramp***



Under free-flow conditions, sufficient access spacing should be provided along the cross road to allow drivers to first merge with the cross road traffic, maneuver into the proper lane, and decelerate to the back of any queue before turning at a driveway or intersection. The following sections provide guidelines for these access configurations:

- **Spacing between an exit ramp terminal and the first full-movement street intersection or driveway** (i.e., where left-turns are allowed): see *Figure 8-4*.
- **Spacing between an exit ramp terminal and the first downstream right-in/right-out street intersection or driveway** (i.e., where left-turns are prohibited by a non-traversable median): see *Figure 8-5*.
- **Spacing between right-in/right-out street intersection or driveway and a downstream entrance ramp** (i.e., where left-turns are prohibited by a non-traversable median): see *Figure 8-6*.

Figure 8-4: Illustration of Driver Maneuvers required for a Downstream Full-Access Street Intersection

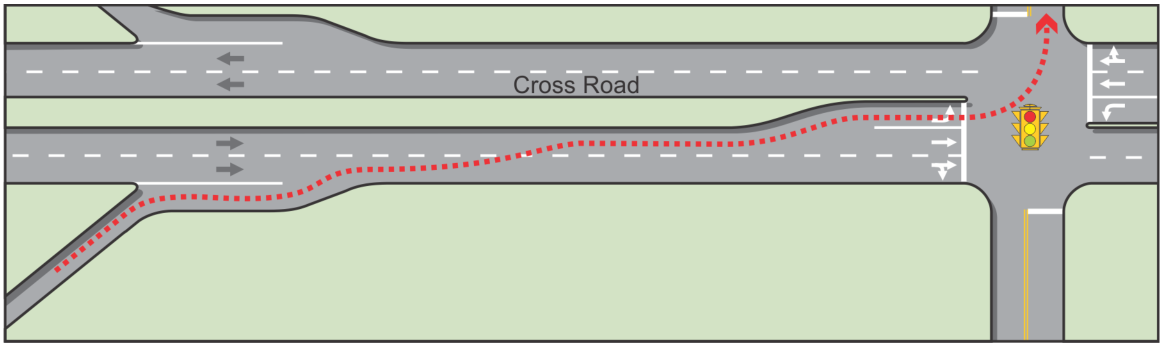


Figure 8-5: Illustration of Driver Maneuvers required for a Downstream Right-In/Right-Out Street Intersection or Driveway

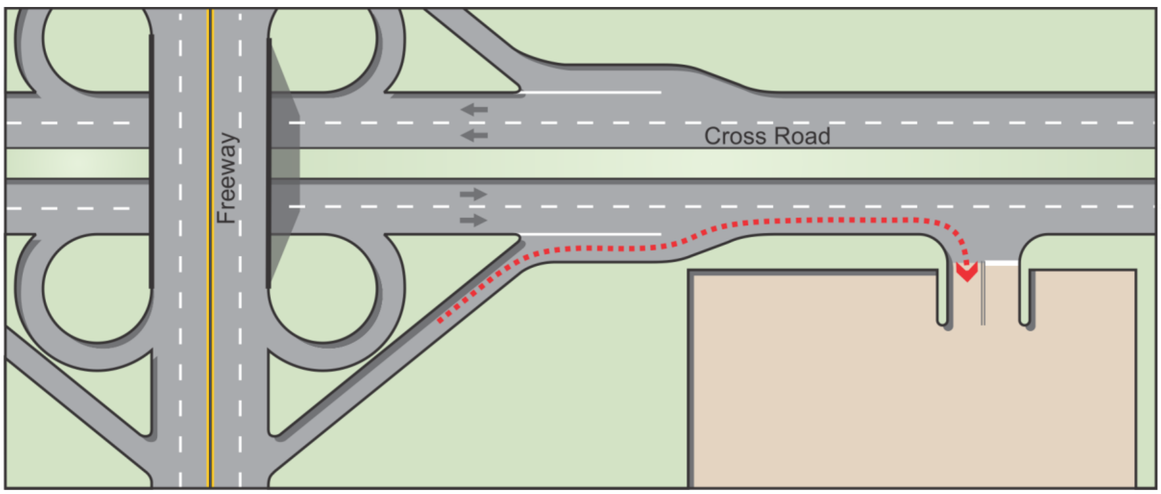
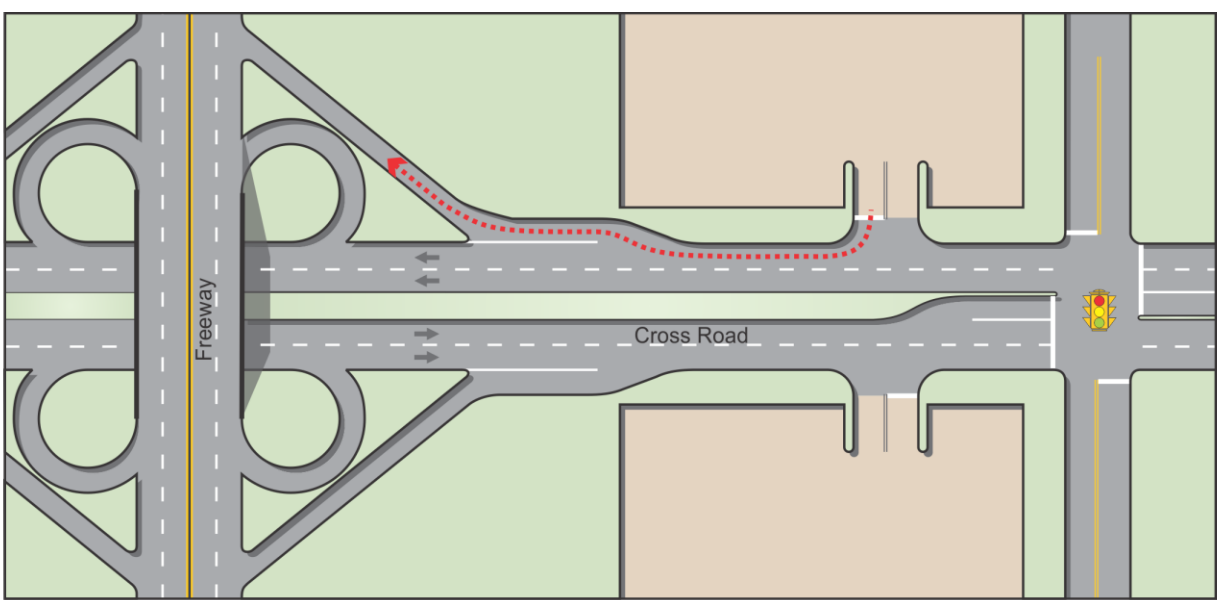


Figure 8-6: Illustration of Driver Maneuvers required for a Right-In/Right-Out Street Intersection or Driveway and a Downstream Entrance Ramp

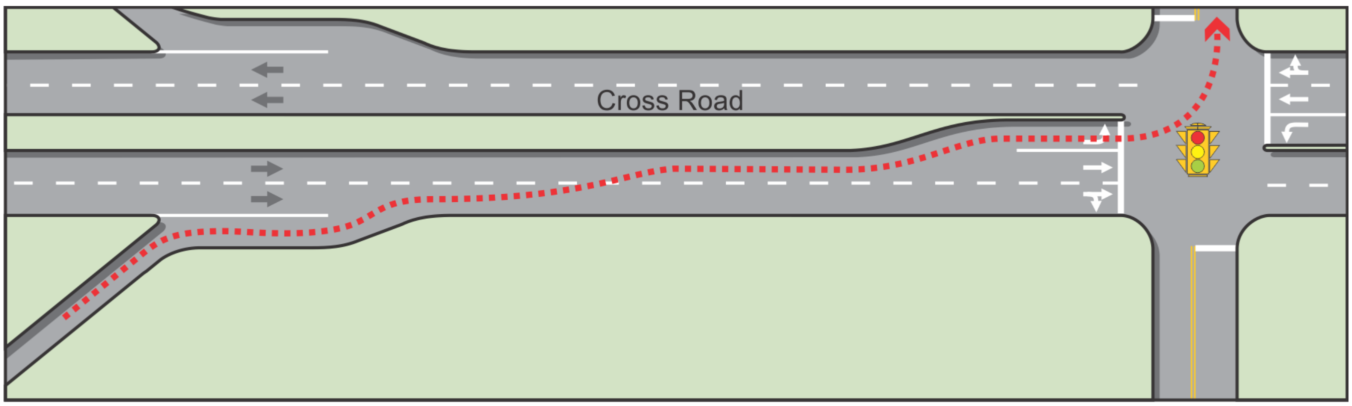


8.2.2.1 Spacing to First Full-Movement Street Intersection or Driveway

A full-movement street intersection or driveway is one where all turning movements, including left-turns, are allowed from all approaches. Relative to right-in/right-out street intersections and driveways, a full-movement street intersection or driveway requires greater spacing from the ramp terminal. This is because, as shown in *Figure 8-7*, in order for a driver exiting the freeway to make a downstream left-turn on the cross road, the driver must:

1) Merge from the freeway ramp into the vehicle stream on the cross road;
2) Weave across traffic on the cross road to enter the left lane;
3) Transition into the exclusive left-turn lane[23]; and
4) Decelerate to the back of the left-turning queue at the downstream, full-movement street intersection or driveway and complete the left-turn.

Figure 8-7: Illustration of Driver Maneuvers required for a Downstream Full-Access Street Intersection

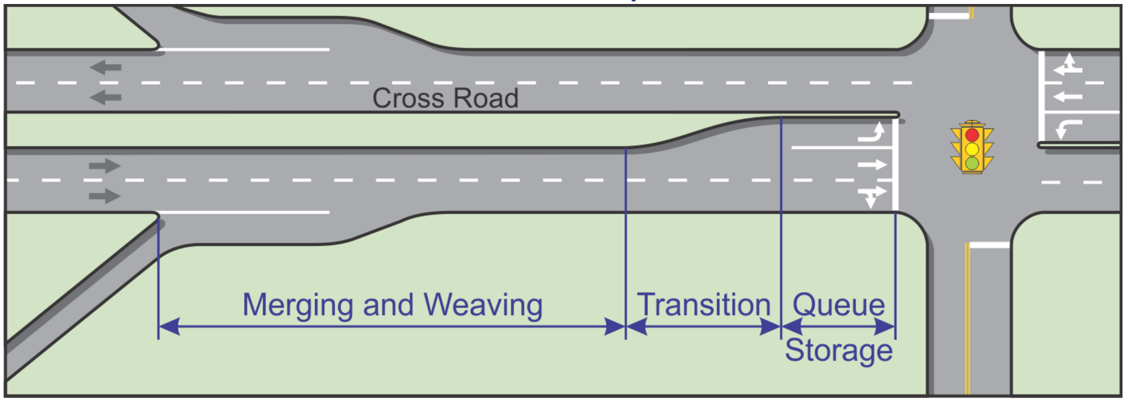


Of all possible turning movements at the downstream location, the merge, weave, and transition to the left-turn lane described above requires the greatest distance for the driver to complete. Therefore, full-movement street intersections and driveways require the greatest spacing from the ramp terminal. The following guidelines for desirable spacing distances should be applied to all full-movement street intersections and driveways in the vicinity of exit ramp terminals. These distances are illustrated in *Figure 8-8* and *Figure 8-9*, respectively. The desirable spacing distance equals the minimum spacing distance plus an additional decision distance.

[23] If an exclusive left-turn lane exists.

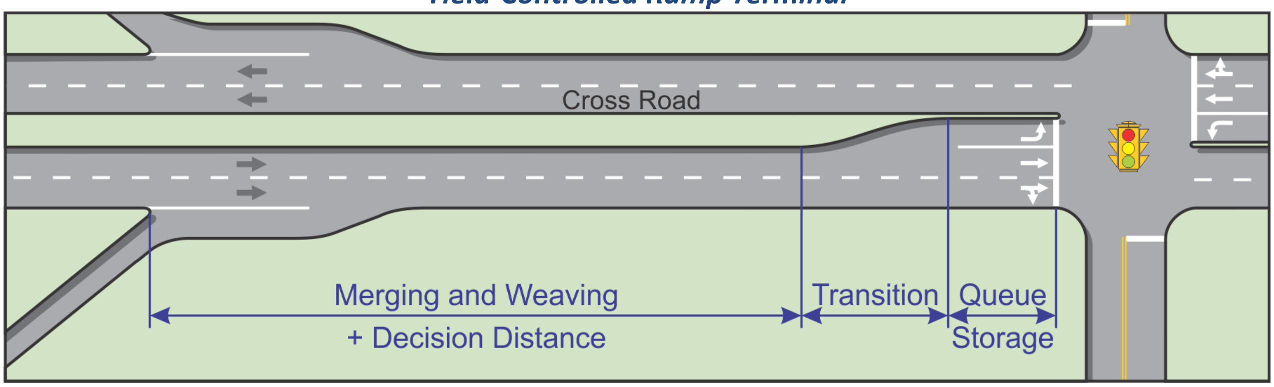
Minimum Spacing Distance to First Full-Movement Street Intersection or Driveway = (Merging and Weaving Distance) + Transition Distance + Queue Storage Distance

Figure 8-8: Components for Minimum Spacing Distance from a Free-Flow Merge or Yield-Controlled Ramp Terminal



Desirable Spacing Distance to First Full Movement Street Intersection or Driveway = (Merging and Weaving Distance) + Decision Distance + Transition Distance + Queue Storage Distance

Figure 8-9: Components for Desirable Spacing Distance from a Free-Flow Merge or Yield-Controlled Ramp Terminal



The major inputs for the two equations above are determined in specific ways. Below are the particulars of how to arrive at the merging and weaving distance, transition distance, queue storage distance, and decision distance:

Merging and Weaving Distance – The combined merging and weaving distance is measured from the gore point of the ramp (see *Figure 8-8* and *Figure 8-9*) and is a function of the number of lanes on the cross road in the subject direction of travel, as shown in *Table 8-1*.

Table 8-1: Merging and Weaving Distances

Number of Lanes on Cross Road in Direction of Travel	Merging and Weaving Distance
1 Lane	800 feet
2 Lanes	1,200 feet
3 Lanes	1,600 feet

Source: Gluck, J., H.S. Levinson and V. Stover, *NCHRP Report 420: Impacts of Access Management Techniques*, 1999, Table 86, p. 119.

Transition Distance – The length of the transition distance is determined as follows, based on: a) whether there is an exclusive left-turn lane at the downstream street intersection or driveway, and b) whether there is a non-traversable median on the cross road:

- Where there is no exclusive left-turn lane at the downstream street intersection or driveway, no transition distance is needed (transition distance = 0).
- Where an exclusive left-turn lane exists at the downstream street intersection or driveway, and a non-traversable median exists along the cross road, the transition distance is determined using the median taper design guidance provided in AASHTO's *A Policy on Geometric Design of Highways and Streets* (i.e., the "Green Book").[24]
- Where an exclusive left-turn lane exists at the downstream street intersection or driveway, and no median exists on the cross road, the transition distance is 75 feet.

Queue Storage Distance – The queue storage distance is based on the 95th percentile queue length[25] on the approach to the downstream street intersection or driveway in the subject direction of travel during the year of full build-out. The queue storage distance is the greater of:

1) The 95th percentile queue length calculated for the left-turn movement at the downstream intersection, in the subject direction of travel, or

2) The 95th percentile queue length calculated for the through movement adjacent to the left-turn movement at the downstream intersection, in the subject direction of travel.

Decision Distance – Because the driving population at Port Authority facilities often includes significant numbers of visitors who may be unfamiliar with the facility, it is desirable to provide additional time and distance for sign reading and decision-making by those drivers. The decision distance is given in *Table 8-2*, based on the posted speed on the cross road in the subject direction of travel.

Table 8-2: Decision Distance

Posted Speed (mph)	Decision Distance (feet)
30	535
35	625
40	715
45	800
50	890

Source: Adapted from AASHTO, *A Policy on Geometric Design of Highways and Streets*, 2011, Table 3-3, p. 3-7.

Where the decision distance given in *Table 8-2* is not achievable, a design exception is needed.

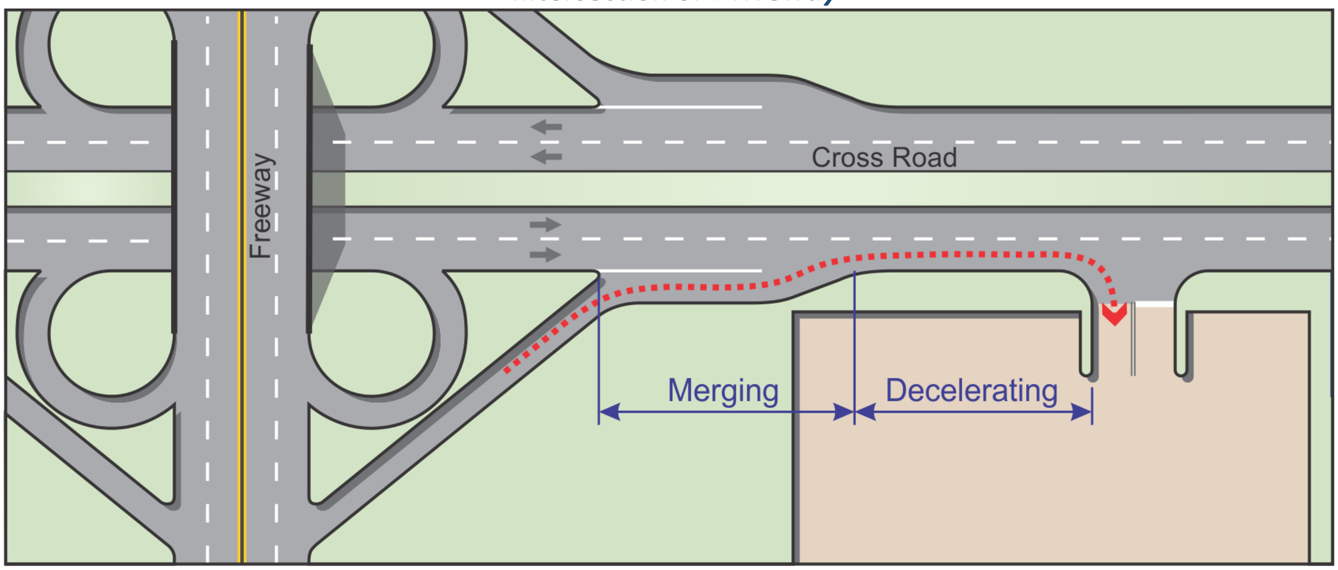
24 See pages 9-127 to 9-130 of the 2011 edition, or superseding edition.

25 The 95th percentile queue length represents the distance that would not be exceeded by a queue of vehicles 95 percent of the time during the analysis period. For major street approaches to two-way stop-controlled intersections where only the intersecting minor street is stop-controlled, the queue length = 0.

8.2.2.2 Spacing to First Downstream Right-In/Right-Out Street Intersection or Driveway

A right-in/right-out intersection is one where all left-turn movements are prohibited by a non-traversable median along the cross road. Relative to full-movement street intersections and driveways, right-in/right-out street intersections and driveways require less spacing from the ramp terminal. As shown in *Figure 8-10*, a driver exiting the freeway via the ramp and making a downstream right-turn from the cross road into a street intersection or driveway must: 1) merge from the freeway ramp into the right-lane of the cross road; and 2) decelerate to turn right into the downstream street intersection or driveway.

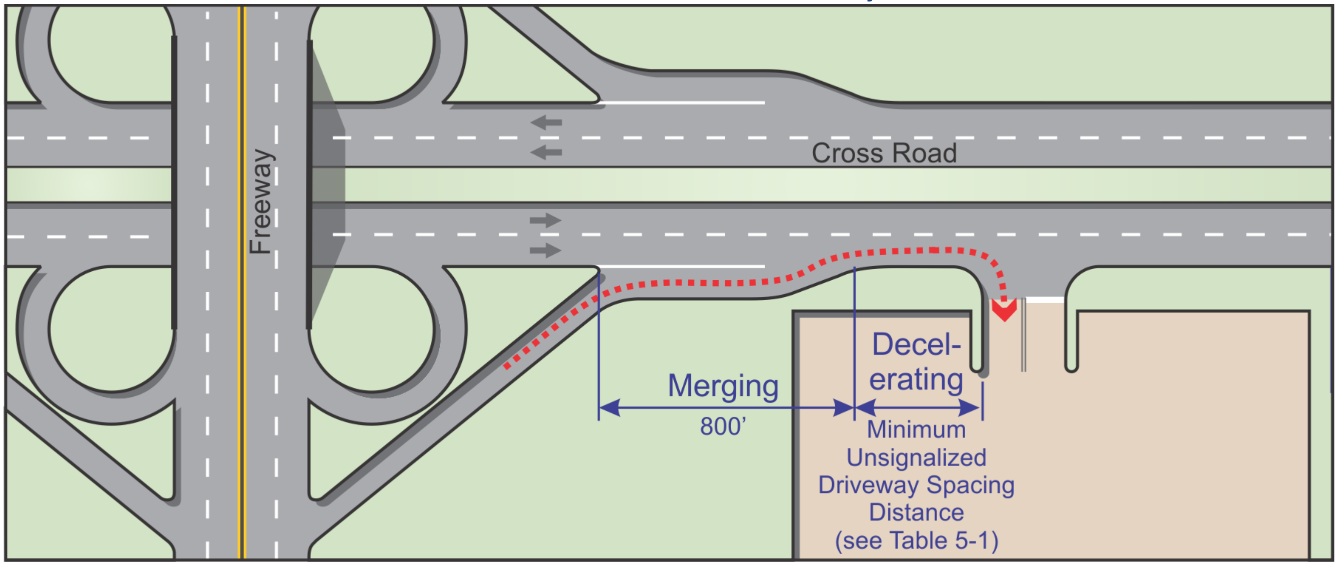
Figure 8-10: Illustration of Driver Maneuvers required for a Downstream Right-In/Right-Out Street Intersection or Driveway



The following guidelines for minimum and desirable spacing distances have been identified for downstream right-in/right-out street intersections and driveways in the vicinity of ramp terminals. These *Guidelines* reference the unsignalized driveway spacing guidelines presented in *Chapter 5*, based on the roadway access classification of the cross road and the posted speed in the direction of travel along the cross road. These distances are illustrated in *Figure 8-11* and *Figure 8-12*, respectively.

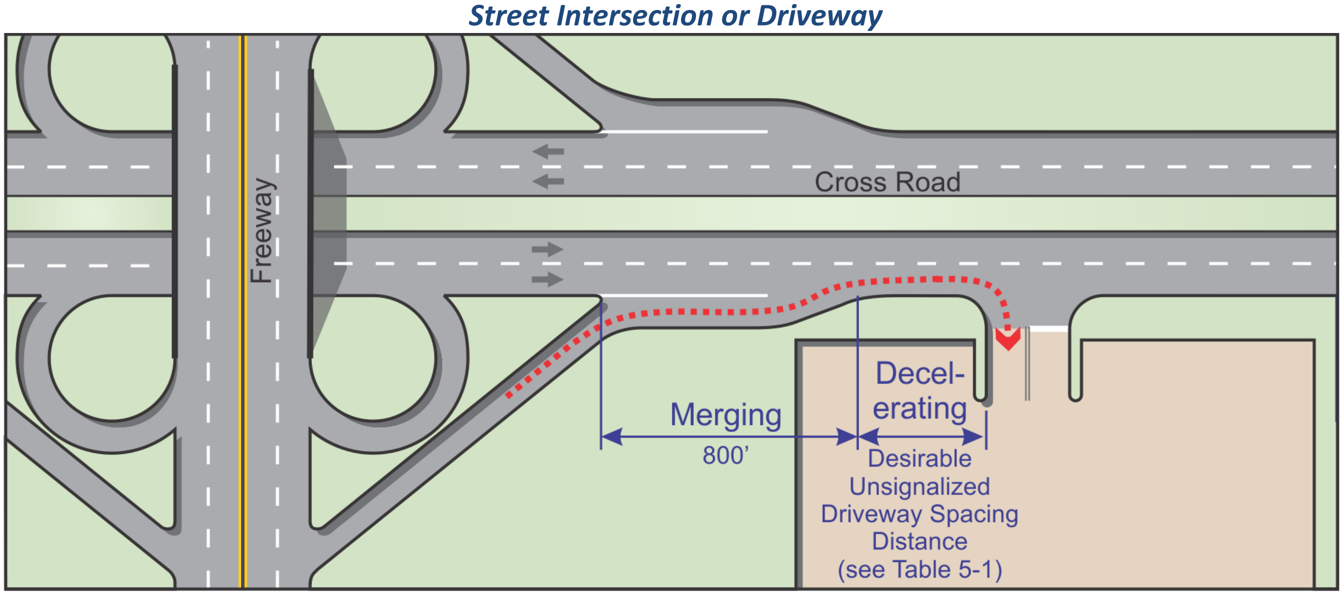
Minimum Spacing Distance to First Right-In/Right-Out Street Intersection or Driveway = 800 feet[26] + **MINIMUM** Unsignalized Driveway Spacing Distance

Figure 8-11: Components for Minimum Spacing Guidelines for a Downstream Right-In/Right-Out Street Intersection or Driveway



Desirable Spacing Distance to First Right-In/Right-Out Street Intersection or Driveway = 800 feet + **DESIRABLE** Unsignalized Driveway Spacing Distance

Figure 8-12: Components for Desirable Spacing Guidelines for a Downstream Right-In/Right-Out Street Intersection or Driveway

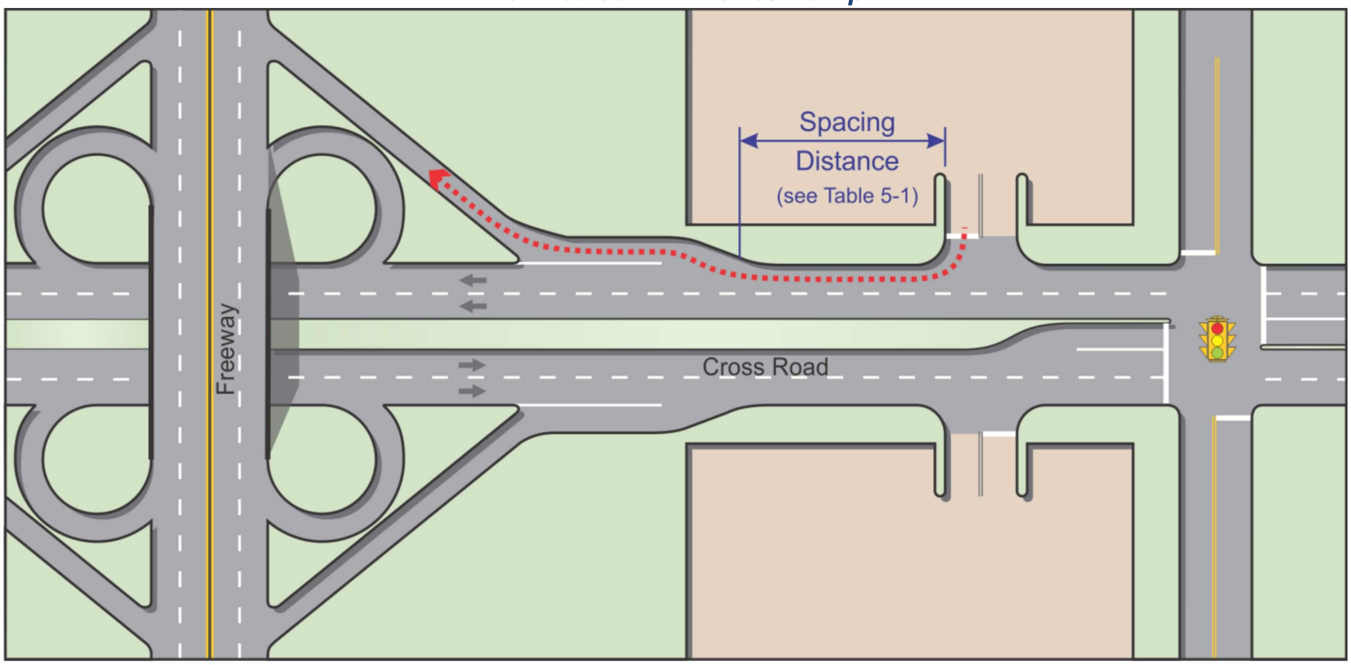


[26] The 800 foot distance begins at the gore point of the ramp, and is a constant. It does not vary based on speed, volume, or grade.

8.2.2.3 Spacing between Right-In/Right-Out Street Intersection or Driveway and Downstream Entrance Ramp

A right-in/right-out street intersection or driveway may also be located along the cross road *upstream* of a freeway entrance ramp (i.e., on-ramp), as shown in *Figure 8-13*. Under these conditions, the unsignalized driveway spacing guidelines presented in *Chapter 5* shall be applied to determine the distance between the right-in/right-out street intersection or driveway and the downstream entrance ramp. As shown in *Figure 8-13*, the spacing distance is measured from the edge of the street intersection or driveway to the start of the transition taper for the ramp.

Figure 8-13: Spacing Guideline for a Right-In/Right-Out Street Intersection or Driveway and a Downstream Entrance Ramp



8.3 Example Calculations

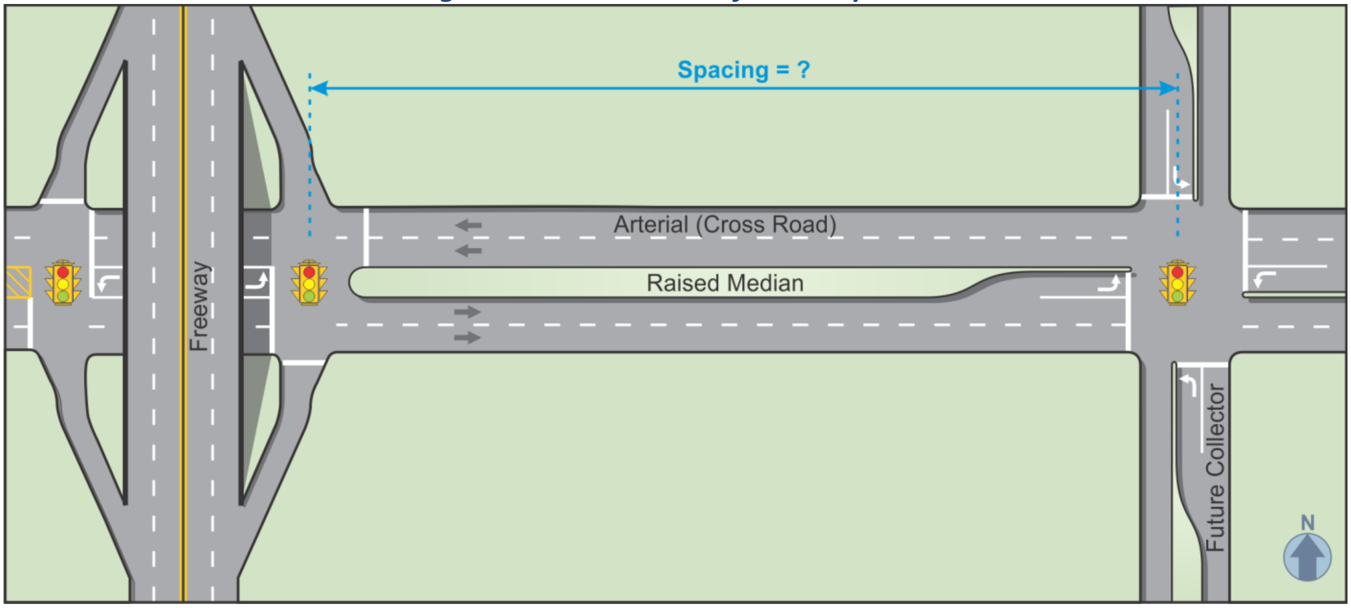
8.3.1 Example #1: Spacing from Signalized Ramp Terminal to First Full-Movement Street Intersection

Given:

- A freeway interchange with both ramp terminals signalized on the cross road (see *Figure 8-14*). The cross road is classified as an arterial with a posted speed of 35 mph.
- Left-turn ingress and egress between the arterial and abutting properties are currently prohibited by a non-traversable median along the arterial.
- The Port Authority is planning to build a new collector roadway that will intersect with the arterial some distance from the interchange, as shown in *Figure 8-14*. A break in the non-traversable median along the arterial would be needed to provide left-turn access. An engineering study conducted following the *Port Authority Intersection Signalization Procedures* has determined that a traffic signal would be warranted at the arterial/collector intersection. No other traffic signals are located within one mile of the interchange.
- The Port Authority's signal control strategy in this area is to optimize vehicle progression along the

arterial at a progression speed of 35 mph. The existing cycle length at the interchange signals is 60 seconds; the arterial/collector intersection would operate on the same cycle length.

Figure 8-14: Illustration for Example #1



Problem: Determine the desirable spacing along the arterial between the interchange ramp terminal and the signalized full-movement intersection for the planned future collector roadway.

Solution:

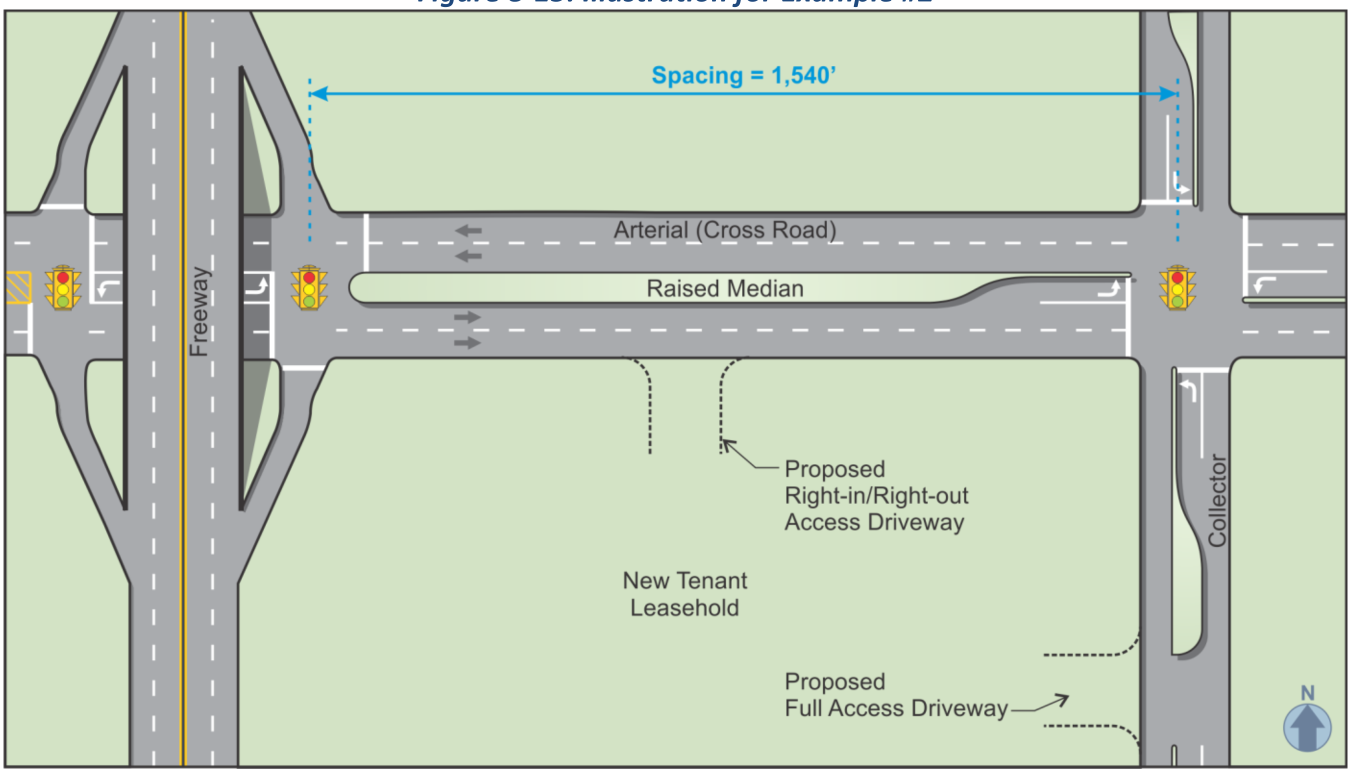
- Because the intersection of the ramp terminal with the arterial cross road is signalized, the traffic signal spacing guidelines presented in *Chapter 7* were applied to determine the location of the new signalized intersection between the arterial and the planned future collector.
- The traffic signal spacing decision tree shown in *Figure 7-1* were consulted to determine the appropriate guidelines to apply under these circumstances. As described above, the proposed traffic signal is not part of a Port Authority redevelopment program, but is warranted based on the results of the engineering study.
- Because there are no traffic signals within one mile in either direction – and the Port Authority has indicated that the desired signal control strategy is to optimize vehicle progression – the speed and cycle length table (*Table 7-1*) was consulted to determine the spacing of the planned signalized arterial/collector intersection from the existing signalized intersection between the ramp terminal and the arterial. According to *Table 7-1*, for a progression speed of 35 mph and a cycle length of 60 seconds, the traffic signal spacing along the arterial cross road is 1,540 feet (approximately 0.3 miles).
- Therefore, the desirable spacing between the interchange ramp terminal and the signalized full-movement intersection is 1,540 feet.

8.3.2 Example #2: Spacing from Signalized Ramp Terminal to First Downstream Right-In/Right-Out Driveway

Given:

- The roadway configuration illustrated in Example #1, assuming construction of the collector roadway and signalization of the arterial/collector intersection.
- A new tenant is expected to lease and develop Port Authority property on the south side of the arterial, as shown in *Figure 8-15*. The tenant desires a full-access driveway on the west side of the collector, as well as right-in/right-out access driveway on the eastbound direction of the arterial.
- Operational analysis of the traffic signals shows that, under projected future traffic conditions, the 85th percentile vehicle queue on the eastbound approach to the arterial/collector intersection is 300 feet.

Figure 8-15: Illustration for Example #2



Problem: Find the recommended location for the new tenant's proposed right-in/right-out driveway on the eastbound direction of the arterial.

Solution:

- To determine the location of the tenant's right-in/right-out driveway on the arterial, the corner clearance distances relative to the traffic signals on either side of the tenant's proposed driveway were verified according to the procedures in *Chapter 6: Corner Clearance*.
- Because the interchange cross road is an arterial, *Table 6-2* was consulted to identify the desirable corner clearance distance from the upstream and downstream signalized intersections. The "non-traversable median" case was applied due to the presence of the raised (i.e., non-traversable) median.

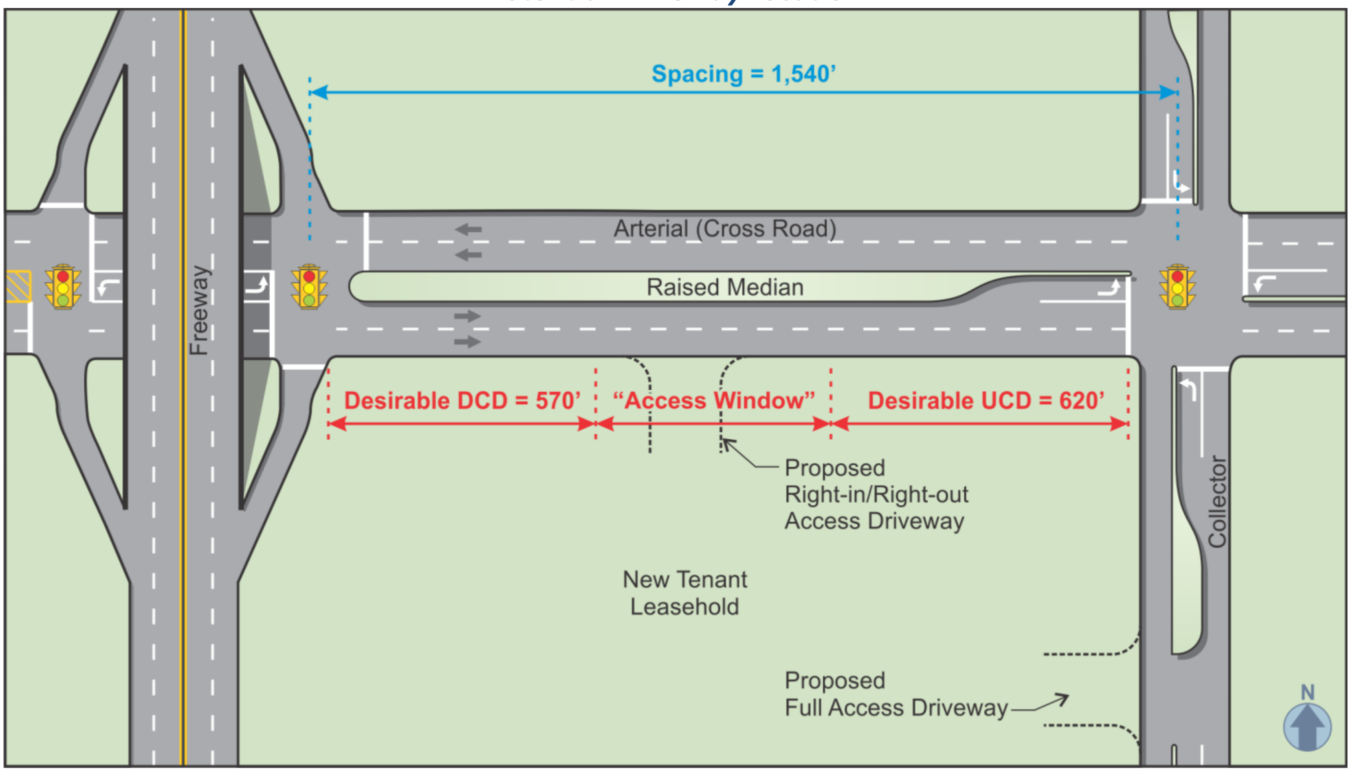
- Based on the guidance in *Table 6-2*, the desirable UCD and DCD are as follows:

  Downstream Clearance Distance (DCD) from interchange ramp terminal:
  - Desirable Distance[27] = **570 feet**

  Upstream Clearance Distance (UCD) from arterial / collector intersection:
  - Desirable Distance = (PIEV + M + D Distance) + 85th Percentile Queue Length
    = 320 feet + 300 feet = **620 feet**

Given the spacing along the arterial between the intersections with the ramp terminal and the collector roadway, the tenant's right-in/right-out driveway can be located anywhere within the "access window" shown in *Figure 8-16* and still meet the desirable upstream and downstream corner clearance distances identified above.

Figure 8-16: Example #2 – Desirable Corner Clearances and "Access Window" for New Tenant's Potential Driveway Location



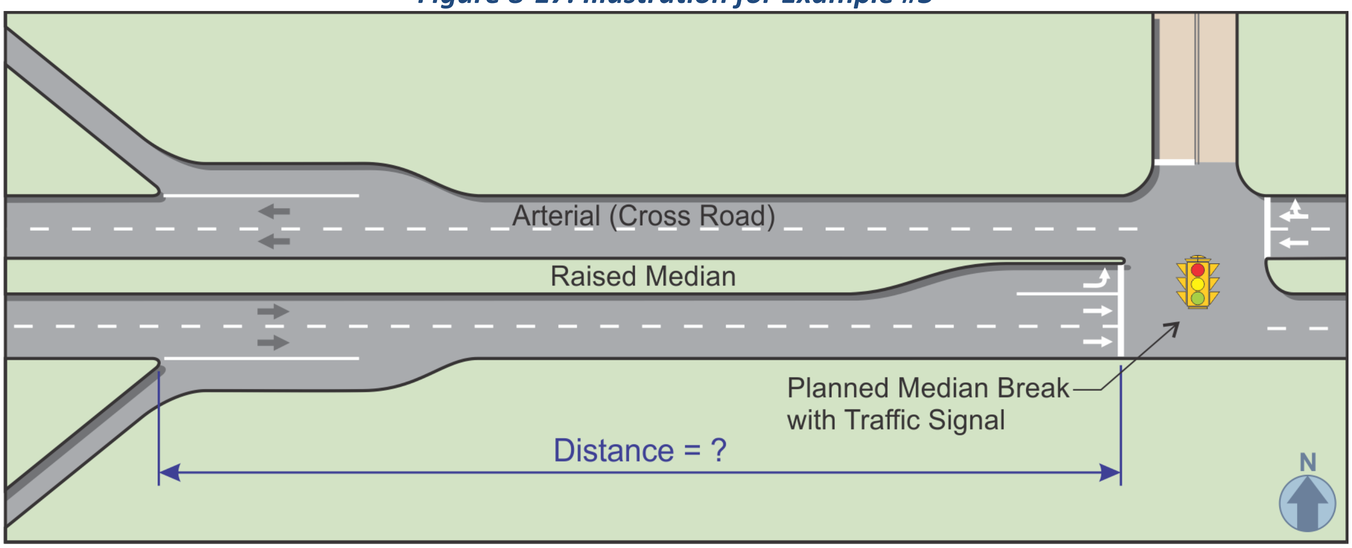
[27] Based on desirable unsignalized driveway spacing distance (see *Table 5-1*).

8.3.3 Example #3: Spacing from Free-Flow Ramp Terminal to First Full-Movement Driveway

Given:

- A grade-separated interchange between an arterial cross road and a freeway. All freeway ramps connect to the arterial via free-flow merges (see *Figure 8-17*).
- The arterial is divided by a non-traversable median with two lanes in each direction. The posted speed on the arterial is 35 mph.
- A median break is desired to accommodate a full-movement, signalized access driveway on the arterial, some distance east of the interchange. There are currently no other driveways along the arterial.
- Due to high existing traffic volumes along the arterial, the driveway will need to include an exclusive left-turn lane on the eastbound approach. Operational analysis of the driveway under projected future traffic conditions indicates that the left-turn lane requires storage for a 95th percentile vehicle queue of 200 feet and that the 95th percentile queue in the adjacent (eastbound) through lanes is 300 feet.
- Based on guidance in the AASHTO "Green Book," the median transition taper into the left-turn lane is determined to be 100 feet.

Figure 8-17: Illustration for Example #3



Problem: Find the desirable spacing distance along the arterial between the free-flow ramp and the proposed full-access driveway.

Solution:

- Based on the guidance in *Table 8-1*, the distance needed for vehicles to merge onto the arterial from the on-ramp and merge across two lanes on the arterial is 1,200 feet.
- Based on the guidelines in *Section 8.2.2.1* of this chapter, calculate the desirable spacing distance as follows:

Desirable Spacing Distance to First Full-Movement Driveway

= (Merging and Weaving Distance) + Decision Distance + Transition Distance + Queue Storage Distance[28]

= 1,200 feet + 625 + 100 feet + 300 feet

= 2,225 feet

The decision distance was identified from the values in *Table 8-2*. Based on a posted speed of 35 mph, the decision distance to be added is 625 feet.

If the desirable distance between the off-ramp and the proposed driveway (i.e., 2,225 feet) cannot reasonably be achieved, property access strategies described in *Chapter 13* should be investigated or a design exception would be needed for the proposed driveway location. (See *Chapter 14* for more guidance relative to general design exception criteria.)

[28] 95th percentile queue is greater of: A) the queue in the exclusive left-turn lane, and B) the queue in the adjacent through lane(s).

CHAPTER 9: DRIVEWAY DESIGN

9.1 Overview

Driveways are roadway connections that provide vehicular access between roadways and abutting properties or leaseholds within Port Authority facilities. For purposes of this chapter, the term "driveway" also includes the space in the immediate vicinity of the physical connection between the driveway and the roadway. This chapter does not address the design of drive aisles within a site or leasehold area, except where such a design affects the intersection of the driveway with the Port Authority roadway.

Driveways are integral to the roadway transportation system. Every driveway connection to a Port Authority roadway creates an intersection, which, in turn, creates conflicts for the motorist with bicyclists, pedestrians, and other motor vehicles. Proper driveway design balances the needs of all users by minimizing conflicts while accommodating the demands for mobility and access. The designer should consider the following factors in the design of driveways:

- Driveway setting and location
- User mix and attributes, by mode (passenger cars, trucks, bicyclists, pedestrians, pedestrians with disabilities)
- Dimensions and turning paths of design vehicles (passenger cars, trucks, buses)
- Design volumes (especially peak hour trips, by mode)
- Design vehicle speed
- Intersection sight distance
- Pedestrian walking speed

This chapter contains guidelines for the geometric design of driveways, with the following objectives in mind:

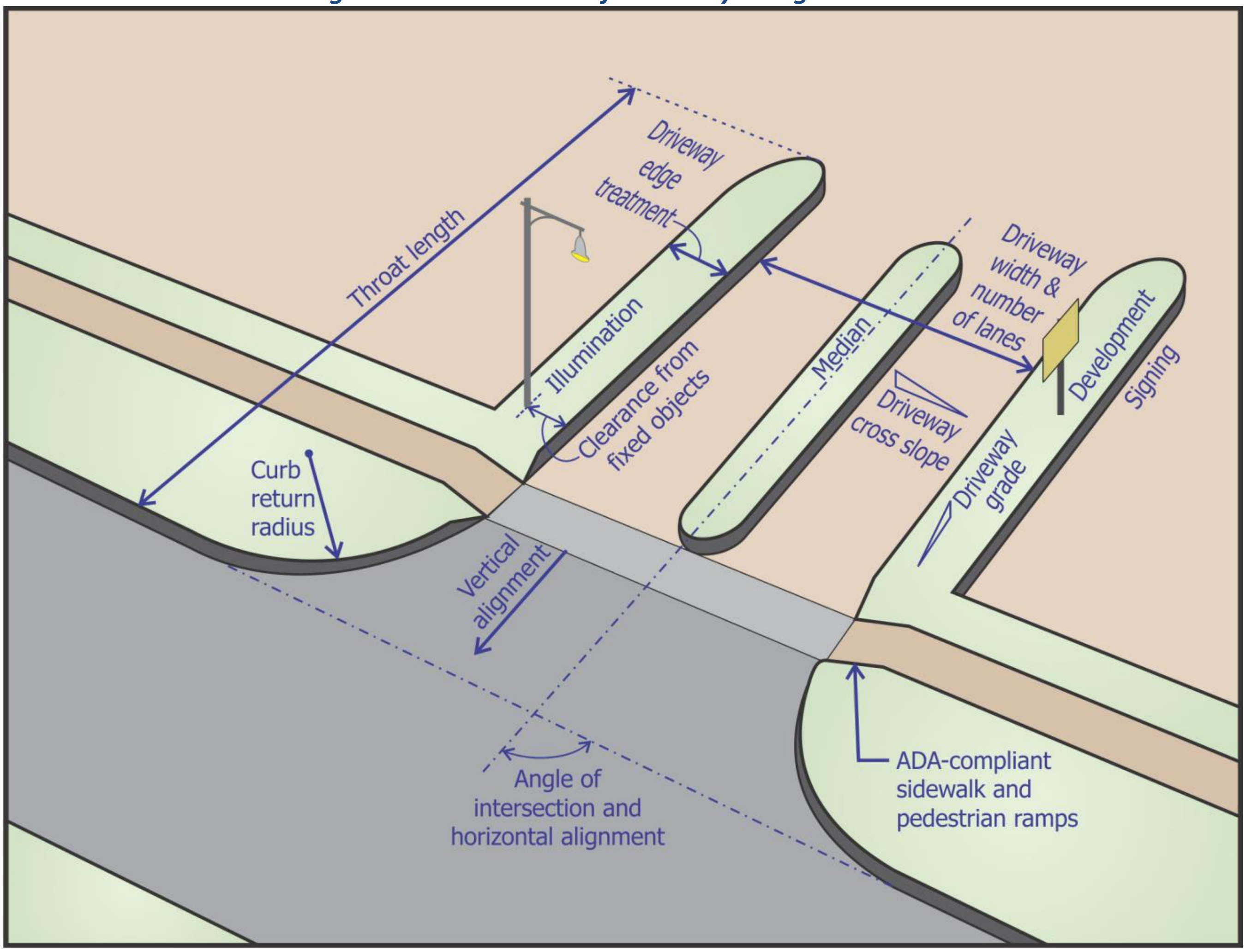
- Promoting a safe environment for various users including motorists, bicyclists, and pedestrians (including both transit passengers and pedestrians with disabilities)
- Providing a geometry that accommodates the characteristics and limitations of the various users, and avoiding geometric conditions that create traffic operational problems
- Providing driveways that allow traffic to flow smoothly
- Providing driveways that are conspicuous and clearly delineated for the various users

To achieve these objectives, design guidelines for the following driveway design features, shown in *Figure 9-1*, are addressed in this chapter:

- Width and number of lanes
- Curb return radius and throat transition geometry
- Throat length and internal site queue storage
- Angle of intersection and horizontal alignment
- Non-traversable medians and islands located on the driveway
- Cross-slope
- Driveway edge treatment

- Clearance from fixed objects
- Vertical alignment and grade
- Development signing
- Illumination

Figure 9-1: Illustration of Driveway Design Features



Other chapters of these *Guidelines* address: driveway spacing (*Chapter 5*) and intersection sight distance (*Chapter 10*), as well as left-turn lanes (*Chapter 11*) and right-turn lanes (*Chapter 12*) on the Port Authority roadway, as opposed to on the driveway.

9.2 Guidelines

The application of these *Guidelines* to the driveway design is an item to be discussed with Port Authority Engineering at the team conceptual planning meeting.

9.2.1 Driveway Width and Number of Lanes

The width of a driveway is a function of the physical space needed to accommodate all driveway users and design vehicles. To determine the driveway width, the designer should consider:

- the number of lanes
- the widths of those lanes
- the presence and width of a median on the driveway
- the needs of motorized, pedestrian, and bicycle traffic.

Although a wider driveway with more lanes may increase the vehicular capacity and accommodate the turning paths of larger vehicles turning into and out of the driveway, it also increases the time necessary for pedestrians to cross the driveway, thereby increasing their exposure to conflicts with motorized vehicles. Because of these design trade-offs, the designer should balance the competing needs of reducing vehicle delay by adding lanes and limiting pavement width and facilitating pedestrian crossings.

It is assumed that two-way driveways have at least two lanes: one lane entering the property and one lane exiting. However, as traffic volumes increase, the addition of a second exit lane should be considered to avoid excessive delays and queuing on the driveway. Without two exit lanes at a STOP-controlled driveway, for example, a motorist wanting to turn left blocks others in the queue from exiting.

If it is determined at the team conceptual planning meeting that the number of driveway lanes needs to be determined by a transportation study, *Section 2.6.3* can be consulted for a sample scope. As part of the determination of the optimum driveway configuration, the traffic study should examine the traffic control devices (e.g., STOP signs, traffic signals, etc.) and allowable vehicle movements (e.g., left-turns, through movements, and right-turns) at all access points to the subject property or properties.

An *open frontage*, a wide-open, undefined driveway across the full frontage of the property, as shown in *Photos 9-1* and *5-1,* should be avoided. The undefined lane arrangement of an open frontage results in motorists lacking positive guidance, allowing them to enter and leave the property at any location. As such, vehicles on-site are exposed to incoming and outgoing traffic, with no safe refuge. These designs are also particularly unfriendly to bicyclists and pedestrians. This situation creates many more conflict points (including those involving pedestrians and bicyclists) than a well-defined driveway.

Photo 9-1: Undesirable "Open Frontage"

Photo source: Google Earth™ mapping service

In summary, the following guidance shall apply when determining the driveway width and number of lanes at driveways along Port Authority roadways:

- The design for the entry and exit lane geometry for all driveways along Port Authority roadways should:
  - provide adequate driveway capacity, including exclusive left-turn and right-turn exit lanes where needed (*see Figure 9-2*)
  - reflect the needs of all users, including pedestrians and bicyclists, in determining the driveway width
  - define a shape that conforms to the path of the turning vehicle, preventing vehicles from encroaching into other lanes (see *Figure 9-3*)
  - enable vehicles to enter the driveway without significantly impeding the upstream flow of through traffic on the roadway (see *Figure 9-3*).
- If it is determined at the team conceptual planning meeting that the number of driveway lanes needs to be determined by a transportation study, *Section 2.6.3* can be consulted for a sample scope.

Figure 9-2: Driveway with Exclusive Left-Turn and Right-Turn Lanes

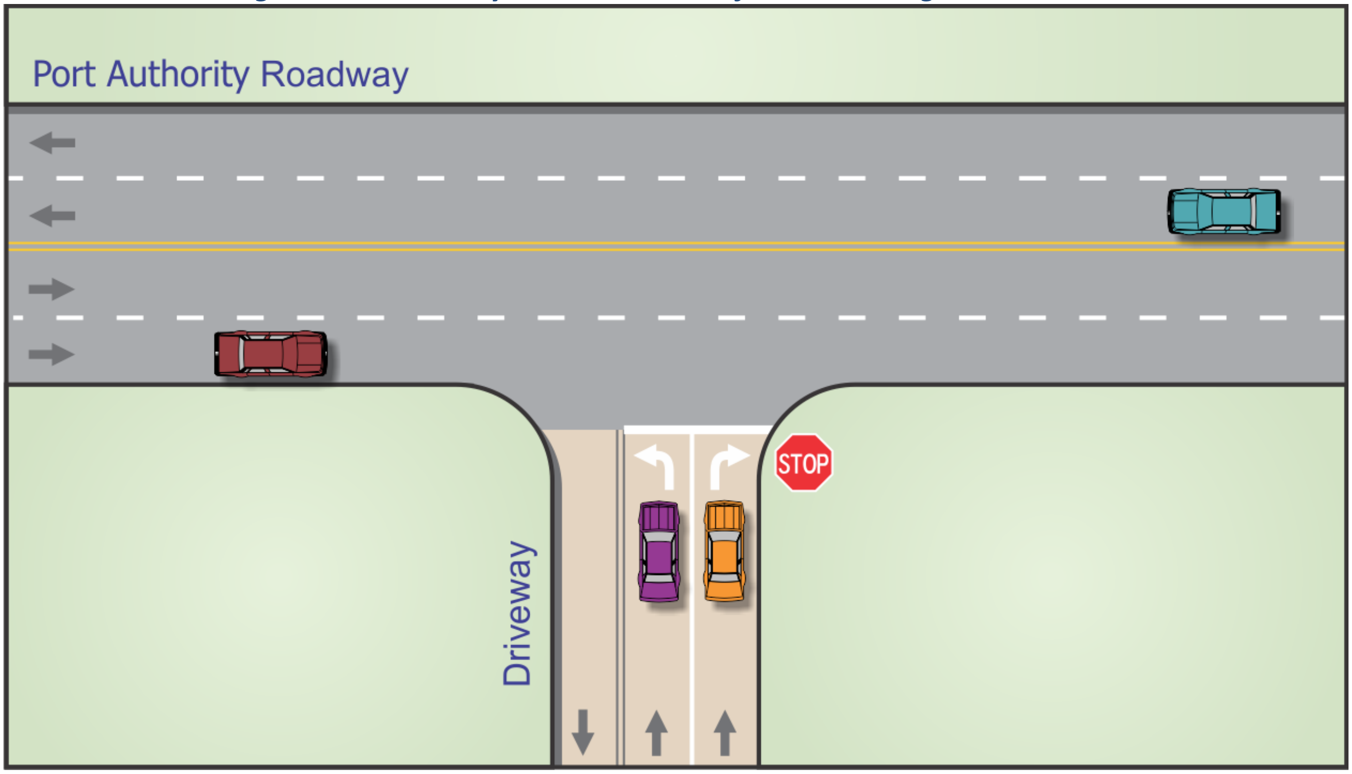
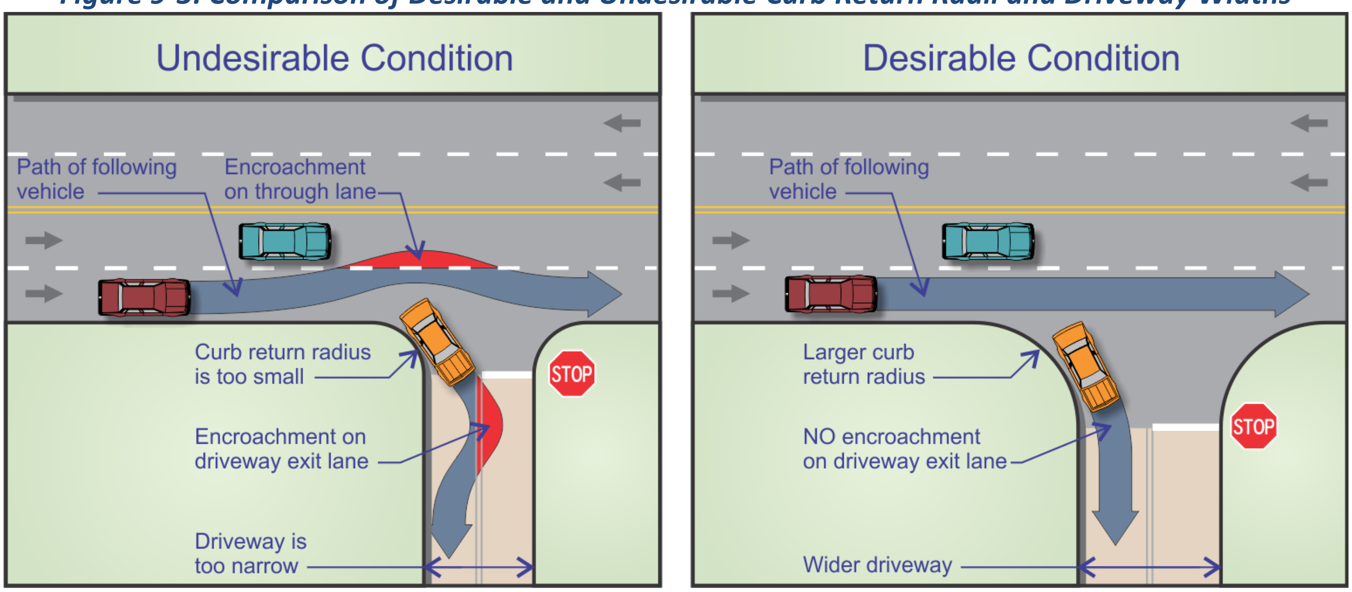


Figure 9-3: Comparison of Desirable and Undesirable Curb Return Radii and Driveway Widths



In addition:

- Open frontages should be avoided.
- The number of lanes exiting from the driveway and turning in one direction should not exceed the number of available traffic lanes on the roadway in that direction. For example, for a driveway intersecting a two-lane, two-way roadway, no more than one left-turn lane and one right-turn lane would be allowed on the driveway approach to the intersection. Where double turn lanes are provided, the receiving lanes should be designed to accommodate two design vehicles located side-by-side turning simultaneously, without these vehicles encroaching into the travel lanes for traffic traveling in the opposing direction or in the

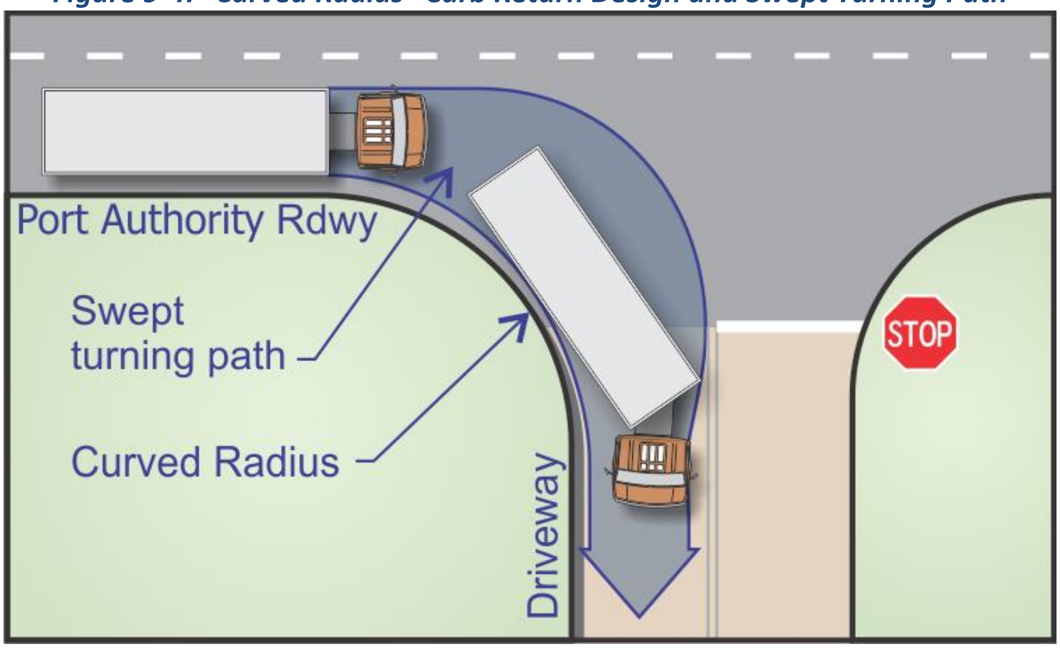
adjacent turn lane.

9.2.2 Curb Return Radius and Throat Transition Geometry

For a driveway to intersect a Port Authority roadway, a break in the curb line or the edge of the roadway is needed. The following guidance shall apply to the design of all driveways along Port Authority roadways:

- A curved radius design (see *Figure 9-4*) should be used, unless the driveway meets the design requirements provided for a “taper layout” at a “Minor Commercial” driveway as specified in the New York State Department of Transportation’s *Policy and Standards for the Design of Entrances to State Highways*.[29]
- The curb return radius should be designed to accommodate the swept turning path of the design vehicle (see *Figure 9-4*). The designer should verify that the turning path of the design vehicle does not over-track the corner.[30]

Figure 9-4: “Curved Radius” Curb Return Design and Swept Turning Path

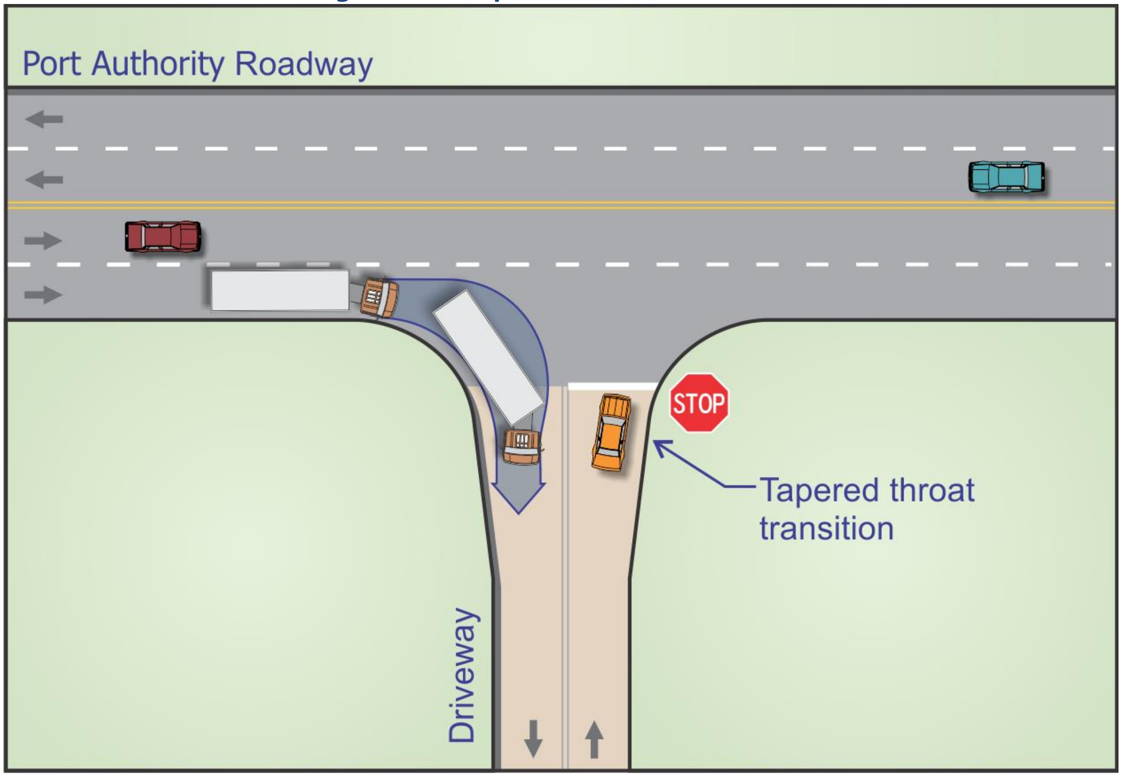


- Driveways may also be constructed to include a wider cross-section close to the intersecting roadway, with the driveway width tapering to a narrower section some distance back from the intersecting roadway (see *Figure 9-5*). This type of throat transition geometry may be incorporated into the design of the driveway to accommodate the off-tracking and swept paths of very large turning vehicles (e.g., tractor-trailers) entering and exiting the driveway. The design will require a transition from the wider cross-section width to the narrower cross-section width.

[29] See Section 5A.10, and Figures 5A-1 through 5A-5, of the November 24, 2003 NYSDOT *Policy and Standards for the Design of Entrances to State Highways*:https://www.dot.ny.gov/divisions/operating/oom/transportation-systems/repository/Policy%20and%20Standards%20for%20the%20Design%20of%20Entrances%20to%20Stat.pdf

[30] Software, such as AutoTurn™, may be used to identify the swept path for a given design vehicle.

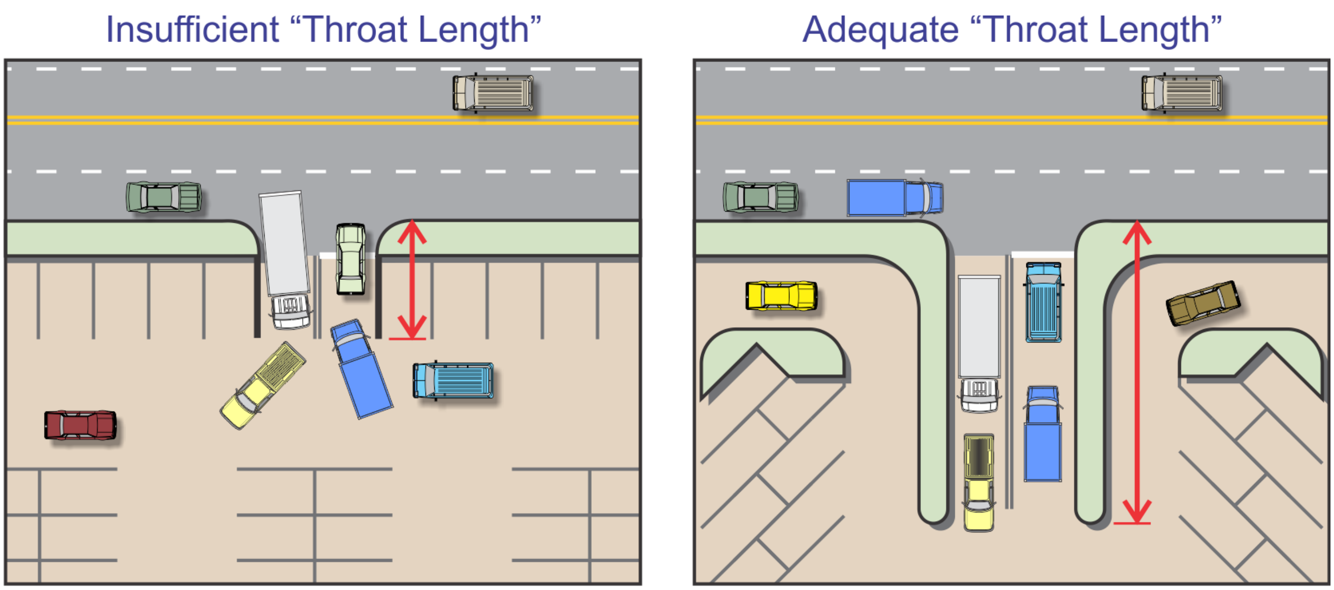
Figure 9-5: Tapered Throat Transition



9.2.3 Throat Length and Internal Site Queue Storage

The *throat length* of a driveway is the storage length available that is free of conflicts for vehicles entering and leaving the driveway. It is measured from the outer edge of the traveled way of the intersecting roadway to the first point at which there are conflicting traffic movements on the subject property or leasehold served by the driveway. As shown on the left side of ***Figure 9-6***, in locations with insufficient throat length, drivers entering the site may be forced to stop or slow down in order to turn within the site or maneuver around queued vehicles waiting to exit. These conditions have the propensity to generate queues that spill back onto the roadway, causing an operational problem that should be avoided through proper driveway design. In addition, vehicle queues of motorists waiting to exit the property can spill back into the site and obstruct the free movement of traffic within the site.

Figure 9-6: Insufficient versus Adequate Throat Lengths



Thus, throat lengths for all driveways along Port Authority roadways should be designed to provide adequate storage distance to accommodate the 95th percentile queue length[31] for both:

1) vehicles *entering* the driveway (as determined from a queuing analysis of internal site operations[32]) to reduce the propensity for queue spill-back onto the roadway, and
2) vehicles *exiting* the driveway (as determined through a capacity analysis of the driveway/roadway intersection) to reduce traffic congestion on the subject property.

Of the two conditions above, the former is typically more critical than the latter, due to the potential for a more severe crash associated with higher-speed traffic on the roadway conflicting with slower-speed vehicles turning into the driveway. Although a traffic queue that backs up into a property may generate congestion on that property, the congestion is generally limited to the property, speeds are generally lower, and the crash potential is not as severe. Therefore, the designer should give priority to ensuring that vehicles entering the driveway do not spill back onto Port Authority roadways.

9.2.4 Angle of Intersection and Horizontal Alignment

Whereas throat length is related to the overall storage distance needed to accommodate vehicle queues entering and exiting the driveway, the distance needed for the *horizontal alignment* is related to the *geometric alignment of the driveway* at its intersection with the roadway. Driveways that intersect the roadway at angles much less than 90 degrees are undesirable because they are more difficult for drivers to navigate. Smaller angles cause drivers greater difficulty in turning their heads to scan the roadway for an adequate gap in traffic, resulting in more distance and time required to complete the turning movement.

Also, a horizontal driveway alignment that is straight through the connection transition area (i.e., near the driveway's intersection with the roadway) provides the following advantages over a curved alignment:

[31] The 95th percentile queue length represents the distance that would not be exceeded by a queue of vehicles 95 percent of the time during the analysis period.
[32] Internal site operations should consider the location of entrance gates, guard booths, etc.

- Improves the efficiency and capacity of the driveway by reducing the follow-up time required for vehicles waiting in queue. Vehicles behind the first vehicle in the queue are already positioned to move straight ahead.

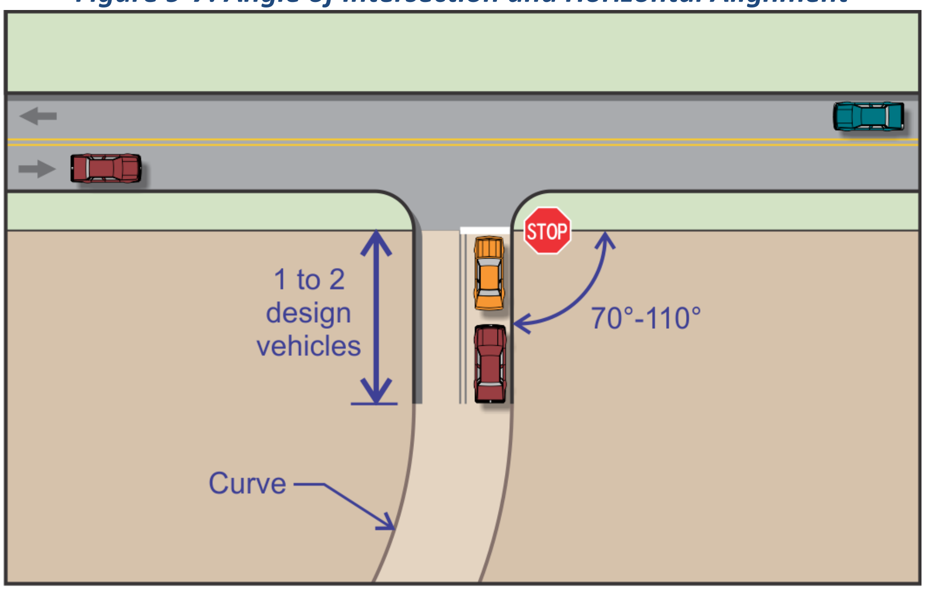
- Eliminates the added driving task of steering through one or more curves when entering or leaving the driveway. These actions divert a driver's attention from other driving tasks such as monitoring crossing bicyclists, pedestrians, and other vehicles.

- Makes it easier for drivers to position and align their vehicles as they approach the intersection, avoiding sideswiping other vehicles when they make turning maneuvers.

The following guidance shall apply to the horizontal alignment design of all driveways along Port Authority roadways:

- All two-way driveway approaches to Port Authority roadways should intersect the roadway at angles of between 70 and 110 degrees (see *Figure 9-7*).

Figure 9-7: Angle of Intersection and Horizontal Alignment



- One-way/right-out driveways should intersect with the roadway at angles of from 90 to 120 degrees to facilitate the right-out exiting movement.

- The driveway's horizontal alignment should include a minimum tangent section before any curvature. The desirable length of this tangent section should be two design vehicles (see *Figure 9-7*).

9.2.5 Non-Traversable Medians and Islands located on the Driveway Approach

Non-traversable median islands can provide several benefits, but they can also complicate snow removal and obstruct the turning paths of very large trucks. The benefits of non-traversable median islands include the following:

- Physically separating traffic traveling in opposing directions

- Guiding vehicular traffic in the intended direction of travel

- Reducing wide areas of pavement
- Reducing pedestrian crossing distances
- Providing a refuge for pedestrians
- Providing a location for the placement of signs (which is compliant with sight distance triangles)
- Allowing for landscaping (which is compliant with sight distance triangles)

The following guidance shall apply to the use of non-traversable median islands on driveway approaches to all Port Authority roadways:

- A non-traversable median on the driveway may be considered where a driveway has any of the following:
    - two or more entrance lanes
    - two or more exit lanes
    - a large pavement area that could confuse drivers
    - right-in/right-out operation, which may be unclear to some drivers
    - high traffic volume or
    - existing or future traffic signal control.
- The desirable *width* of the non-traversable median island in the driveway should be 6 feet.
- The desirable *length* of the non-traversable median island in the driveway should be 50 feet, so that it is prominent enough to be clearly recognized by motorists.

9.2.6 Cross-Slope

Pavement cross-slope is an important cross-sectional design element. The cross-slope drains water from the roadway laterally and helps minimize ponding of water on the pavement. The typical cross-slope is 1.5 percent to 2.5 percent. Driveways crossing a sidewalk should be designed so that both pedestrians and drivers are able to traverse the sidewalk-driveway crossing. Guidance related to the design of the driveway cross-slope, including American with Disabilities Act (ADA) requirements, is available from Port Authority Engineering.

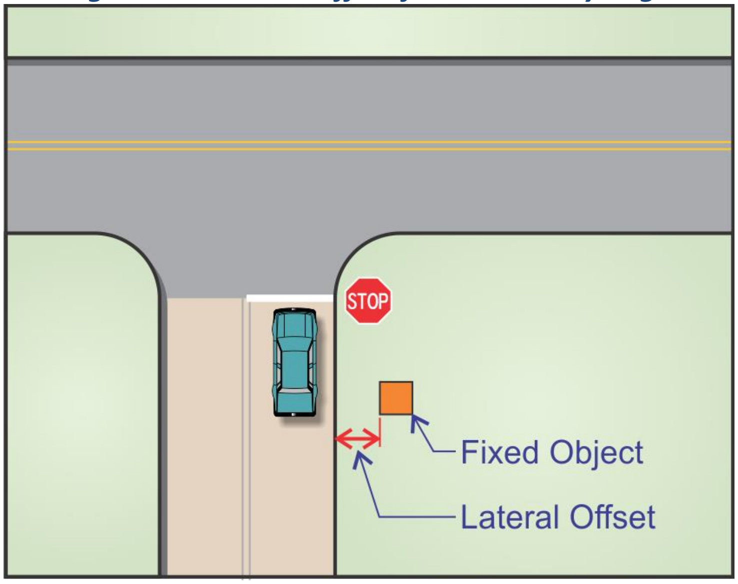
9.2.7 Driveway Edge Treatment

Defining the driveway edge helps all users ascertain the lateral limits of motor vehicle operation at the driveway. The edge of all driveways along Port Authority roadways should be clearly defined and visible to all users (including drivers, pedestrians, and bicyclists) through the use of striping, curbs, reflectors, and/or other similar devices that help increase visibility.

9.2.8 Clearance from Fixed Objects

Fixed (non-breakaway) objects – such as utility poles and retaining walls – should be set back from the edge of the driveway by a lateral offset (see *Figure 9-8*). The lateral offset distance allows clearance for vehicle side mirrors and accounts for possible off-tracking of the wheel and body paths of turning vehicles. The following guidance shall apply to clearance from fixed objects at all driveways along Port Authority roadways:

Figure 9-8: Lateral Offset from Driveway Edge



- Fixed (non-breakaway) objects should be set back from the edge of the driveway by a lateral offset distance. The lateral offset distance is measured perpendicularly from the face of the curb along the driveway to the nearest point on the fixed object.
- The desirable lateral offset distance on both sides of all driveways should be 5 feet.
- In undeveloped areas[33] or developing areas[34], the minimum lateral offset distance on both sides of all driveways should be 2 feet. In developed areas[35] where the sidewalk width is limited, or where existing utility poles are located close to the curb, the minimum lateral offset distance on both sides of all driveways should be 1.5 feet.
- The designer should consider the specific usage of the driveway and the needs of the subject property to determine the length of the driveway throat to which the lateral offset distance applies.
- Wheel and body paths for design vehicles should be verified by the designer[36], such that they do not over-track beyond the edge of the driveway.

9.2.9 Vertical Alignment and Grade

Because changes in vertical profile are often found at driveway entrances, these locations can cause damage to the undercarriage of the vehicle as well as to the pavement surface (see *Photo 9-2*). Large differences between successive grades – or an abrupt change of grade – at the driveway creates crests and sags that can cause the underside of a vehicle to drag. Any excessive grade change between the cross slope of the roadway and the driveway grade, between the driveway grade and an intersecting sidewalk, or between successive driveway grades can cause this undesirable vehicle drag.

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[33] An undeveloped area is one characterized by one or more of the following features: (a) little to no roadside development, (b) few, if any, intersecting driveways and roadways, (c) right-of-way available for roadway improvements, and/or (d) little to no pedestrian activity.

[34] A developing area is one that is (or will be) undergoing changes related to roadside development activity. These areas are typically characterized by one or more of the following features: (a) roadside development that is planned, imminent, or already taking place, (b) a growing number of driveways and intersecting roadways, (c) increasing pedestrian activity, and/or (d) a need to consider transit.

[35] A developed area is one that is characterized by one or more of the following features: (a) dense roadside development, (b) a substantial number of existing intersecting roadways, (c) limited right-of-way available for roadway improvements, (d) existing environmental and/or topographic constraints, and/or (e) significant pedestrian or transit considerations.

[36] Scaled vehicle turning templates or software, such as AutoTurn™, can be used for this purpose.

Photo 9-2: Undercarriage Scraping at Driveway due to Inadequate Vertical Profile

Photo source: *NCHRP Report 659: Guide for the Geometric Design of Driveways*, 2010, Exhibit 5-66, p. 69.

In addition, vehicles with a particularly low ground clearance and a long wheelbase or overhang can become lodged on alignments with sharp grade changes. It is also possible that a vehicle will be overloaded or follow an unusual or out-of-the-ordinary path in negotiating the driveway, further reducing ground clearance and resulting in dragging.

Furthermore, changes affecting the effective ground clearance at a driveway may occur over time. For example, as Port Authority leaseholds change hands or as redevelopment occurs, the land uses served by a driveway may change, resulting in the driveway being used by different types of vehicles than those for which it was originally designed. In addition, the vertical profile of the driveway itself is also subject to change. As the roadway is milled or resurfaced, its elevations and cross-slopes change. Also, the roadway, driveway, and associated features (such as sidewalks) may deform over time due to applied loads, the effects of weather, or other causes.

The issues described above are particularly acute at driveways that intersect with high-volume or high-speed roadways. Excessive differences in speed between the through vehicles on the roadway and the vehicles turning into or out of the driveway – due to the vertical profile – can increase the propensity for crashes. In addition, bumps, steep grades, and abrupt changes in grade due to poor vertical alignment can cause discomfort to vehicle occupants. Dragging results in motorist discomfort, vehicular delay, and/or minor damage to the undercarriage of the vehicle and to the pavement surface.

While additional research is needed with respect to the vertical alignment of driveways (particularly regarding the ground clearance characteristics of various vehicle types that make up the motor vehicle population), the designer should observe vertical design guidelines. The designer should consider the following factors in the design of driveways:

- To design the vertical alignment elements of a driveway, the designer should determine an appropriate design vehicle and its corresponding dimensions, including the wheelbase and front and rear overhangs. This design vehicle should be identified based on the anticipated population of vehicles expected to use the driveway. The design vehicle used for purposes of designing the vertical alignment may be different from the design vehicle used to design the horizontal alignment (i.e., for turning radius purposes).

- Driveways should be designed to avoid the underside of the design vehicle dragging on the roadway or driveway surface. The vertical alignment of the driveway should allow for a convenient entry with minimal conflicts. To achieve these objectives, grade changes should not be abrupt.
- The designer should have a complete understanding of the vertical driveway profile to be negotiated by the design vehicle. This includes, for example, the roadway cross slope, the driveway grade line, and other controls (e.g., locations and elevations of intersecting sidewalks).
- The vertical profile(s) used in the design of the driveway should reflect the horizontal turning movement paths expected to be used by the design vehicle.
- As Port Authority leaseholds change hands or as redevelopment occurs over time, the types of vehicles using the driveway should be considered with respect to the needed vertical profile of the driveway. Design modifications to the vertical alignment of the driveway should be undertaken when deemed necessary to maintain or improve the vertical profile for the design vehicle.

9.2.10 Development Signing

Signs, when located close to a driveway, help drivers who are scanning the upcoming roadside to detect the location of the driveway serving their destination. Conversely, a business sign located far from the subject property's driveway may actually divert a driver's view away from the driveway location, be misleading or even be confusing, thereby increasing the possibility of drivers making errors and also increasing the likelihood of a crash.

The need to provide information to the driver in a timely manner is critical because the driver may have to negotiate heavy traffic volumes and may not be able to change lanes or decide quickly on when and where to make turns. However, motorists may also be faced with numerous competing signs and traffic control devices. As a result, there is a balance between providing drivers with sufficient information and not overwhelming them with too much information.

The following guidelines apply to the signing of driveways along Port Authority roadways:

- Signs to direct motorists to businesses located on Port Authority leaseholds should be located and positioned in a manner that helps clearly identify the entrance driveway(s) serving the subject property.
- All business signs should be placed so that they:
    - do not obstruct sight lines (see *Chapter 10*)
    - do not compete with traffic signs
    - do not protrude into sidewalks or other pedestrian areas and
    - are not obstructed by signal poles, street lights, other signs, or other roadside appurtenances
- Signs should be installed sufficiently far from the curb to prevent contact with vehicles.
- Signs should be lighted or have reflective properties such that they are visible at night, during inclement weather, and under poor ambient lighting conditions.
- The design and placement of business signs should be subject to the guidelines presented in the other sections of this chapter (i.e., *Section 9.2.8: Clearance from Fixed Objects*), as well as the intersection sight distance and roadside buffer guidelines in *Chapter 10*.
- Chapter 2D, "Guide Signs – Conventional Roads" in the *Manual on Uniform Traffic Control Devices* applies to guide signs used to direct users to destinations within Port Authority facilities.

- The Port Authority's *Airport Roadway Sign Design Manual* should be consulted for additional signing guidance at airport facilities.
- Tenants shall keep landscaping (e.g., grass, flowers, shrubs, and trees) trimmed and pruned so that drivers have a clear view of signs needed by drivers to identify the locations of the business and the location of the entrance driveways. These provisions should be included in leasehold agreements whenever possible.

9.2.11 Illumination

Statistics indicate that nighttime crash rates are higher than crash rates during daylight hours. This fact, to a large degree, may be attributed to lower visibility. In locations without adequate lighting, drivers traveling at night, during inclement weather, or under poor ambient lighting conditions may not be able to identify the access driveway to a business or leasehold. In addition, the lack of proper illumination may prevent drivers from seeing pedestrians, bicyclists, and other vehicles at adequate sight distances. The following guidelines apply to the illumination of driveways along Port Authority roadways:

- Adequate illumination[37] should be provided in the vicinity of all intersections and driveways to provide for the necessary sight distances for all users of the driveway, including motorists, pedestrians, and bicyclists. The necessary level of illumination should be based on consideration of the following factors:
  - traffic, pedestrian, and bicycle volumes
  - vehicle speeds
  - nighttime crash history
  - intersection geometrics and
  - general nighttime visibility
- Illumination should be installed where any of the following conditions exist:
  - potential for wrong-way movements, as indicated through crash experience or engineering judgment
  - high pedestrian or bicyclist volumes
  - need for motor vehicle travel path adjustment at or near the intersection due to a shifting lane alignment, a turn-only lane assignment, or a pavement width transition
- The following illumination criteria[38] should apply irrespective of the type or classification of the roadway:
  - 150-Watt High-Pressure Sodium at 26 feet
  - 250-Watt High-Pressure Sodium at 40 feet
  - Average maintained: 0.6 to 0.9 foot-candles
  - Light loss factor: 0.75 foot-candles
  - Minimum: 0.2 foot-candles
  - Average/Minimum: 4:1 or better
  - Conventional Cutoff Cobra head

[37] The reader is referred to AASHTO's *Roadway Lighting Design Guide* (2005 or superseding edition) for more information on roadway illumination.

[38] Criteria for illumination provided by Harshad N. Patel in Port Authority Electrical Engineering Discipline of the Engineering Department.

CHAPTER 10: ROADSIDE BUFFER AND INTERSECTION SIGHT DISTANCE

10.1 Roadside Buffer

10.1.1 Overview

As shown in *Figure 10-1*, the "roadside buffer" is defined as the area starting at the edge of the traveled way and extending away from the roadway centerline a horizontal distance specified in *Section 10.1.2*. The desired width of the roadside buffer is dependent upon the design speed of the roadway. The purpose of the roadside buffer is to provide space for:

- placing and maintaining utilities,

- locating roadside guide signs, and

- having a recovery area for errant vehicles that leave the shoulder.

Figure 10-2 illustrates the roadside buffer when no shoulder is present.

Figure 10-1: Illustration of Roadside Buffer and Clear Zone on a Roadway with a Shoulder

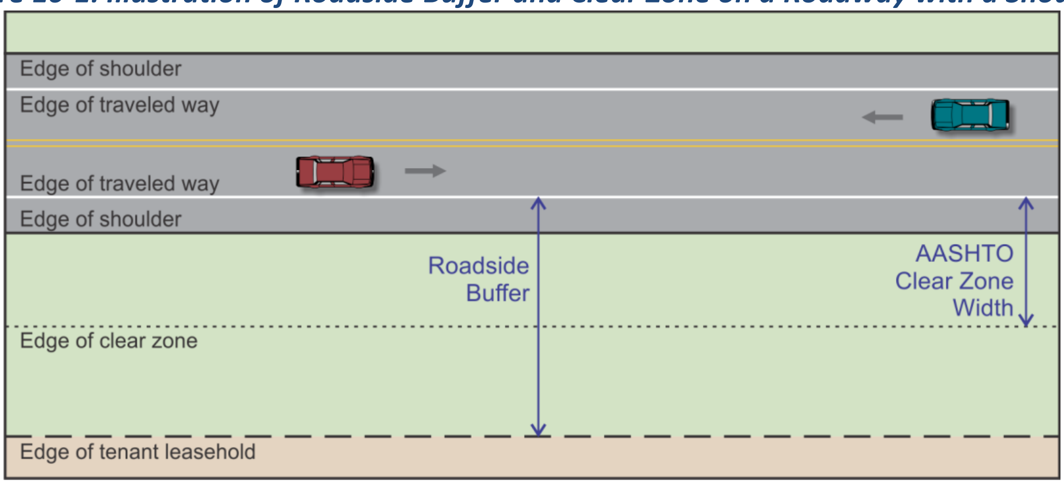
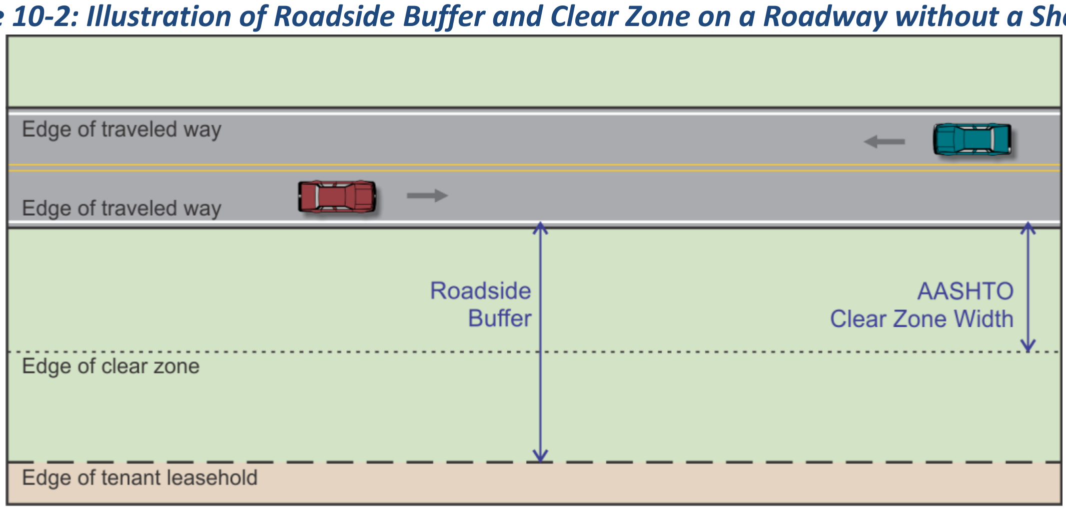


Figure 10-2: Illustration of Roadside Buffer and Clear Zone on a Roadway without a Shoulder

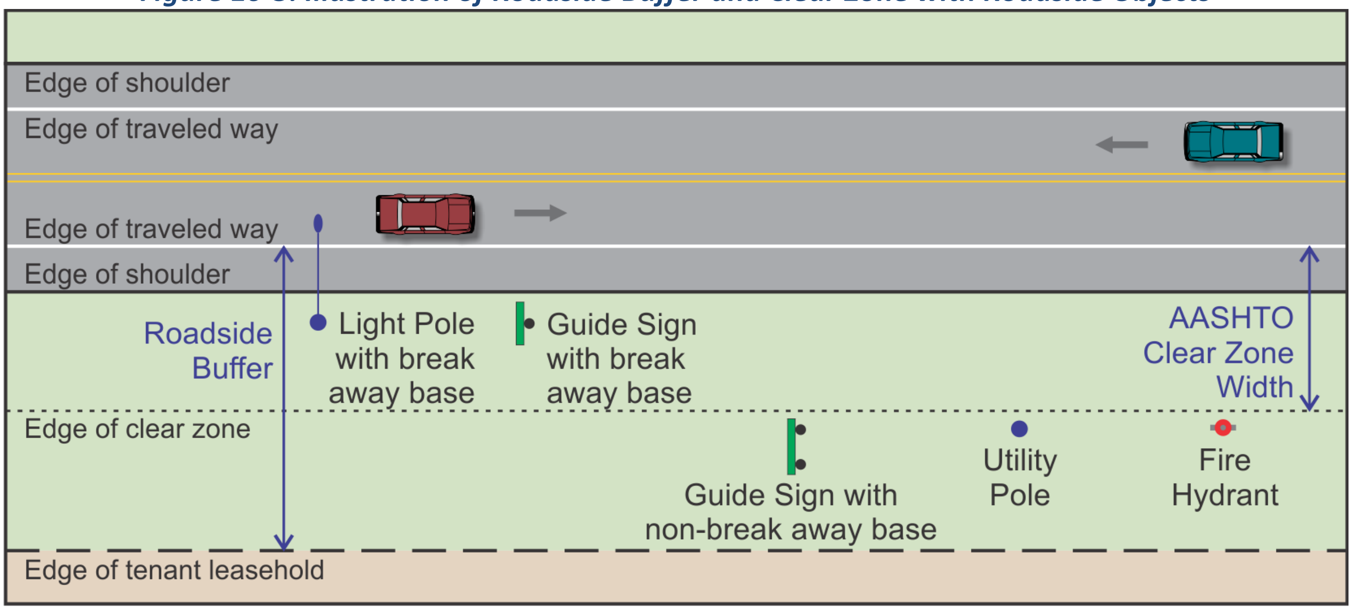


Also, as can be seen in *Figure 10-1* and *Figure 10-2*, the roadside buffer is distinct from the roadside "clear zone" which is defined in the AASHTO *Roadside Design Guide* and may consist of a shoulder, a recoverable slope, and/or a clear run-out area for vehicles departing the roadway. The Port Authority requires a roadside buffer to eliminate obstructions within the clear zone width.

According to the American Association of State Highway and Transportation Officials (AASHTO), approximately thirty percent of traffic fatalities – or almost one in every three – are the result of a single vehicle running off the road and crashing, which is why a clear zone – a traversable recovery area for vehicles leaving the roadway – is a significant traffic safety component of the roadside environment. The roadside buffer and clear zone are consistent with AASHTO's concept of a "forgiving roadside."

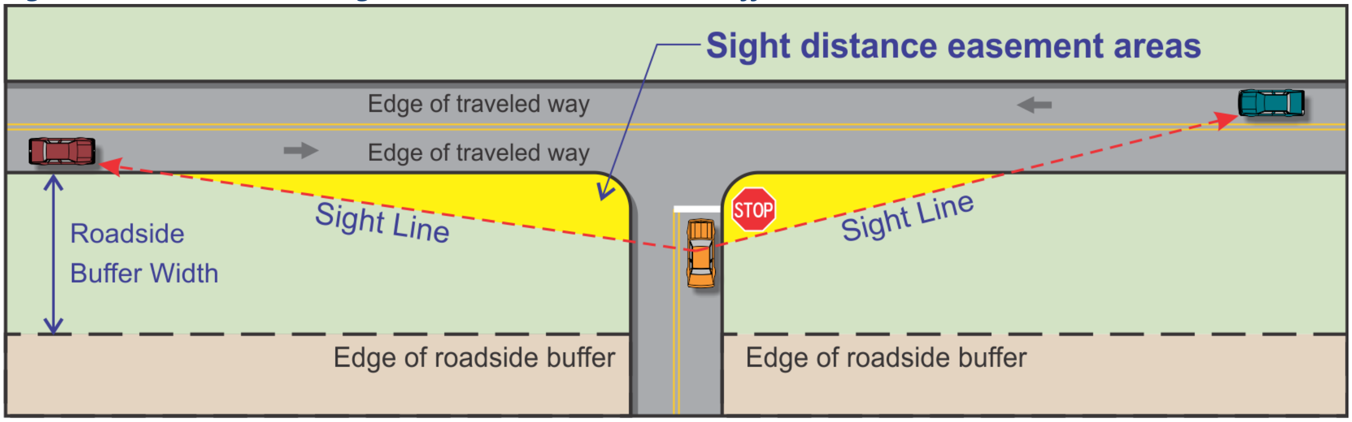
Typically, roadside objects (i.e., guide signs, light poles, and a fire hydrant) are located within the roadside buffer, as illustrated in *Figure 10-3*. All roadside objects within the roadside buffer that are non-break away should be placed outside the clear zone. To express this another way, all roadside objects located within the clear zone should be designed to break away upon impact by a vehicle.

Figure 10-3: Illustration of Roadside Buffer and Clear Zone with Roadside Objects



In addition to providing physical space along the roadside for the recovery of errant vehicles, the roadside buffer offers a variety of safety and operational benefits. First, the roadside buffer area affords space for roadside guide signs and placement and maintenance of utilities close to the roadway, as shown in *Figure 10-3*. Roadside appurtenances such as signs and street lights must remain near the roadway to serve their intended functions and should be designed to comply with the provisions in the AASHTO *Roadside Design Guide*. The visibility of guide signs is particularly important at Port Authority facilities because drivers who are unfamiliar with the facility rely on guide signs to locate various tenants and navigate into and out of terminals. Therefore, the roadside buffer should be sufficiently wide to accommodate guide signs that are large enough and contain adequate information to direct drivers into, out of, and within the facility. Second, as shown in *Figure 10-4*, the roadside buffer provides unobstructed sight lines necessary for drivers to see oncoming traffic when they are waiting to turn from intersecting roadways and driveways. It also allows space for pedestrian and/or bicycle pathways, including those that are separated by a buffer from moving vehicles or transit facilities (i.e., bus stops and bus pull-outs). The roadside buffer also can be used for snow storage.

Figure 10-4: Intersection Sight Lines Within Roadside Buffer



10.1.2 Guidance

The following guidance applies to roadside buffers along roadways at Port Authority facilities:

- The Port Authority's guidelines for the width of the roadside buffer are dependent on the roadway's design speed, as shown in *Table 10-1*.

Table 10-1: Desirable Roadside Buffer Widths

Design Speed	Desirable Width
40 mph or less	20 feet
45 and 50 mph	25 feet
55 mph	30 feet

- The roadside buffer area should be a criterion to be considered when determining the location of lease-lines. Tenant lease-lines should not be located within the boundaries of the roadside buffer area. Alternatively, a roadside buffer easement may be defined within the tenant leasehold to accommodate all, or part, of the needed buffer area. This easement restricts the height, size, and placement of objects on the tenant's leasehold within the roadside buffer.

- In some instances – such as along terminal frontage roadways – it may not be feasible to achieve the roadside buffer width shown in *Table 10-1*. Under these circumstances, the design of the roadway should be tailored to conditions at the specific location, considering the roadway's crash history, existing and future vehicle, pedestrian, and bicyclist traffic volumes, and the presence of heavy vehicles. In addition, a design exception is needed (see *Chapter 14*).

- Clear zone widths should be determined using the procedures in the AASHTO *Roadside Design Guide*.[39]

- Fixed (i.e., non-break away) objects on the roadside should be located as far from active travel lanes as practical and should either be designed to be break away or shielded from vehicular impact (to be determined on a project-by-project basis). Fixed objects along the roadside should be located outside the clear zone and may be located within the roadside buffer. Roadside objects that are designed to break

[39] Methodologies to determine clear zone width should be based on latest edition of the AASHTO *Roadside Design Guide*.

away upon impact by a vehicle (e.g., light poles, signs, etc.) are not considered fixed objects and may be located within the clear zone and the roadside buffer.

- Above-ground utilities should be considered for underground installation. Where this is not possible and poles are needed, the utility poles should be located on only one side of the roadway and away from active travel lanes and driveways. Consideration should be given to relocating poles to less vulnerable locations (e.g., on the inside of horizontal curves) and sharing poles among various utilities to reduce pole density. These parameters should be determined on a project-by-project basis.

10.1.3 Example Problem

Given: A Port Authority roadway with a speed of 45 mph.

Problem: Determine the desirable distance that a tenant's fence (i.e., lease line) should be set back from the edge of the traveled way, based on the Port Authority's roadside buffer guidelines.

Solution: Consult *Table 10-1* and use the given design speed to find the desirable roadside buffer width for the setback related to the tenant's fence and lease-line, as highlighted below.

Design Speed	Desirable Width
40 mph or less	20 feet
45 and 50 mph	**25 feet**
55 mph	30 feet

As shown above, the desirable roadside buffer width is 25 feet. In summary, to accommodate the required roadside buffer, it is desirable to set back the tenant's lease-line and fence 25 feet from the edge of the traveled way. If this distance cannot be achieved, a design exception will be required and the tenant's lease-line and fence should be located as far as practical from the edge of the traveled way.

10.2 Intersection Sight Distance

10.2.1 Overview

The provision of adequate intersection sight distance at all intersections – including driveways – along roadways is a fundamental aspect of traffic operations and safety. Sufficient sight distance is needed at all intersections to allow drivers to perceive the presence of potentially conflicting vehicles, whether they are relying on a traffic-control device to determine right-of-way or, in the absence of such a device, relying on the rules of the road. This perception should occur in sufficient time for drivers to stop or adjust their speed, as appropriate, to avoid colliding in the intersection.

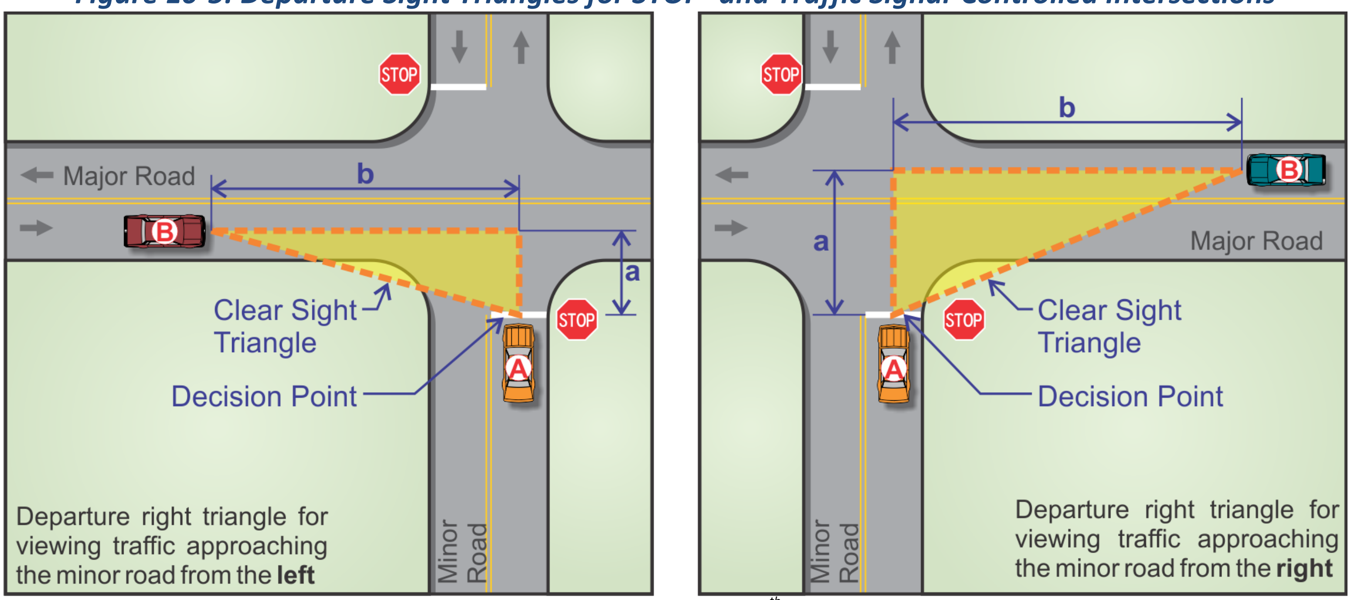
The driver of a vehicle approaching an intersection needs to have not only an unobstructed view of the entire intersection and any traffic control devices, but also sufficient time (and distance) along the intersecting roadway to anticipate and avoid potential collisions. The sight distance needed under various assumptions of physical conditions and driver behavior is directly related to vehicle speeds and to the resultant distances traversed during perception-reaction time and braking.

As such, specified areas along the intersection's approach legs, and across their corners, should be clear of sight obstructions that might block a driver's view of potentially conflicting vehicles. These specified areas are known as "clear sight triangles." The dimensions of the sight triangles depend on the design speeds of the intersecting roadways and the type of traffic control at the intersection. An overview of sight triangles is provided below. AASHTO's *A Policy on Geometric Design of Highways and Streets, 6th Edition*, 2011, pp. 9-28 to 9-54 has been adapted as the basis for the material in this section.

10.2.1.1 Departure Sight Triangles

For intersection approaches controlled by STOP signs or traffic signals, the need for approaching vehicles to stop at the intersection is determined by the traffic control devices and not by the presence or absence of vehicles on the intersecting approaches. Under these conditions, a *departure sight triangle* is needed to provide sufficient sight distance for stopped drivers on a minor roadway approach to view and assess the location and speed of approaching traffic that will conflict with their forward movement from the stop line into the intersection. The drivers must assess the gaps within the conflicting traffic flows and search for a gap of adequate length for the desired movement, which may be a right-turn, a left-turn, or a crossing of the intersection. *Figure 10-5* shows typical departure sight triangles, to the left and to the right, for a vehicle on the minor roadway at the intersection stop line (Driver "A"). Providing clear departure sight triangles also allows the drivers of vehicles on the major roadway (Driver "B") to see any vehicles stopped on the minor roadway approach and be prepared to slow or stop, if necessary.

Figure 10-5: Departure Sight Triangles for STOP- and Traffic Signal-Controlled Intersections



Source: Adapted from AASHTO, *A Policy on Geometric Design of Highways and Streets*, 6th *Edition,* 2011, Exhibit 9-15, p. 9-30.

10.2.1.2 Identification of Obstructions within Sight Triangles

Not only should the profiles of intersecting roadways be designed to provide the recommended sight distances for drivers on the intersection approaches, but also sight triangles should not contain objects that would obstruct the driver's view. Within a sight triangle, any object at a height above the elevation of the adjacent roadways, which could obstruct views, should be removed or lowered. Such objects may include buildings, parked vehicles, highway structures, roadside hardware, hedges, trees, bushes, unmowed grass, walls, fences, and the terrain itself. Even temporary conditions such as piles of plowed snow are sight obstructions if they are located within an intersection's sight triangle.

To determine whether an object constitutes a sight obstruction, the horizontal and vertical alignment of both intersecting roadways, as well as the height and position of the object, should be considered. In making this determination, it should be assumed that the object to be seen is 3.5 feet above the surface of the intersecting road. Where the sight distance value used in design is based on a passenger car as the design vehicle, it should be assumed that the driver's eye is 3.5 feet above the roadway surface. Where the design vehicle is a single-unit or combination truck, it is also appropriate to use the recommended eye height of a truck driver – 7.6 feet above the roadway surface – in checking sight obstructions. However, even in instances where the design vehicle is a truck, adequate sight distance should also be provided for drivers of passenger cars, with the driver's eye assumed to be 3.5 feet above the roadway surface.

10.2.1.3 Calculation of Sight Triangle Dimensions

Because different types of traffic control devices impose different constraints on drivers – and, therefore, result in different driver behaviors – the recommended dimensions for approach and departure sight triangles vary with the type of traffic control devices used at an intersection and the associated traffic movements, as summarized below:

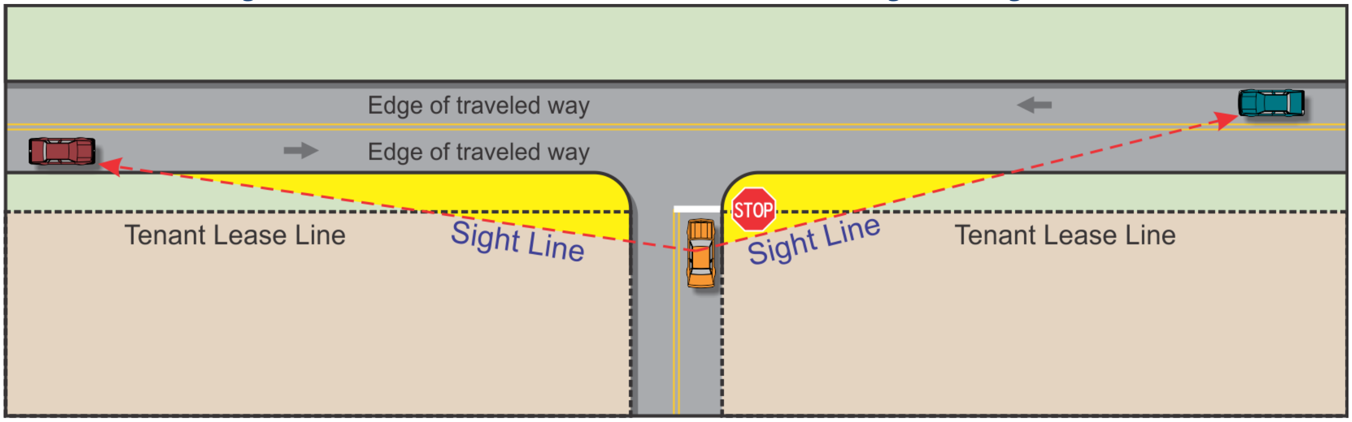
- **Case A:** Intersections with no traffic control
- **Case B:** Intersections with STOP control on the minor road:
    - **Case B1:** Left-turn from the minor road
    - **Case B2:** Right-turn from the minor road
    - **Case B3:** Crossing maneuver from the minor road
- **Case C:** Intersections with yield control on the minor road
    - **Case C1:** Crossing maneuver from the minor road
    - **Case C2:** Left-turn or right-turn from the minor road
- **Case D:** Intersections with traffic signal control
- **Case E:** Intersections with all-way stop control
- **Case F:** Left-turns from the major road

The detailed calculation procedures for determining the sight triangle dimensions for all cases listed above are found in AASHTO's *A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011* (pp. 9-28 to 9-54), or superseding editions.

10.2.1.4 Sight Triangle Easements

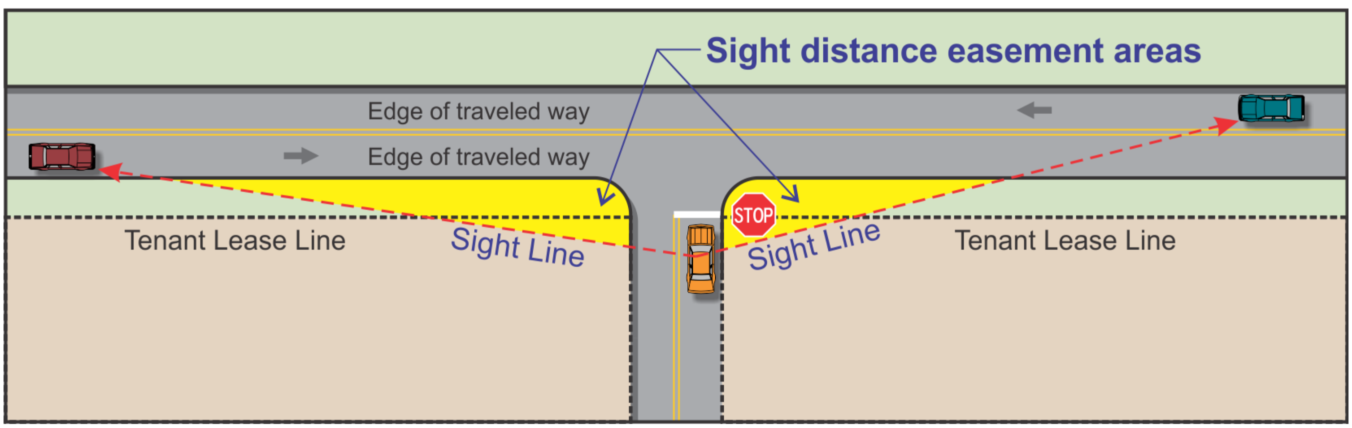
To provide unobstructed sight lines, tenant lease-lines should be set back outside the sight triangle areas, as shown in *Figure 10-6*.

Figure 10-6: Tenant Lease-Lines Located Outside Sight Triangle Areas



Alternatively, a sight distance easement may be defined within the tenant leasehold to accommodate the needed sight lines, as shown in *Figure 10-7*. This easement restricts the height, size, and placement of objects on the tenant's leasehold within the area of the sight distance triangles including fences, gates, signs, and landscaping. Tenants and other stakeholders should ensure that adequate sight lines are preserved.[40]

Figure 10-7: Intersection Sight Lines Extending Beyond Tenant Lease-Lines



10.2.2 Intersection Sight Distance Guidelines

The following guidance applies to intersection sight distance for all roadways at Port Authority facilities:

- The sight distance guidelines described in this chapter should apply to all types of intersections (including driveways) along Port Authority roadways, regardless of the vehicle types involved and the function of the roadway. This provision should also apply to crosswalks and Restricted Vehicle Service Roads.
- The vertical and horizontal profiles of intersecting roadways (including driveways) should be designed to provide adequate sight distances for drivers on the intersection approaches.

[40] For more guidance, refer to *Municipal Regulation of Traffic View Obstructions*, by J. H. Vogel and E. H. Campbell, February 1953.

- Within a sight triangle, any object at a height above the elevation of the adjacent roadways that would obstruct the driver's view should be removed or lowered. Such objects may include buildings, parked vehicles, highway structures, roadside hardware, hedges, trees, bushes, unmowed grass, walls, fences, and the terrain itself.

- The decision of which case to use for the intersection sight distance calculations should be based on the decisions made at the team conceptual planning meeting.

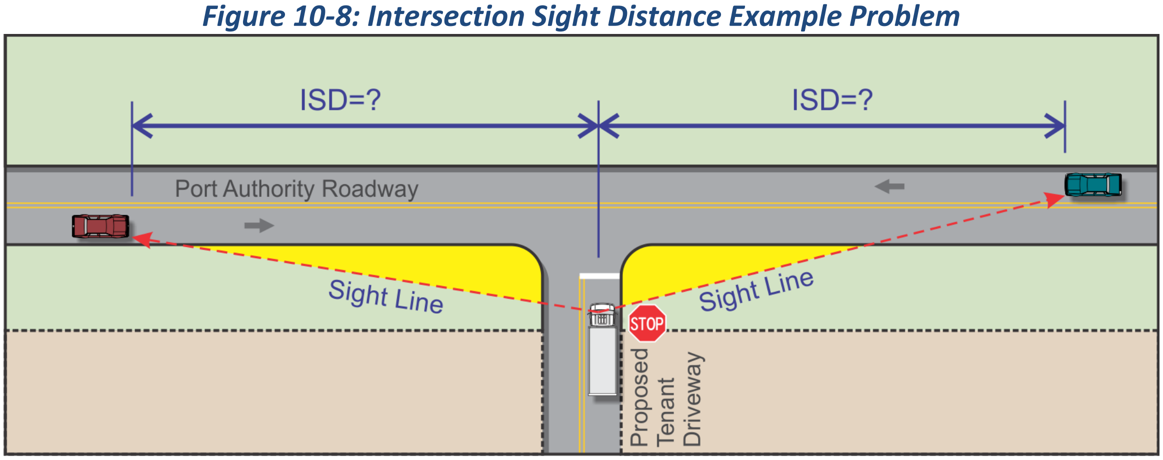
- Intersection sight distance triangles should be a criterion to be considered when determining the location of lease-lines. These lines should be recorded in appropriate legal documents such as deeds and leasehold agreements.

- In order to provide adequate sight trian*gles, tenant lease-lines should be set back from the edge of the travele*d way and should not be located within the sight triangles. Alternatively, a sight distance easement may be defined within the tenant leasehold to provide for adequate sight distance. This easement restricts the height, size, and placement of objects on the tenant's leasehold within the sight triangles, such that drivers stopped at the driveway can view vehicles approaching the driveway along the intersecting roadway without their sight lines being obstructed by trees, bushes, terrain, signing, and other obstacles.

10.2.3 Example Problem

Given: A new tenant driveway is proposed to be located along a two-way Port Authority roadway that has one lane in each direction (see *Figure 10-8*). The driveway will be stop-controlled at its intersection with the Port Authority roadway. The design speed on the Port Authority roadway is 45 mph (prevailing travel speeds are also observed to be 45 mph). The approach grade of the driveway is two percent.

Figure 10-8: Intersection Sight Distance Example Problem



Problem: Calculate and compare the Intersection Sight Distance (ISD) needed at the tenant's proposed driveway based on both a single-unit truck (SU) as the design vehicle and a combination tractor-trailer as the design vehicle.

Solution: The procedures on pages 9-28 to 9-54 of the 2011 AASHTO "Green Book" should be used for calculating the needed intersection sight distance. The situation described above – an intersection with STOP control on the minor roadway – is "Case B" in AASHTO.

Equation 9-1 on page 9-37 of the "Green Book" provides the following formula for calculation of Intersection Sight Distance (ISD) for left-turns from the minor road, in US customary units:

$$\mathbf{ISD = 1.47 \times V_{major} \times t_g}$$

Where: **1.47 = a constant (feet-hour/mile-seconds)**

V_{major} = design speed of major roadway (mph)

t_g = time gap for minor roadway vehicle to enter the major road (seconds)

Table 9-5 on page 9-37 of the 2011 AASHTO "Green Book" provides the values of the time gap (t_g) for various vehicle types. For a SU truck, t_g = 9.5 seconds. For a combination truck, t_g = 11.5 seconds. Therefore:

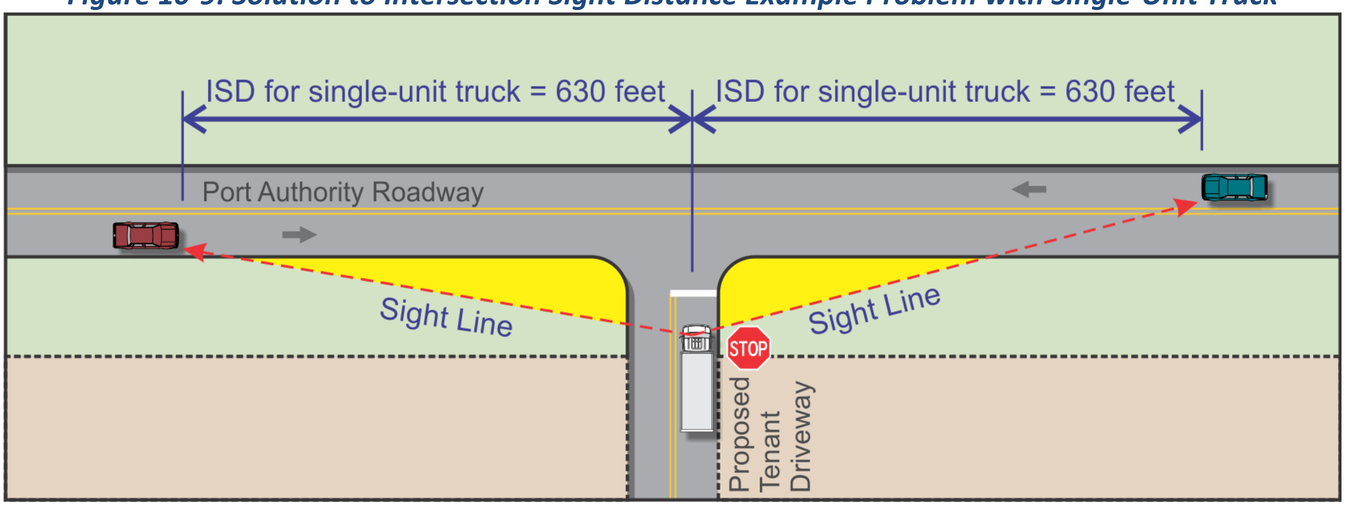
ISD for a SU truck = 1.47 feet-hour/mile-seconds × 45 miles/hour × 9.5 seconds = 628.43 feet

ISD for a combination truck = 1.47 feet-hour/mile-seconds × 45 miles/hour × 11.5 seconds = 760.73 feet

As shown in *Figure 10-9,* the calculated intersection sight distance for the SU truck is 628.43 feet, or 630 feet rounded for design purposes. As shown in *Figure 10-10*, the calculated intersection sight distance for the combination truck is 760.73 feet, or 765 feet, rounded for design purposes. No grade adjustment[41] is needed because the approach grade of the driveway is less than four percent.

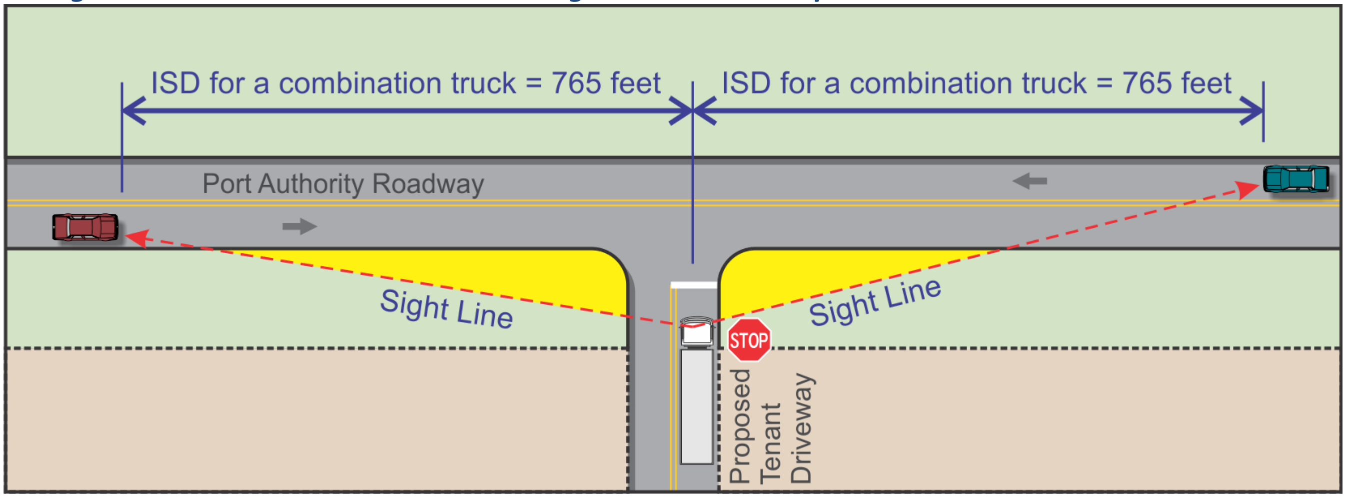
Additionally, as this is a T-intersection, there is no crossing maneuver from the minor road, so Case B3 (crossing maneuver from the minor road) does not apply. Also, it should be noted that Case B2 (right-turn from the minor road) results in an intersection sight distance that is shorter than the distance calculated above (for left-turns from the minor road) and, therefore, is not used for design purposes.

Figure 10-9: Solution to Intersection Sight Distance Example Problem with Single-Unit Truck



[41] Table 9-4 on page 9-35 of the 2011 AASHTO "Green Book" provides grade adjustment factors.

Figure 10-10: Solution to Intersection Sight Distance Example Problem with Combination Truck



Following the procedures in the AASHTO "Green Book," the dimensions of the sight triangles to the right and left of the tenant's proposed driveway can now be determined based on the calculated intersection sight distance in both directions for a SU truck or a combination truck (630 feet and 765 feet, respectively) and the distance between the driver's eye and the edge of the traveled way (14.5 feet as per the AASHTO "Green Book"). Objects located, or planned to be located, within these sight triangles should be limited in size, relocated, or eliminated entirely so as not to obstruct intersection sight lines.

Furthermore, when determining the acceptable sizes and locations of objects within the sight triangle areas, the vertical aspects of the needed sight lines should be taken into account, in addition to the horizontal aspects. This involves consideration of the vertical profiles for both the roadway and the driveway. It also involves using designated values for the height of the driver's eye and the height of the oncoming vehicle (which are 3.5 feet for passenger cars, as per the AASHTO "Green Book").

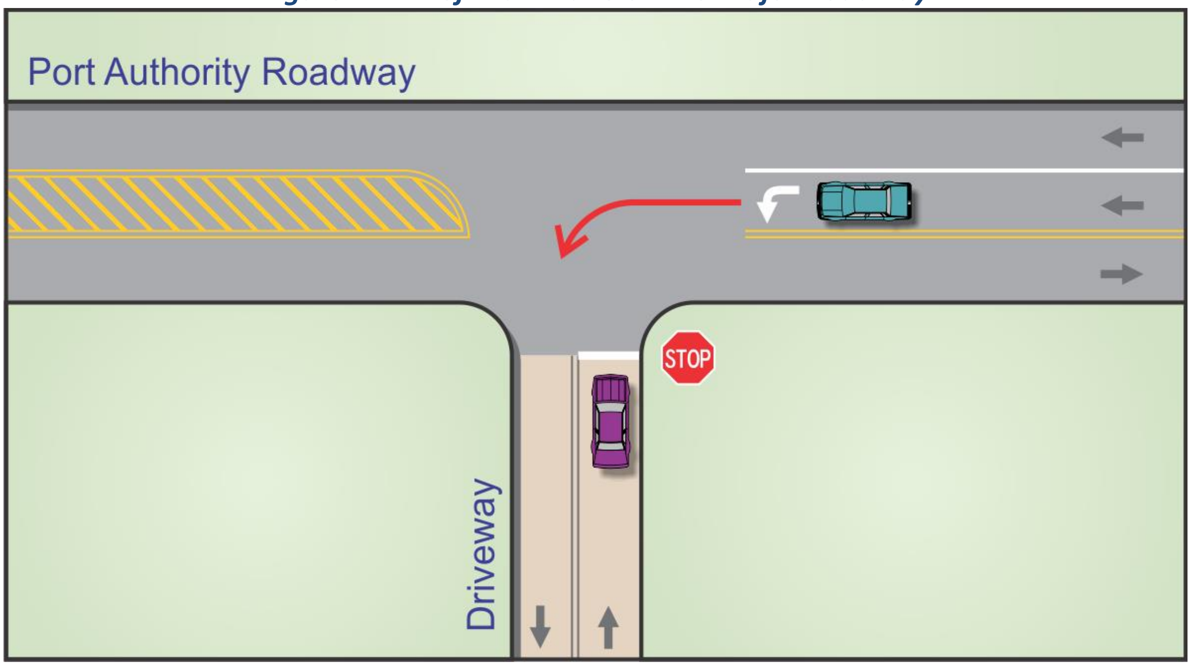
Because the design vehicle is a truck in the example problem above, AASHTO recommends using a driver's eye height of 7.6 feet (higher than the passenger car eye height of 3.5 feet). However, it is important to note that the use of this higher eye height may not adequately preserve sight lines for drivers of passenger cars, who are also likely to use the driveway. Therefore, both values for eye height – 3.5 feet for a passenger car and 7.6 feet for a truck – should be checked as part of the design process to ensure that adequate sight lines for all vehicles are accommodated at the driveway.

CHAPTER 11: LEFT-TURN LANES

11.1 Overview

Left-turn movements, especially those that are made from lanes that are shared with through traffic, may cause delays. In addition, research has demonstrated that ingress left-turn movements (left-turns from the roadway into a driveway) are associated with approximately 47 percent of all crashes at driveways. This chapter focuses on the provision of left-turn lanes on roadways at Port Authority facilities, as shown in *Figure 11-1*. Guidelines for left-turn lanes located on driveways are provided in *Chapter 9*.

Figure 11-1: Left-Turn Lane on the Major Roadway



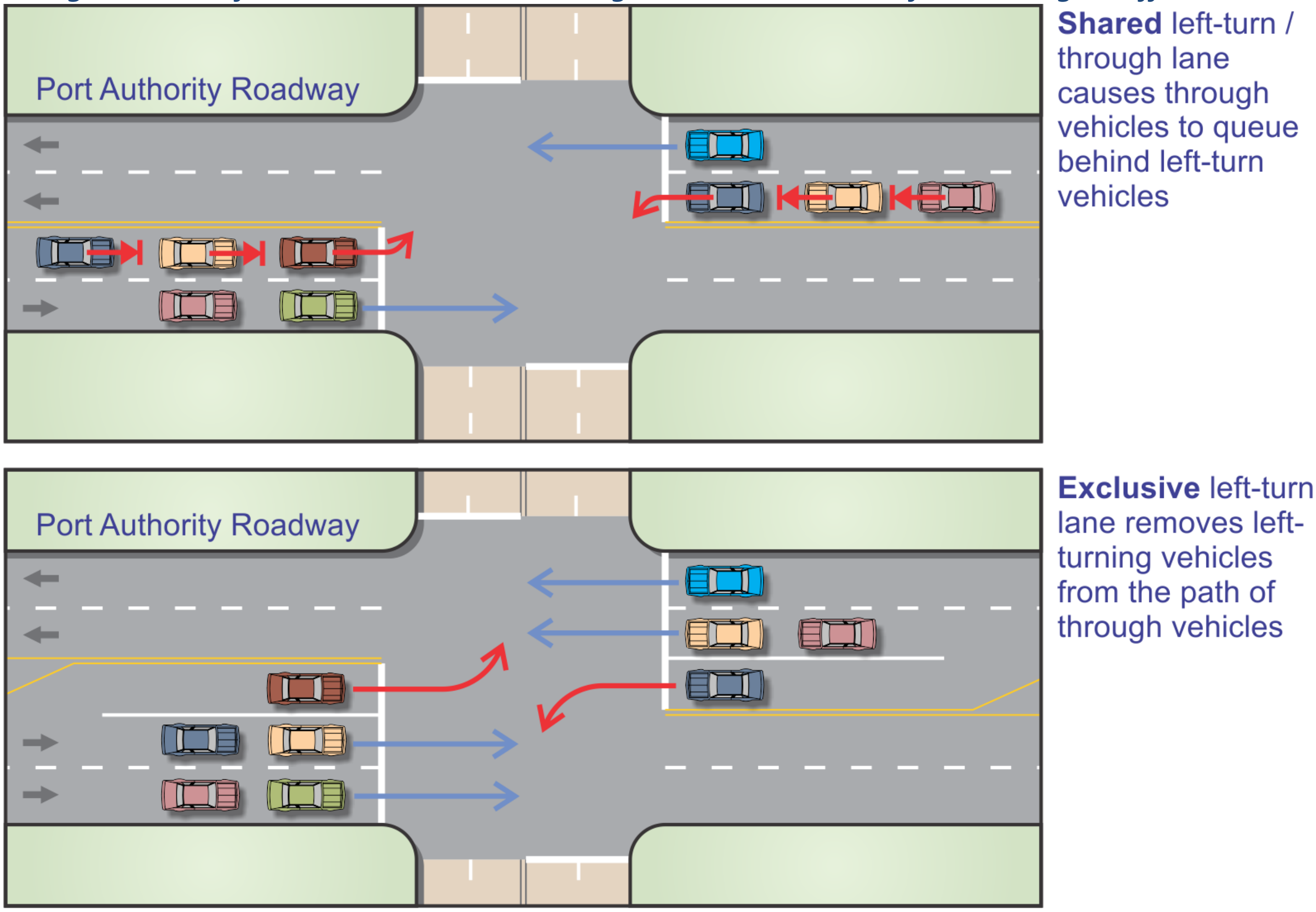
Auxiliary lanes include both left-turn lanes and right-turn lanes. They provide a refuge for left-turning and right-turning vehicles by removing those vehicles from the through traffic lane(s). As such, they are an effective means of eliminating the speed differential that exists between a turning vehicle and the through vehicles that follow when left-turns and right-turns are made from a shared through/turn lane. The addition of exclusive left-turn lanes has been shown to provide a variety of traffic safety and operational benefits including the following:

- Reducing the number of conflicts and crashes (particularly rear-end, angle, and sideswipe crashes)
- Physically separating left-turning traffic and queues from through traffic (see *Figure 11-2*)
- Decreasing vehicular delay and increasing intersection capacity
- Providing an area for left-turning vehicles to decelerate outside of the through travel lane
- Providing greater operational flexibility (e.g., additional traffic signal phasing opportunities)

In addition, research[42] has shown that left-turn lanes are likely to be warranted at most unsignalized intersections (except at those with very low volumes) based primarily on the cost savings attributable to an expected decrease in the number of crashes as a result of the left-turn lane installation.

[42] NCHRP Report 745: *Left-Turn Accommodations at Unsignalized Intersections*, 2013.

Figure 11-2: Left-Turn Lanes Remove Turning Vehicles and Queues from Through Traffic Stream



Source: FHWA, *Signalized Intersections: An Informational Guide*, August 2004, Figure 13, p. 41.

Despite the many potential safety and operational benefits associated with providing left-turn lanes, the decision to install a left-turn lane should also consider the potential drawbacks of doing so. These include the need for additional right-of-way along the roadway to accommodate the added width and length of the left-turn lane, as well as longer crossing times for pedestrians at the subject intersection, resulting in increased pedestrian exposure to moving vehicular traffic. Installing a left-turn lane dedicates more of the available roadway cross-section to accommodating motor vehicle traffic, rather than providing accommodations for pedestrians, bicycles, and transit facilities (i.e., bus stops and bus pull-outs). See *Chapter 4* for additional guidance regarding "complete streets."

11.2 General Considerations for Left-Turn Lane Installation

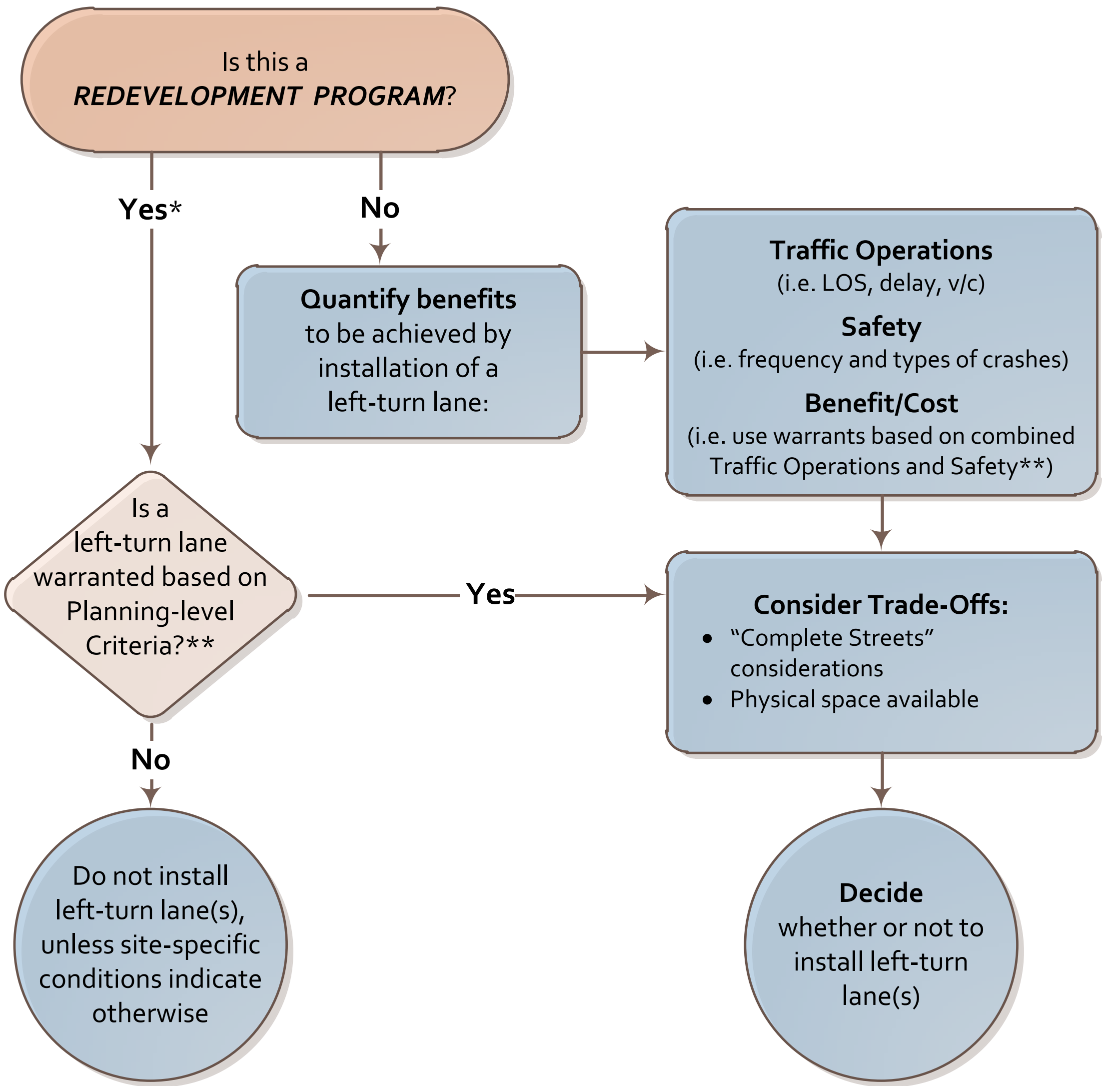
Whether to install a left-turn lane should be determined on a site-specific, case-by-case basis considering a range of factors within the overall context of the particular project. For example, the need for a left-turn lane should be weighed against the need for other cross-sectional features such as medians, sidewalks, bike lanes, roadside clear zones, through lanes, and right-turn lanes. There is no "one size fits all" solution. Specific factors to consider when making the decision to install a left-turn lane should include:

- Safety (potential conflicts and crash history, including crash types, severity, and causes)
- Type of project (i.e., redevelopment program, TAA, etc.) and its context within the Port Authority facility
- Existing cross-section of the roadway and the available right-of-way

- Roadway's access classification and function
- Prevailing vehicle speeds
- Traffic control devices and intersection operations
- Left-turn traffic volume and other movement volumes
- Roadway alignments

Below, in *Figure 11-3,* is a decision tree that provides a basic framework to assist in determining whether to install a left-turn lane. Given the unique characteristics of particular types of Port Authority projects and the associated traffic operations, safety, and benefit/cost considerations regarding a left-turn lane installation, *Figure 11-3* is simply a general guidance framework and not prescriptive guidelines, which are presented below in *Section 11.3*, with respect to the installation of left-turn lanes.

Figure 11-3: Left-Turn Lane Installation Guidance Framework



* Supplemental guidance for redeveloping areas, such as a formal redevelopment program, can be found in:

1) *Traffic Circulation Planning for Communities*, by H. Marks, 1974.
2) *Transportation and Land Development, 2nd Edition*, by V. Stover and F. Koepke, 2002.

** See Table 11-1 for warrant criteria.

11.3 Guidelines

The following Port Authority access management guidelines relative to left-turn lanes should be applied in conjunction with the decision tree shown above in *Figure 11-3*. The guidelines are presented in two sub-sections: 1) installation warrants and 2) design guidelines.

11.3.1 Left-Turn Lane Installation Warrants

The following are warrant guidelines that should be considered when determining whether to install a left-turn lane:

- **Planning-Level Criteria:** As described previously in this chapter, there are many traffic safety and operations benefits to installing left-turn lanes. Often, one of the primary barriers to installation of a new left-turn lane is the availability of sufficient right-of-way to physically accommodate the lane. Port Authority redevelopment programs provide unique opportunities to install left-turn lanes because of the potential for significant changes to be made to tenant lease lines and available rights-of-way. Therefore, left-turn lanes should be considered at all intersections and driveways included as part of Port Authority redevelopment programs, using the left-turn lane warrant volumes shown in *Table 11-1* for planning purposes. These warrants are based on a benefit/cost approach that compares the traffic safety and operational benefits to the costs associated with the left-turn lane installation.

Table 11-1: Left-Turn Lane Warrants

Peak Hour Left-Turn Lane Volume (vehicles/hour)	Peak Hour Major Street Volume (vehicles/hour/approach)	
	Three-Leg Intersection	Four-Leg Intersection
5	450	50
10	300	50
15	250	50
20	200	50
25	200	50
30	150	50
35	150	50
40	150	50
45	150	less than 50
50 or more	100	less than 50

Source: *NCHRP Report 745: Left-Turn Accommodations at Unsignalized Intersections*, 2013.

Excluding redevelopment programs, most Port Authority projects – such as Tenant Alteration Application and roadway improvement projects – are considered retrofit projects. Under these circumstances, the installation of left-turn lanes is often limited by right-of-way constraints, existing building locations, and other features of the built and natural environment. Therefore, under retrofit situations, left-turn lanes should be considered for installation where opportunities arise considering traffic safety criteria and traffic operations criteria, as well as the benefit/cost warrants shown in *Table 11-1*. The traffic safety and operational criteria are described below.

- **Safety Performance Criteria:** Left-turn lanes should be considered where an engineering study, which includes analysis of the crash history on the subject approach, indicates a high number or disproportionate percentage of crash types correctable by installation of a left-turn lane.

- **Operational Performance Criteria:** Left-turn lanes should be considered where a traffic operations analysis shows they are needed to provide an acceptable operational level at the intersection based on:
  - vehicular delay and level-of-service criteria and/or
  - volume-to-capacity criteria

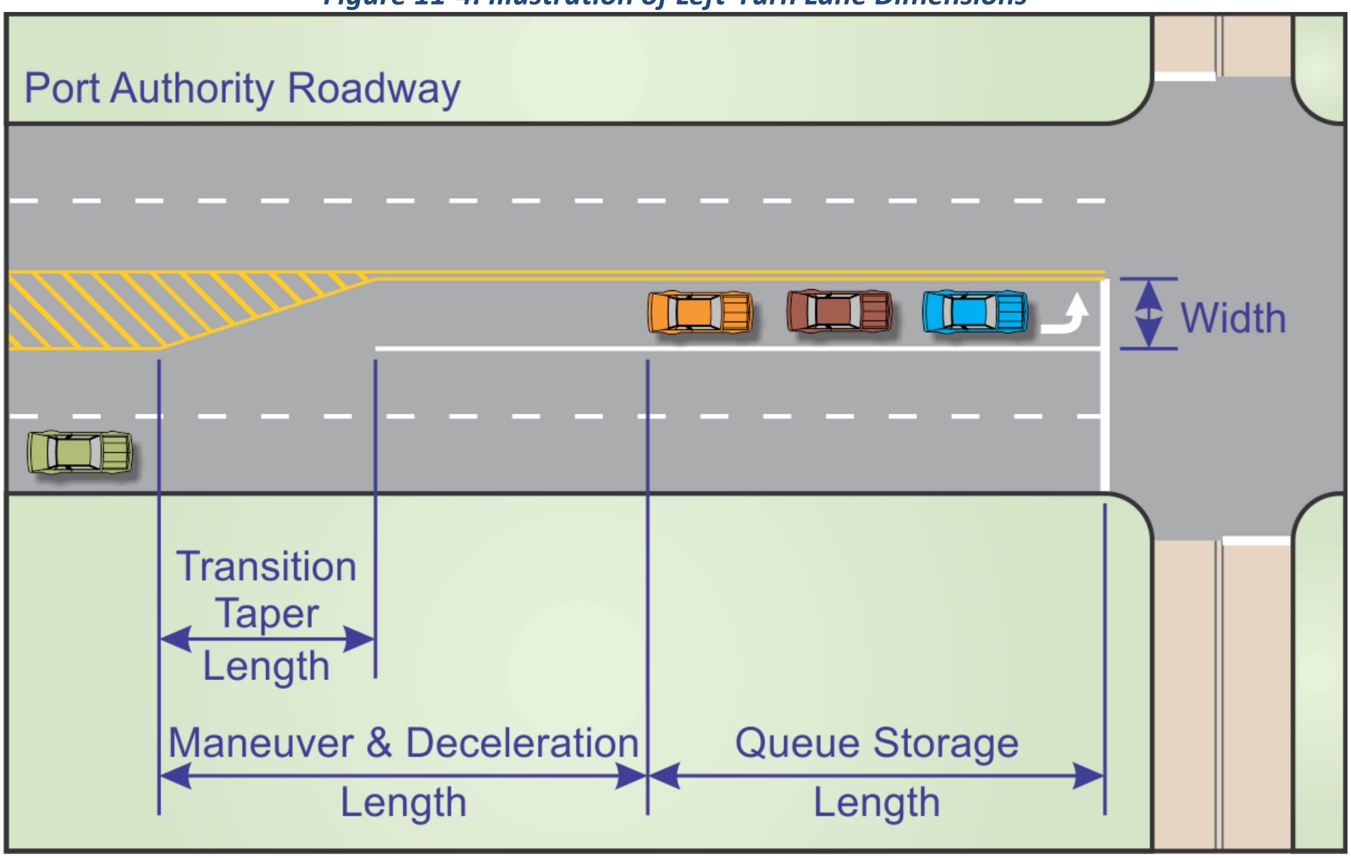
  Left-turn lanes also should be considered where protected left-turn signal phasing is warranted.

  As part of the operations analysis, pedestrian operations should be analyzed when deciding to install a left-turn lane. The projected operational impacts on pedestrians should be considered in the decision to install a left-turn lane.

11.3.2 Left-Turn Lane Design Guidelines

Once a decision to install a left-turn lane has been made, a variety of other decisions should be made relative to the design of the left-turn lane, including its width, queue storage length, and taper. The following design guidance applies to left-turn lanes on all Port Authority roadways (see *Figure 11-4* for an illustration of the left-turn lane dimensions):

Figure 11-4: Illustration of Left-Turn Lane Dimensions



- The desirable width of a left-turn lane should be 12 feet.
- The total length of the left-turn lane should be designed to include: 1) the transition taper length, 2) vehicle maneuver and deceleration length, and 3) vehicle queue storage length. These distances shall be

determined as follows:

- The transition taper should be 75 feet on undivided roadways. On divided roadways, the transition taper should follow the design guidance in AASHTO's *A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011* (pp. 9-127 to 9-130), or superseding edition.

- The desirable maneuver and deceleration length are given in *Table 11-2*. The desirable maneuver and deceleration length is based on the posted speed and ranges from 90 feet (at a posted speed of 20 mph) to 425 feet (at a posted speed of 50 mph).

Table 11-2: Desirable Maneuver and Deceleration Length

Posted Speed (mph)[1]	Maneuver and Deceleration Length (feet)
20	90
25	110
30	160
35	215
40	275
45	345
50	425

Source: Adapted from Stover, V.G. and F.J. Koepke, *Transportation and Land Development, 2nd Edition*, 2002, Table 5-13, page 5-43.

1: The 85th percentile speed may be used in place of the posted speed if an engineering study that supports the use of the 85th percentile speed over the posted speed is completed and approved by Port Authority Traffic Engineering.

- The desirable queue storage length should equal the 95th percentile queue length. The queue storage length should be adjusted to account for the lengths of the various vehicles in the traffic stream (i.e., passenger cars, single-unit trucks, tractor-trailers, etc.).

- Dual left-turn lanes should be considered when the volume of left-turns exceeds 300 vehicles per hour.
- Sight distance restrictions for left-turn movements at intersections should be avoided. This may be accomplished by implementing a positive offset, which is a lateral shift in the left-turn lane alignment to improve the ability of left-turning motorists to see oncoming traffic**.** A positive offset should be considered where there exists:

  - a center (median) lane wider than 12 feet
  - sufficient right-of-way or
  - a crash history reflecting a sight distance issue for left-turn movements

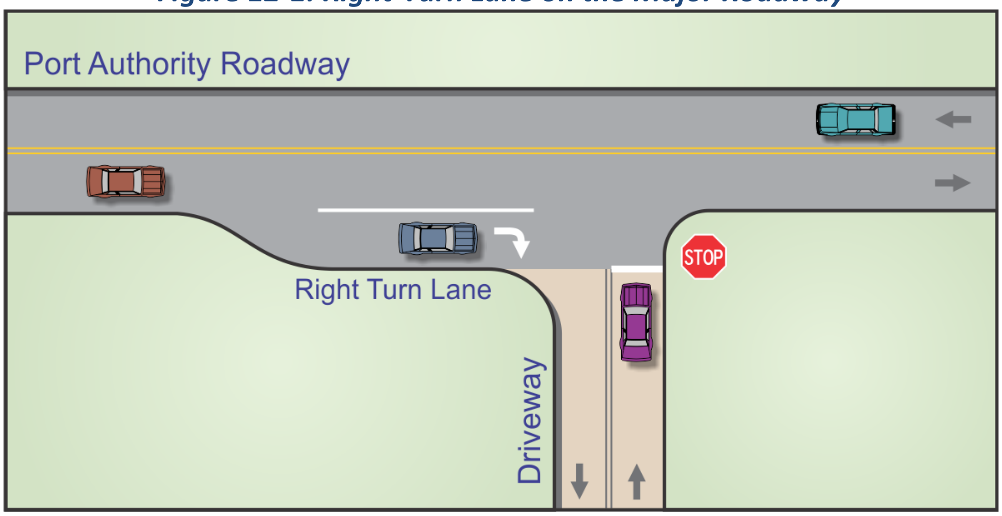
With a positive offset, the sight lines between a left-turning driver and oncoming through traffic are not blocked by left-turning vehicles on the opposing approach. The offset may be accomplished using either pavement markings or a raised channelization island; it is measured between the left edge of the left-turn lane and the right edge of the opposing left-turn lane.

CHAPTER 12: RIGHT-TURN LANES

12.1 Overview

Like left-turn movements, right-turn movements − especially those that are made from lanes that are shared with through traffic − may cause delays. In addition, research has demonstrated that ingress right-turn movements (right-turns from the roadway into a driveway) are associated with approximately 16 percent of all crashes at driveways. Furthermore, the Federal Highway Administration estimates that the addition of an exclusive right-turn lane on a multi-lane approach can reduce fatal/injury collisions by 40 percent and property damage only (PDO) crashes by 10 percent. This chapter focuses on the provision of right-turn lanes on roadways at Port Authority facilities, as shown in *Figure 12-1*. Guidelines for right-turn lanes located on driveways are provided in *Chapter 9*.

Figure 12-1: Right-Turn Lane on the Major Roadway

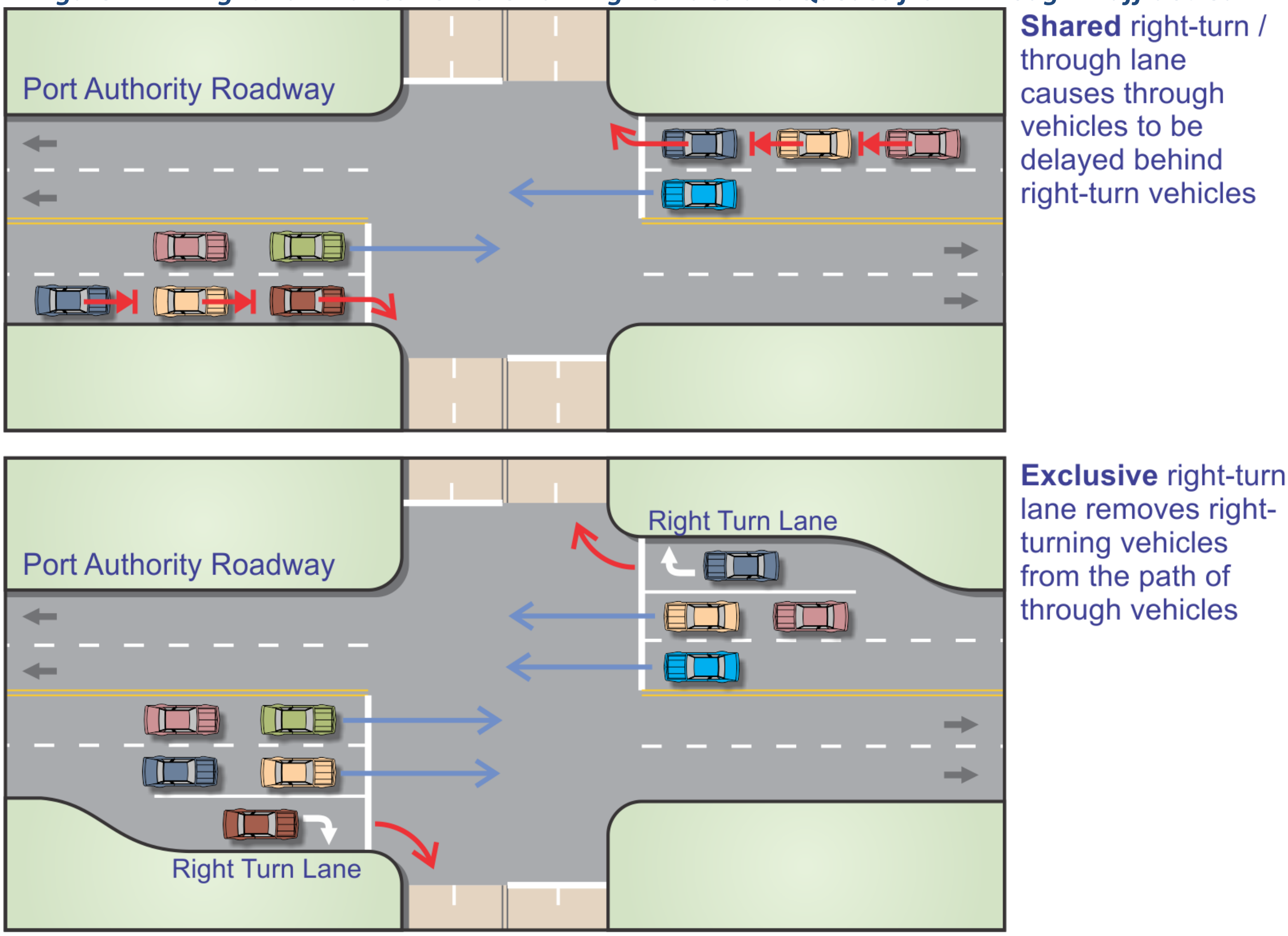


Auxiliary lanes include both left-turn lanes and right-turn lanes. They provide a refuge for left-turning and right-turning vehicles by removing those vehicles from the through traffic lane(s). As such, they are an effective means of eliminating the speed differential that exists between a turning vehicle and the through vehicles that follow when left-turns and right-turns are made from a shared through/turn lane. The addition of exclusive right-turn lanes has been shown to provide a variety of traffic safety and operational benefits including the following:

- Reducing the number of conflicts and crashes (particularly rear-end and sideswipe crashes)
- Physically separating right-turning traffic and queues from through traffic (see *Figure 12-2*)
- Decreasing vehicular delay and increasing intersection capacity
- Providing an area for right-turning vehicles to decelerate outside of the through travel lane
- Providing greater operational flexibility (e.g., right-turn overlap signal phasing, operating concurrently with protected left-turn phasing on the intersecting cross-street)

Despite the many potential safety and operational benefits associated with providing right-turn lanes, the decision to install a right-turn lane should also consider the potential drawbacks of doing so. These include the need for additional right-of-way along the roadway to accommodate the added width and length of the right-turn lane, as well as longer crossing times for pedestrians at the subject intersection, resulting in increased pedestrian exposure to moving vehicular traffic. Installing a right-turn lane dedicates more of the available roadway cross-section to accommodating motor vehicle traffic, rather than providing accommodations for pedestrians, bicycles, and transit facilities (i.e., bus stops and bus pull-outs). See *Chapter 4* for additional guidance regarding "complete streets."

Figure 12-2: Right-Turn Lanes Remove Turning Vehicles and Queues from Through Traffic Stream



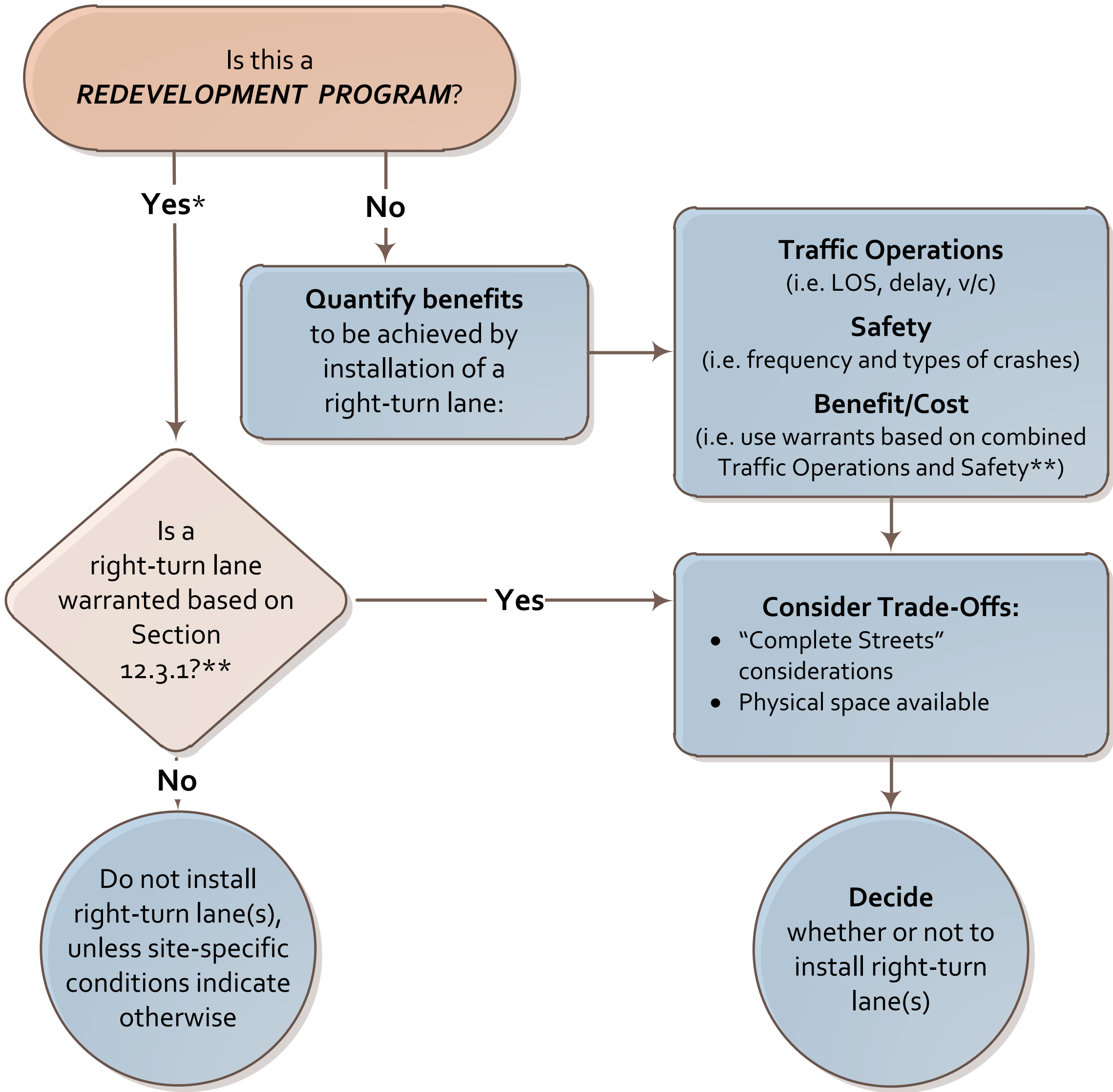
12.2 General Considerations for Right-Turn Lane Installation

Whether to install a right-turn lane should be determined on a site-specific, case-by-case basis considering a range of factors within the overall context of the particular project. For example, the need for a right-turn lane should be weighed against the need for other cross-sectional features such as medians, sidewalks, bike lanes, roadside clear zones, through lanes, and left-turn lanes. There is no "one size fits all" solution. Specific factors to consider when making the decision to install a right-turn lane should include:

- Safety (potential conflicts and crash history, including crash types, severity, and causes)
- Type of project (i.e., redevelopment program, TAA, etc.) and its context within the Port Authority facility
- Existing cross-section of the roadway and the available right-of-way
- Roadway's access classification and function
- Prevailing vehicle speeds
- Traffic control devices and intersection operations
- Right-turn traffic volume and other movement volumes
- Roadway alignments

Below, in *Figure 12-3,* is a decision tree that provides a basic framework to assist in determining whether to install a right-turn lane. Given the unique characteristics of particular types of Port Authority projects and the associated traffic operations, safety, and benefit/cost considerations regarding a right-turn lane installation, *Figure 12-3* is simply a general guidance framework and not prescriptive guidelines, which are presented below in *Section 12.3*, with respect to the installation of right-turn lanes.

Figure 12-3: Right-Turn Lane Installation Guidance Framework



* Supplemental guidance for redeveloping areas, such as a formal redevelopment program, can be found in:
1) *Traffic Circulation Planning for Communities*, by H. Marks, 1974.
2) *Transportation and Land Development, 2nd Edition*, by V. Stover and F. Koepke, 2002.

** See Figures 12-4 through 12-7 for warrant criteria.

12.3 Guidelines

The following Port Authority access management guidelines relative to right-turn lanes should be applied in conjunction with the decision tree shown above in *Figure 12-3*. The guidelines are presented in two sub-sections: 1) installation warrants and 2) design guidelines.

12.3.1 Right-Turn Lane Installation Warrants

The following are warrant guidelines that should be considered when determining whether to install a right-turn lane:

- **Planning-Level Criteria:** As described previously in this chapter, there are many traffic safety and operations benefits to installing right-turn lanes. Often, one of the primary barriers to installation of a new right-turn lane is the availability of sufficient right-of-way to physically accommodate the lane. Port Authority redevelopment programs provide unique opportunities to install right-turn lanes because of the potential for significant changes to be made to tenant lease lines and available rights-of-way. Therefore, right-turn lanes should be considered at all intersections and driveways included as part of Port Authority redevelopment programs, using the right-turn lane warrant curves shown in *Figures 12-4* through *12-7* for planning purposes. These warrants are based on a benefit/cost approach that compares the traffic safety and operational benefits to the costs associated with the turn lane installation.

  Excluding redevelopment programs, most Port Authority projects – such as Tenant Alteration Application and roadway improvement projects – are considered retrofit projects. Under these circumstances, the installation of right-turn lanes is often limited by right-of-way constraints, existing building locations, and other features of the built and natural environment. Therefore, under retrofit situations, right-turn lanes should be considered for installation where opportunities arise considering traffic safety criteria and traffic operations criteria, as well as the benefit/cost warrants shown in *Figures 12-4* through *12-7*. The traffic safety and operational criteria are described below.

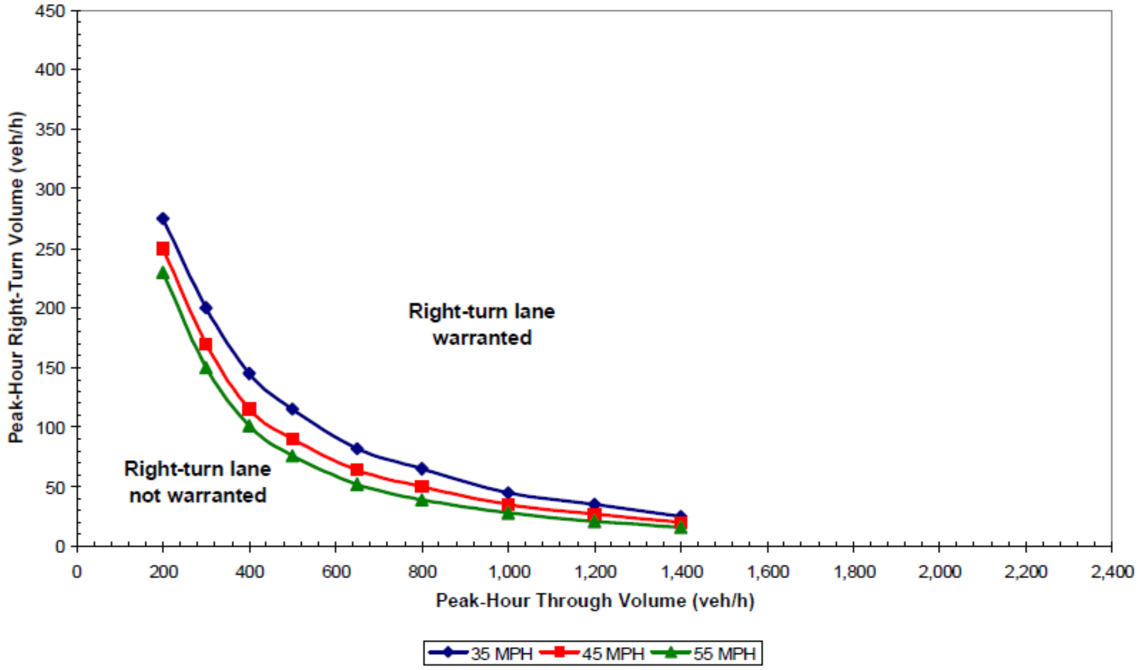
- **Safety Performance Criteria:** Right-turn lanes should be considered where an engineering study, which includes analysis of the crash history on the subject approach, indicates a high number or disproportionate percentage of crash types correctable by installation of a right-turn lane.

- **Operational Performance Criteria:** Right-turn lanes should be considered where a traffic operations analysis shows they are needed to provide an acceptable operational level at the intersection based on:

  - vehicular delay and level-of-service criteria and/or
  - volume-to-capacity criteria

  As part of the operations analysis, pedestrian operations should be analyzed when deciding to install a right-turn lane. The projected operational impacts on pedestrians should be considered in the decision to install a right-turn lane.

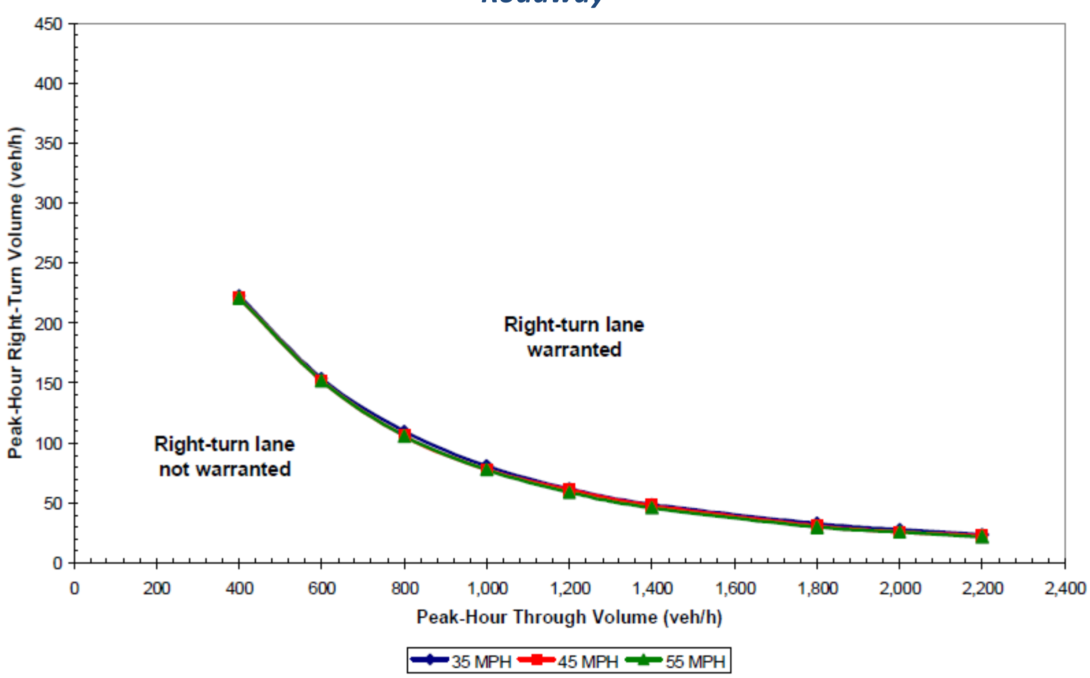
Figure 12-4: Right-Turn Lane Warrant Curves for 4-Leg Unsignalized Intersection on 2-Lane Roadway*



Source: *NCHRP Project 3-72: Lane Widths, Channelized Right-Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas, Final Report*, August 2006, Figure 18, page 107.

*This could be a 4-leg intersection of two roadways, or a 4-leg intersection formed by two driveways aligned on opposite sides of a roadway.

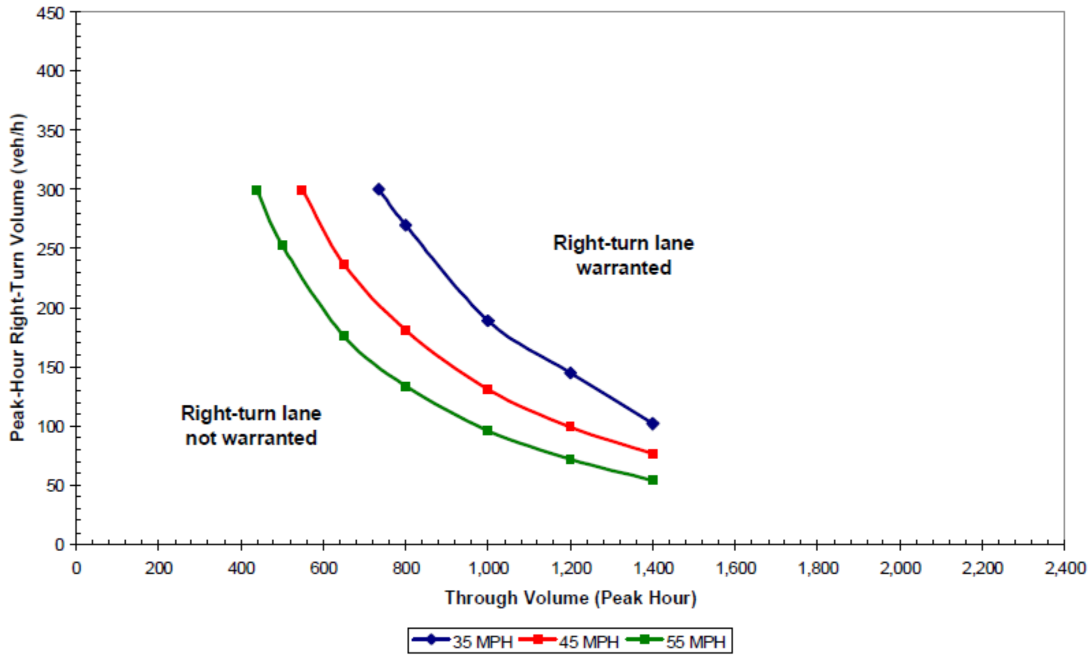
Figure 12-5: Right-Turn Lane Warrant Curves for 4-Leg Unsignalized Intersection on 4-Lane Roadway*



Source: *NCHRP Project 3-72: Lane Widths, Channelized Right-Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas, Final Report*, August 2006, Figure 19, page 107.

*This could be a 4-leg intersection of two roadways, or a 4-leg intersection formed by two driveways aligned on opposite sides of a roadway.

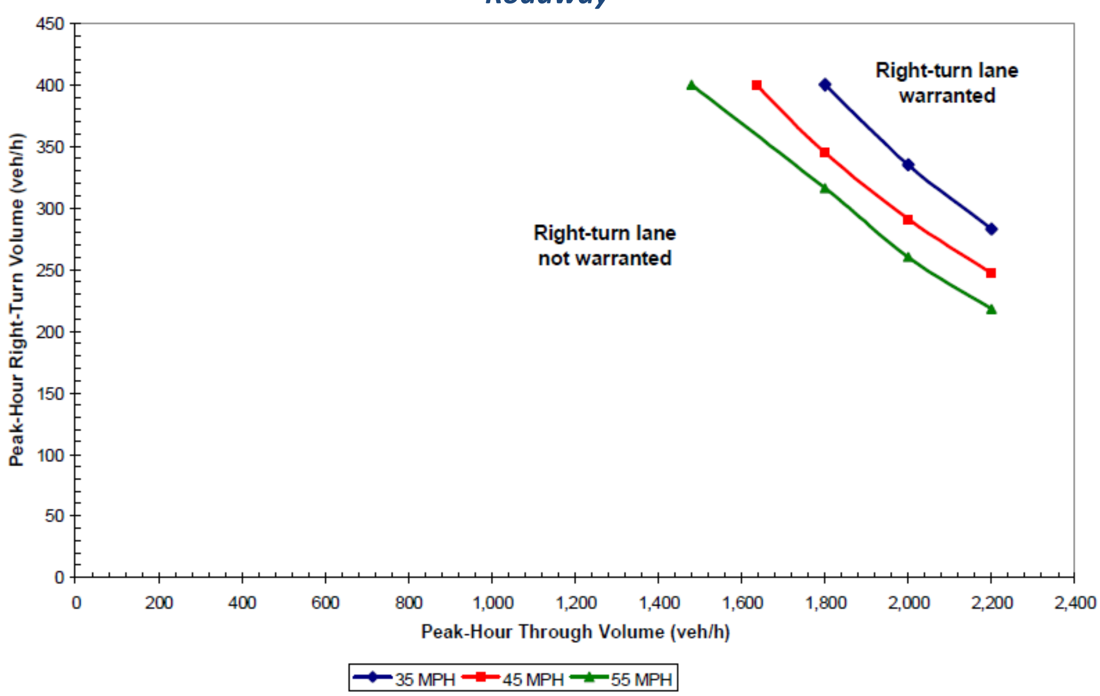
Figure 12-6: Right-Turn Lane Warrant Curves for 3-Leg Unsignalized Intersection on 2-Lane Roadway*



Source: *NCHRP Project 3-72: Lane Widths, Channelized Right-Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas, Final Report*, August 2006, Figure 20, page 108.

*This could be a 3-leg intersection of two roadways, or a 3-leg intersection formed by a driveway intersecting a roadway.

Figure 12-7: Right-Turn Lane Warrant Curves for 3-Leg Unsignalized Intersection on 4-Lane Roadway*



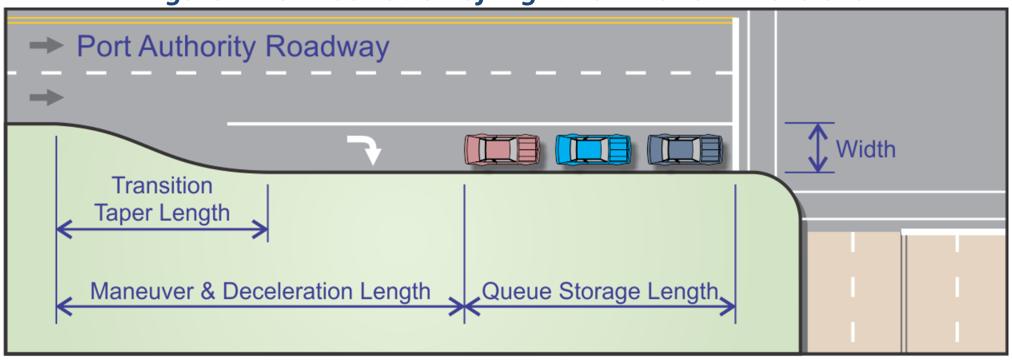
Source: *NCHRP Project 3-72: Lane Widths, Channelized Right-Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas, Final Report*, August 2006, Figure 21, page 108.

*This could be a 3-leg intersection of two roadways, or a 3-leg intersection formed by a driveway intersecting a roadway.

12.3.2 Right-Turn Lane Design Guidelines

Once a decision to install a right-turn lane has been made, a variety of other decisions should be made relative to the design of the right-turn lane, including its width, queue storage length, and taper. The following design guidance applies to right-turn lanes on all Port Authority roadways (see *Figure 12-8* for an illustration of the right-turn lane dimensions):

Figure 12-8: Illustration of Right-Turn Lane Dimensions



- The desirable width of a right-turn lane should be 12 feet.
- The total length of the right-turn lane should be designed to include: 1) the transition taper length, 2) vehicle maneuver and deceleration length, and 3) vehicle queue storage length. These distances shall be determined as follows, based on the illustration in *Figure 12-8*:
  - The length of the transition taper for right-turn lanes should be based on the approach speed and width of the right-turn lane in accordance with the design guidance in AASHTO's *A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011* (pp. 9-127 to 9-130), or superseding edition. As per AASHTO, a taper rate of 8:1 should be used for design speeds up to 30 mph and a taper rate of 15:1 for design speeds exceeding 30 mph.
  - The desirable maneuver and deceleration length distances are given in *Table 12-1*. The desirable maneuver and deceleration length is based on the posted speed and ranges from 90 feet (at a posted speed of 20 mph) to 425 feet (at a posted speed of 50 mph).

Table 12-1: Desirable Maneuver and Deceleration Length

Posted Speed (mph)[1]	Maneuver and Deceleration Length (feet)
20	90
25	110
30	160
35	215
40	275
45	345
50	425

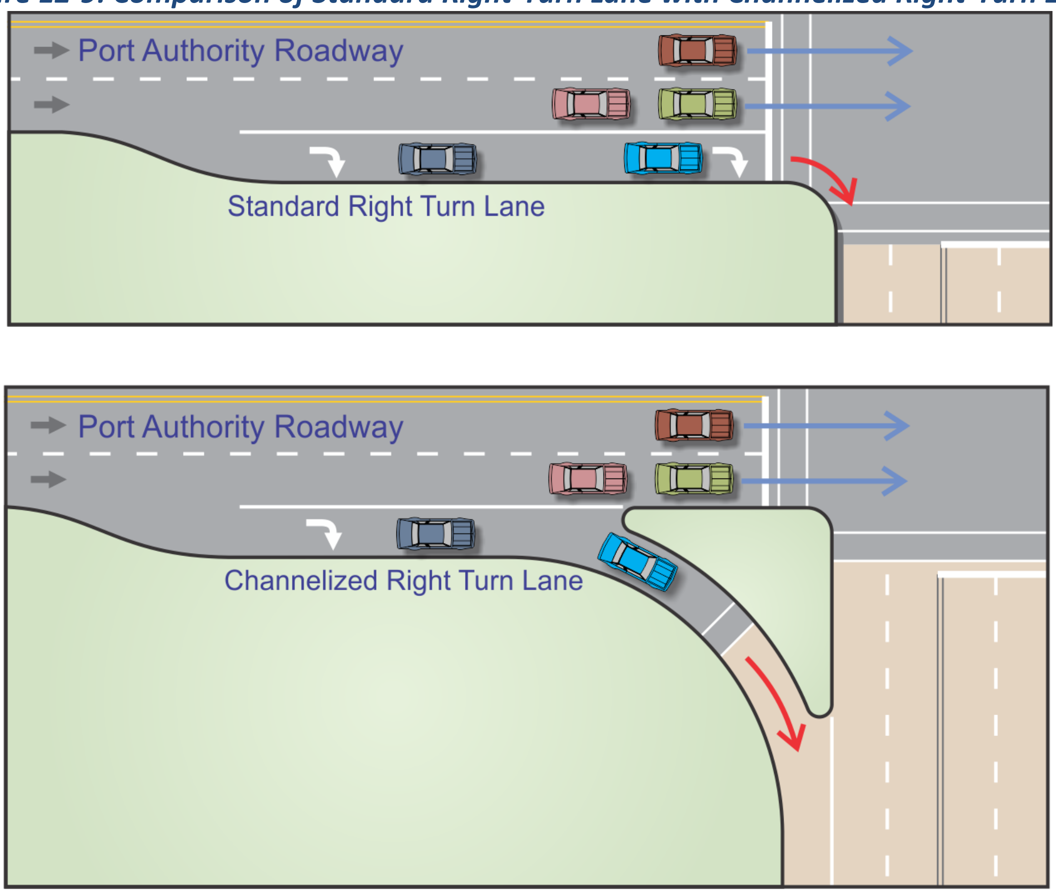
Source: Adapted from Stover, V.G. and F.J. Koepke, *Transportation and Land Development, 2nd Edition*, 2002, Table 5-13, page 5-43.

1: The 85th percentile speed may be used in place of the posted speed if an engineering study that supports the use of the 85th percentile speed over the posted speed is completed and approved by Port Authority Traffic Engineering.

  - The desirable queue storage length should equal the 95th percentile queue length[43]. The queue storage length should be adjusted to account for the lengths of the various vehicles in the traffic stream (i.e., passenger cars, single-unit trucks, tractor-trailers, etc.).

- A channelization island, as shown in *Figure 12-9*, may be used to accommodate free-flow right-turns. A channelized right-turn lane accommodates higher turning speeds, reduces vehicular delays, and adds greater capacity to the intersection than a standard right-turn lane. It should be noted that although a channelization island provides a refuge for pedestrians, the free-flowing right-turning vehicles conflict with pedestrians crossing the right-turn lane. Also, as shown in *Figure 12-9*, the channelized right-turn lane needs more physical space than a standard right-turn lane. The trade-offs should be considered when deciding whether or not to install a channelized right-turn lane. In general, a standard right-turn lane may be preferable in developed areas.

Figure 12-9: Comparison of Standard Right-Turn Lane with Channelized Right-Turn Lane



[43] Most traffic engineering software packages (e.g., HCS, SYNCHRO) calculate 95th percentile queue lengths as one of their output parameters.

CHAPTER 13: PROPERTY ACCESS STRATEGIES

13.1 Overview

In addition to the specific guidelines for access location and design described in the preceding chapters of these *Guidelines*, the design team should consider various strategies to provide for sufficient property access. These strategies include providing access through use of the following:

- secondary roadways[44]
- shared driveways and cross-access between leaseholds
- frontage roads

Each of these strategies is addressed in this chapter and should be considered before seeking a driveway on the primary roadway (*Chapter 5* and *Chapter 6*) or a design exception (*Chapter 14*). The intent of each strategy is to provide *reasonable access* for a particular property, or properties, such that the resulting access configuration conforms to the access management guidelines described in this document. For purposes of these *Guidelines*, *reasonable access* for the strategies above is defined as having the following characteristics:

1) The access is provided via a *parallel or perpendicular roadway*, *easement*, *shared driveway*, or *frontage road*.

2) The access is *designed and located to sufficiently support the volume and type of traffic* to and from the business or use. This means:

   a. Roadways, intersections, and driveways along the route accommodate the size and types of vehicles expected, as well as the anticipated volume of traffic.

   b. Pavement strength along the route is sufficient to accommodate the weight and volume of the anticipated traffic.

3) The access is *convenient*, as indicated by the access fitting with the site layout, aligning properly with the site's traffic circulation aisles, and properly serving the site's internal uses (e.g., parking lots, loading areas, security booths, etc.).

4) The access route is reasonably *direct*, as indicated by the route being relatively straight with a limited number of route choices along the path for the driver.

5) The access route provides a *well-marked* means for reaching the site and returning to the surrounding roadway network. This means signs are provided at key decision points along the route to direct motorists between the roadway and the site.

6) The access provisions for pedestrians and bicyclists involve *logical and direct* paths that are well connected with the street system.

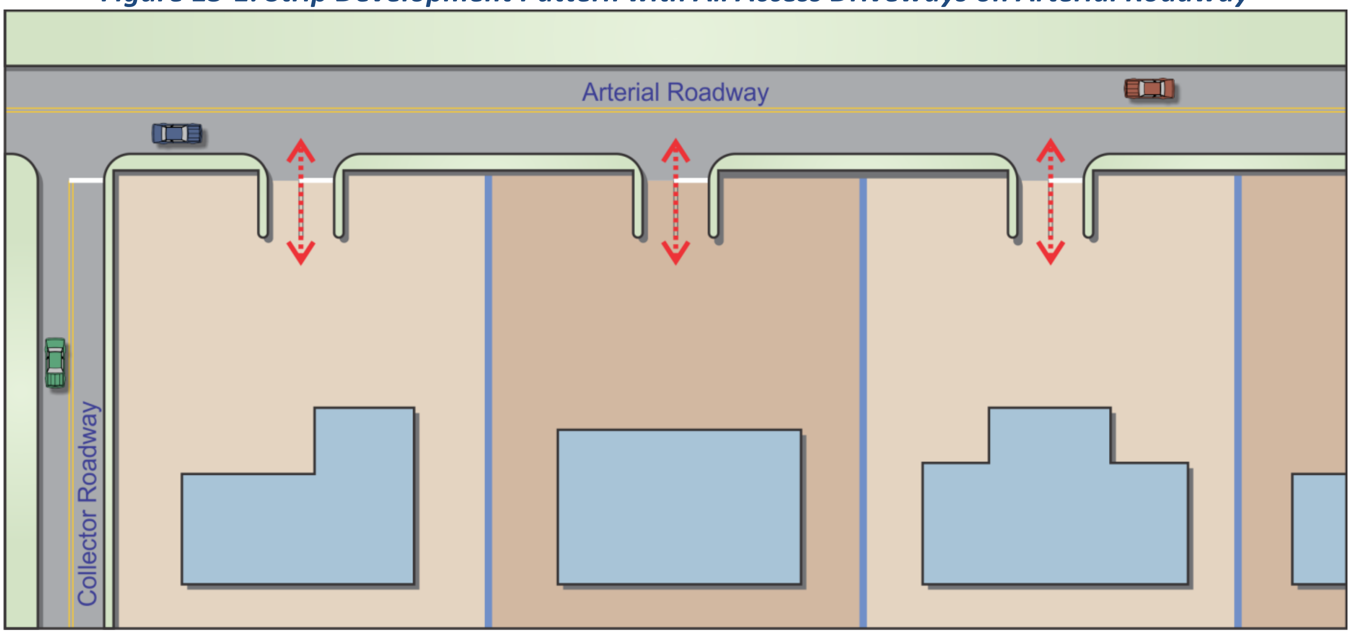
[44] As defined here, a "secondary roadway" is one that has a lower access classification than the intersecting primary roadway (see *Chapter 3*, Table 3-1).

Implementing the strategies cited above may involve several separate but coordinated actions. Further, these strategies may have implications on access to and from adjacent properties and on traffic circulation patterns on the surrounding roadway network.

13.2 Access via Lower Classification Roadways

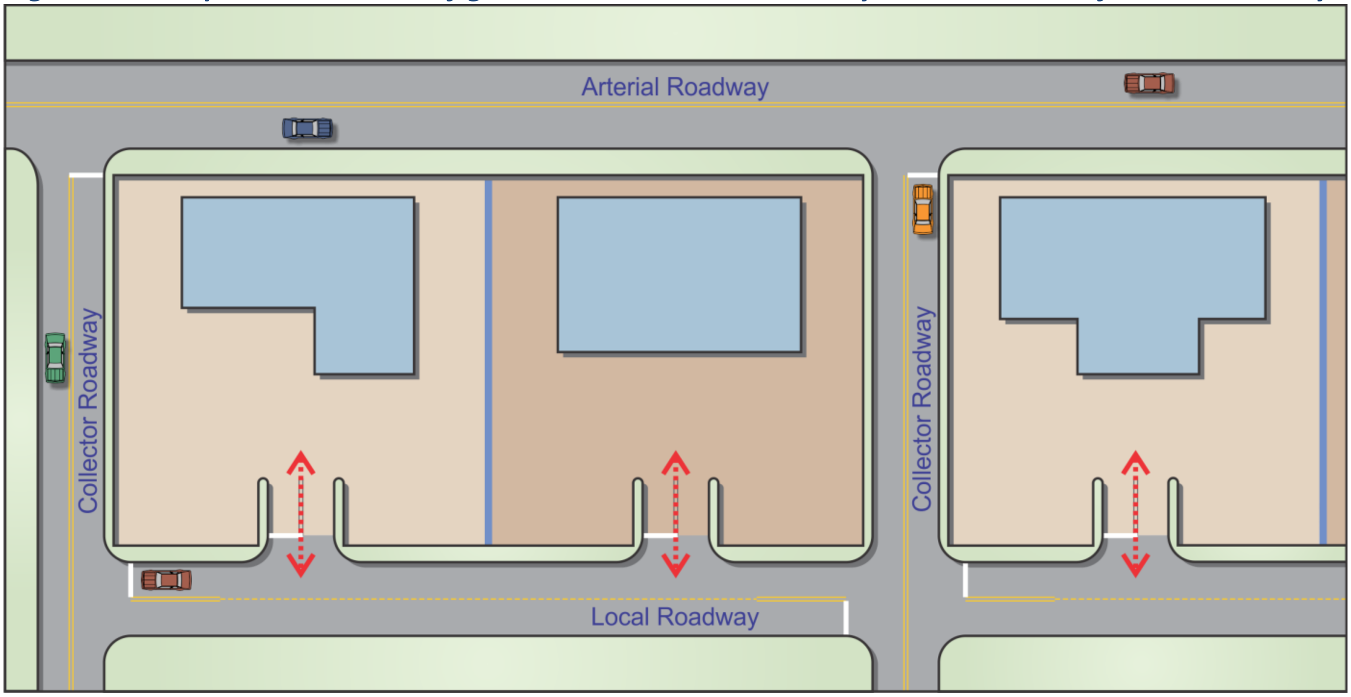
Historically (i.e., from the 1950s through the 1990s), development has often been focused in "strips" along arterials and other higher classification roadways. These strip development patterns result in driveways being located exclusively along the arterial (see *Figure 13-1*). As a result, the arterial is used as the sole access roadway for abutting properties, and access opportunities provided by the local and collector street networks are not used. Under these circumstances, the short spacing between driveways along the arterial leads to a greater number of conflict points, increasing the potential for crashes, decreasing the operating speeds for motor vehicle traffic, and adding to the level of congestion along the arterial. The resulting conflicts between higher-speed traffic and turning vehicles, bicycles, and pedestrians can lead to crashes.

Figure 13-1: Strip Development Pattern with All Access Driveways on Arterial Roadway



This pattern can be changed by promoting the development of a connected network of intersecting and parallel roads that can accommodate access for abutting properties (see *Figure 13-2*). Such an arrangement improves the connectivity of the built environment and transfers some travel demand from arterial roadways to local and collector roadways that are, by definition, better suited to accommodate access. This arrangement also provides for improved connectivity for pedestrians and bicyclists, encouraging the use of those modes for short-distance trips. Local and collectors roads can also be designed to connect to other existing, proposed, and planned roadways in the area. Note that, as shown in *Figures 13-1* and *13-2*, the change in driveway locations may involve changing the layout of the buildings on individual sites, though this is typically not a significant concern where redevelopment is occurring or in newly-developed areas.

Figure 13-2: Improved Access Configuration with Access Driveways on Lower Classification Roadways

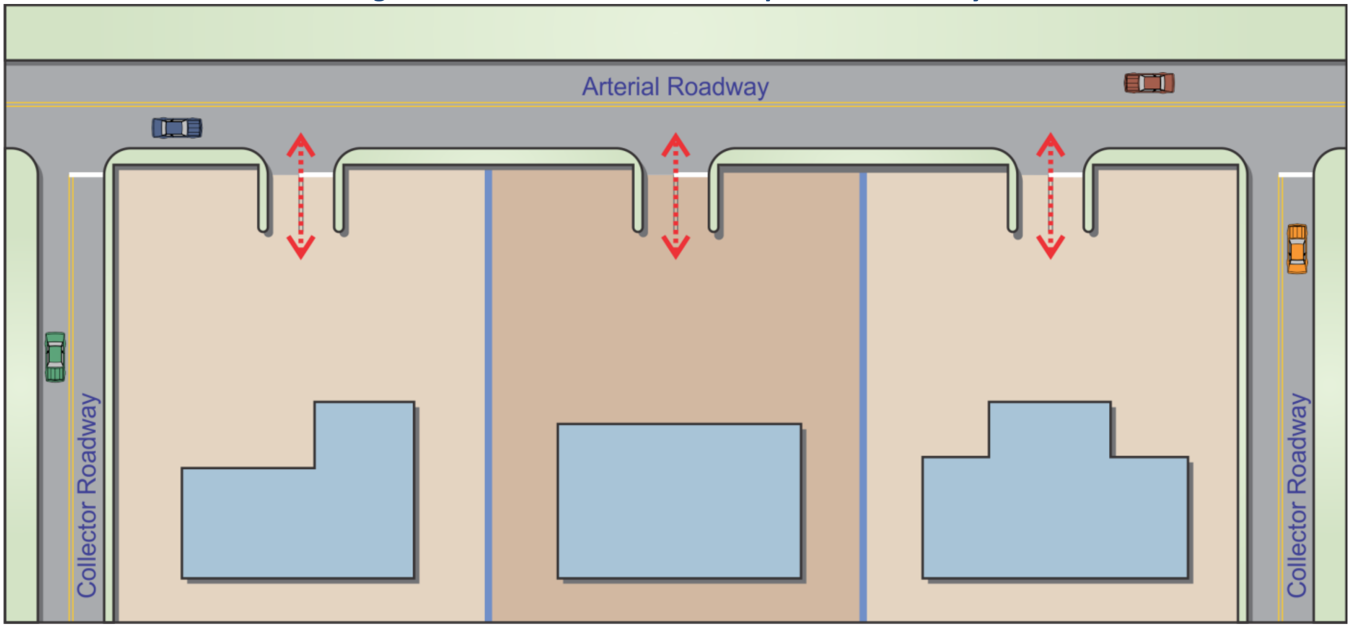


13.3 Shared Access Driveways and Cross-Access between Leaseholds

Effective access management master planning promotes the implementation of shared-access driveways and cross-access easements between (compatible) tenant leaseholds, where possible, which allow pedestrians and vehicles to circulate between leaseholds without reentering the abutting roadway. Where security requirements allow, adjacent tenants located along higher classification roadways (e.g., arterials and collectors) should be encouraged to share access. The sharing of access driveways improves roadway safety and operations by reducing the number of conflict points and separating conflict points along these roadways. The longer spacing between access driveways also facilitates the provision of left-turn and right-turn lanes. In addition, smoother traffic flow on the abutting street helps to reduce the propensity for vehicular crashes and increase egress capacity. Furthermore, cross-access connections between adjacent developments can improve convenience by facilitating vehicle and pedestrian circulation between leaseholds. This helps reduce demand on the higher classification roadways by eliminating the need for vehicles to circulate on those roadways when moving from one leasehold to another.

Figure 13-3 shows an undesirable condition whereby three leaseholds each have an access driveway to the arterial roadway. This configuration leads to closely-spaced driveways along the arterial, in addition to the local street intersections.

Figure 13-3: Leaseholds with Separate Driveways



In contrast, *Figure 13-4* shows the same three leaseholds under an improved access configuration whereby shared access driveways serve adjacent leaseholds, resulting in a reduction in the number of access driveways (and associated conflict points) along the arterial roadway.

Figure 13-4: Improved Access Configuration with Shared Driveway Access

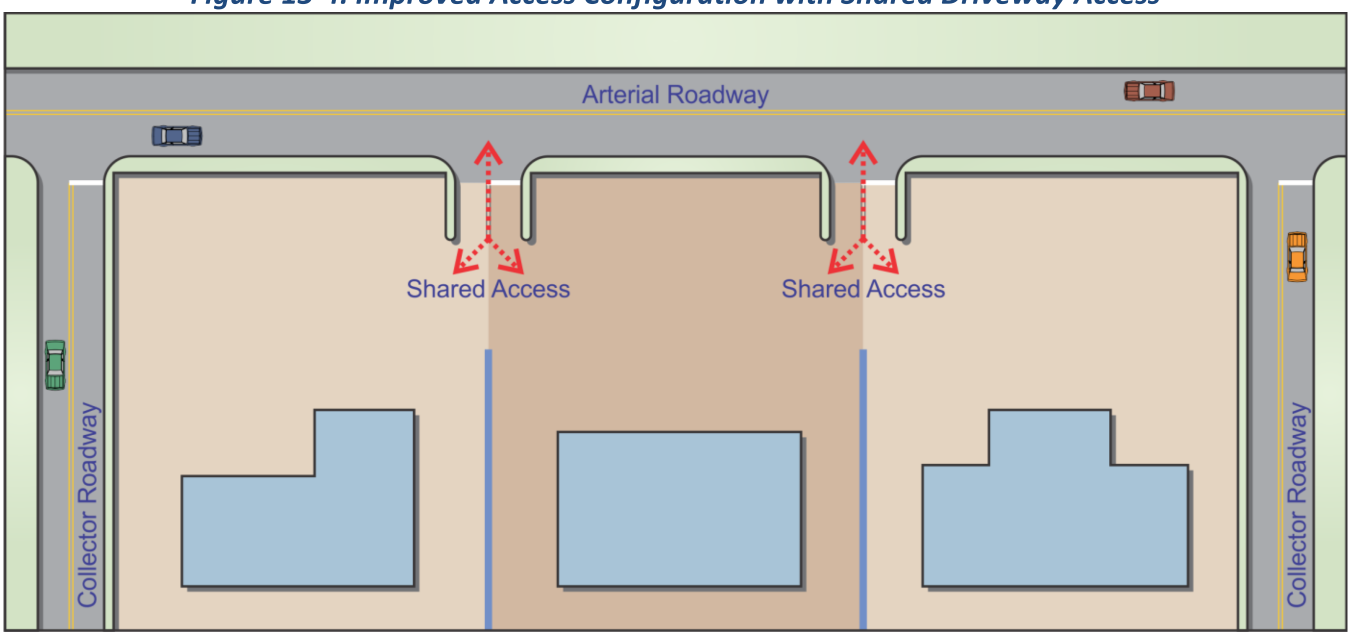
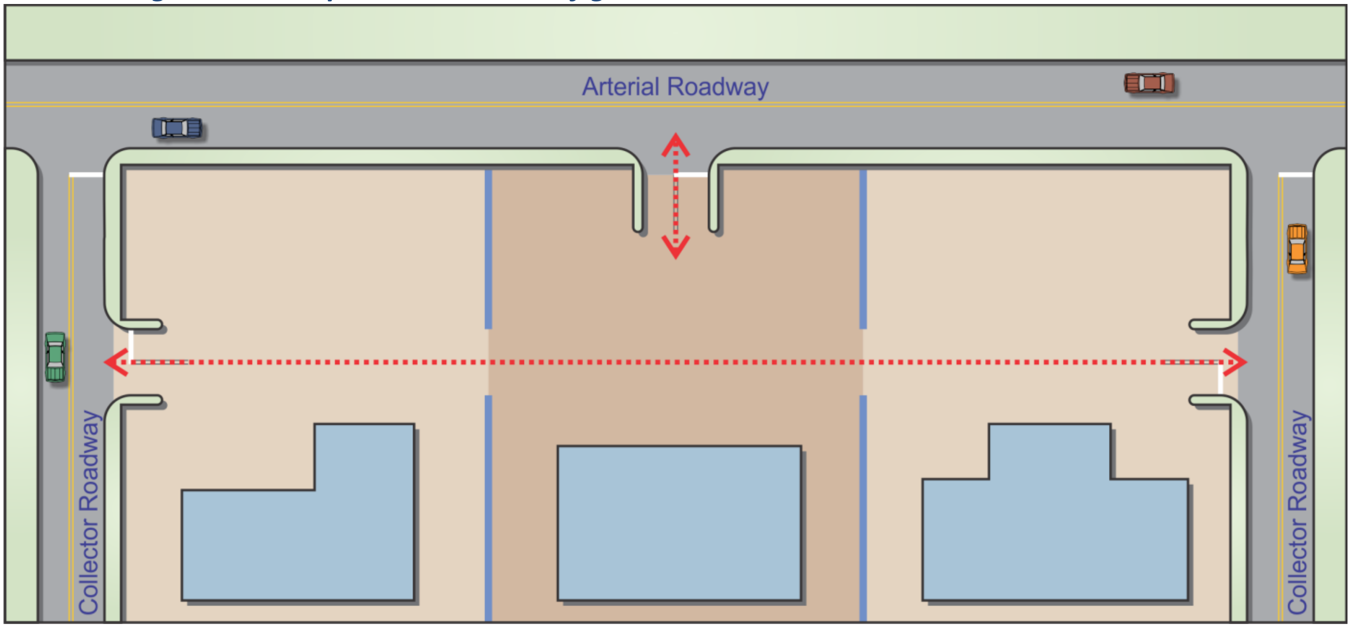


Figure 13-5 shows the same three leaseholds under another improved access configuration: one driveway is provided on the arterial roadway, located to maximize access spacing, and direct access is provided via the two intersecting local streets. Cross-access easements would be established between leaseholds to allow travel among the three leaseholds and the two intersecting local streets without the need to use the arterial.

Figure 13-5: Improved Access Configuration with Cross-Access between Leaseholds

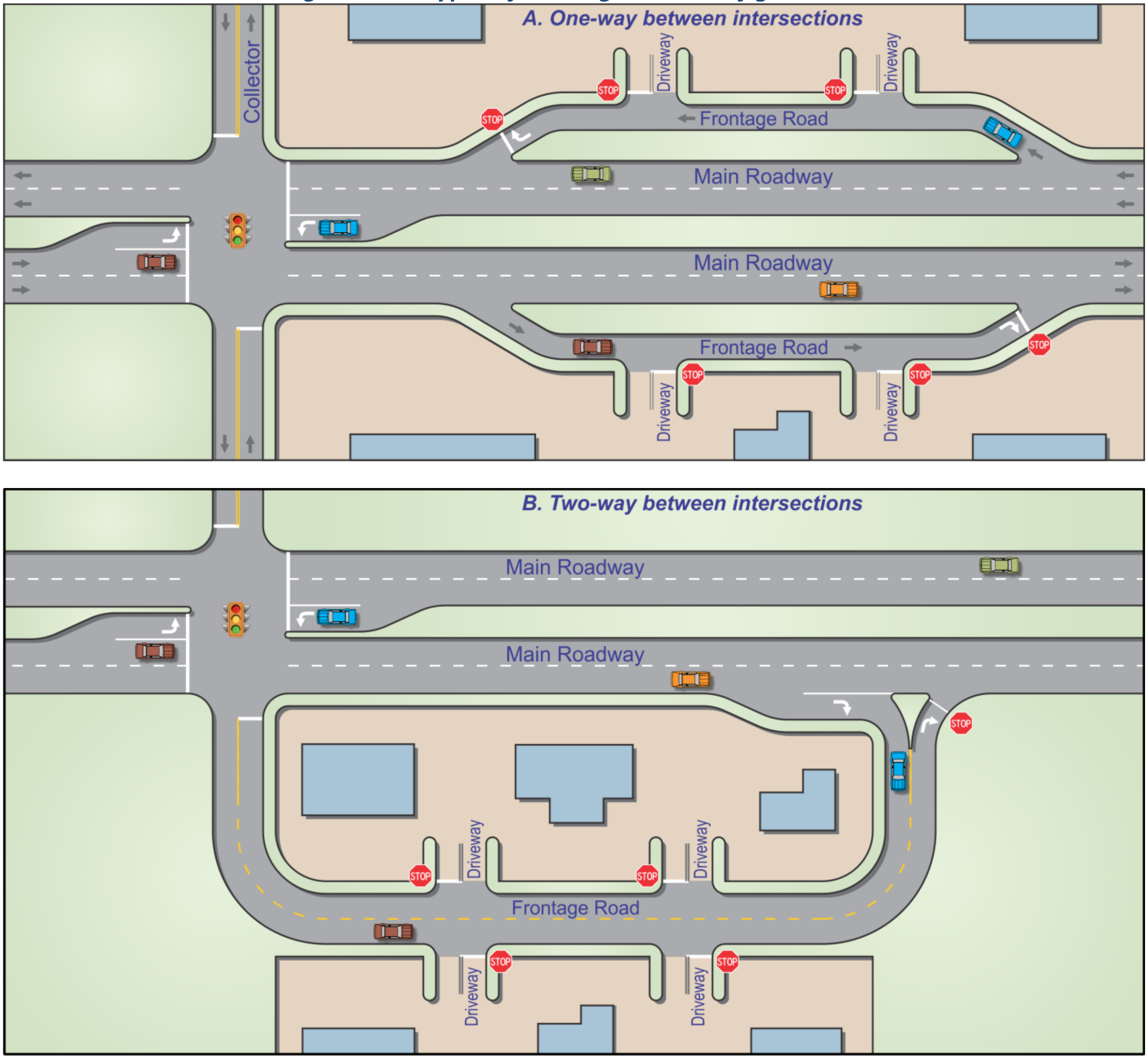


Cross-access (also known as inter-parcel connections) and/or shared access configurations — such as those illustrated in *Figures 13-4* and *13-5* — should be considered in redeveloping areas and newly developed areas. Having a unified transportation master plan and/or sub-area plans for the area, which are then implemented when development or redevelopment opportunities arise, help achieve access management objectives. See *Section 2.4.3* for a discussion of transportation master plans and *Section 2.4.4* for a discussion of sub-area plans.

13.4 Frontage Roads

A frontage road is an access roadway that is generally aligned parallel to a main roadway and is located between the right-of-way of the main roadway and the front building setback line. Frontage roads are used as an access management technique to provide direct access to properties and segregate through traffic from local access-related traffic. This protects the through traffic lanes from conflicts and delays, as well as reducing the frequency and severity of conflicts along the main roadway. In addition, the resulting increase in spacing between intersections along the main roadway facilitates the design of auxiliary lanes for deceleration and acceleration, further improving traffic safety and operations. *Figure 13-6* illustrates two types of frontage road configurations.

Figure 13-6: Types of Frontage Road Configurations

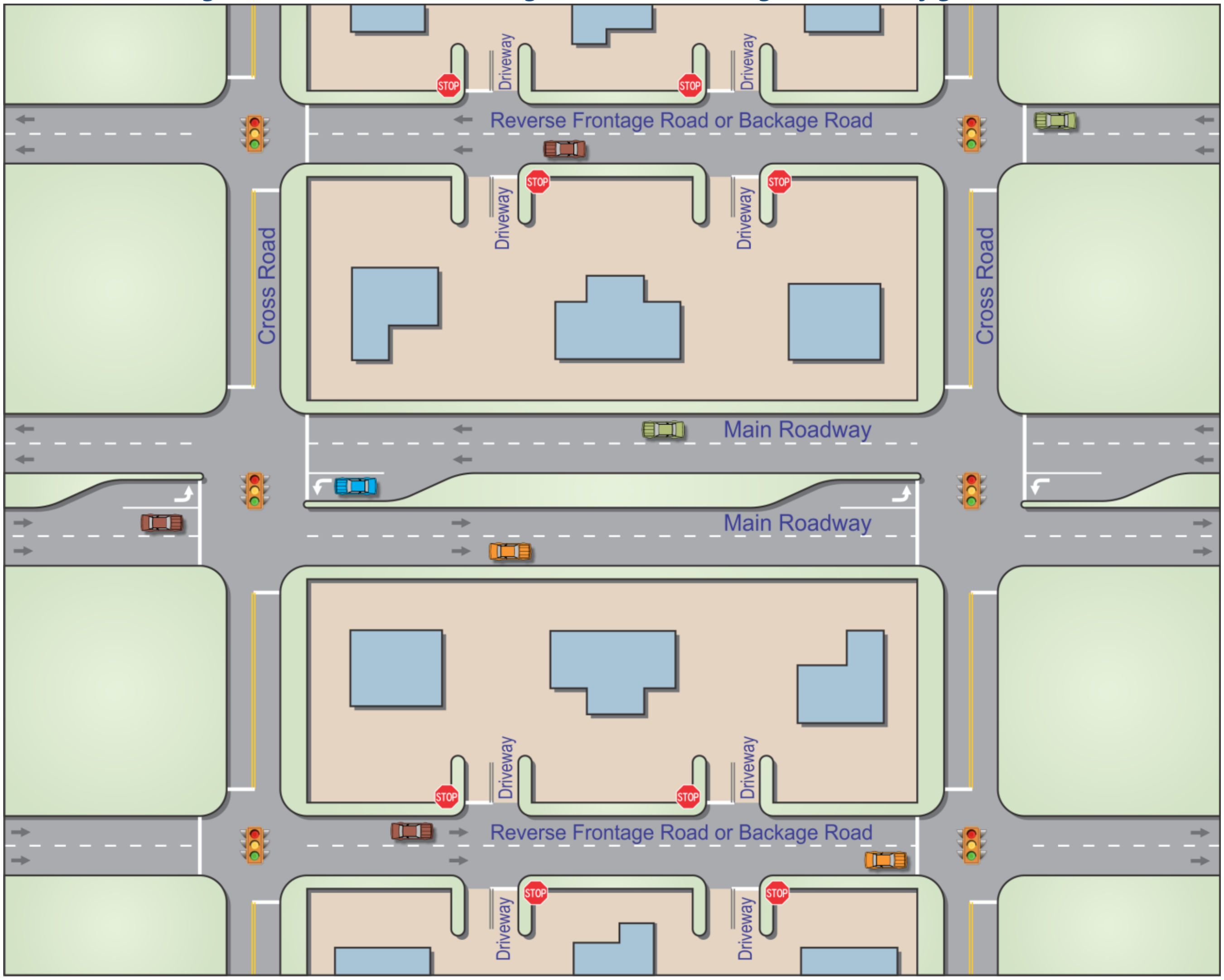


Frontage roads should be designed carefully to avoid escalating conflicts at their junctions with the main roadway and increasing delays on the intersecting roads. The following guidelines should be considered when installing frontage roads:

- Especially under retrofit situations, frontage roads should operate in one direction and should enter or leave the mainline lanes as merging or diverging movements (see *Figure 13-6A*).
- On-street parking and pedestrian and bicycle movements to and from the area served by the frontage road should be accommodated along the frontage road, rather than along the main roadway.

An alternate frontage road configuration – sometimes referred to as a "reverse frontage road" or a "backage road"– is illustrated in *Figure 13-7*. In this configuration, the one-way "frontage" roads are constructed *behind* the properties that front the main roadway. Direct property access can be provided to abutting properties along both sides of the reverse frontage road, eliminating driveways along the main roadway entirely.

Figure 13-7: "Reverse Frontage Road" or "Backage Road" Configuration



As shown in *Figure 13-7*, connections between the main roadway and the reverse frontage roads occur via intersecting cross roads. The distance along the cross road between the intersection with the reverse frontage road and the intersection with the main roadway – the separation distance – should be established to provide sufficient vehicle queue storage for cross road traffic between the reverse frontage roads and the main roadway. The following desirable guidelines apply under these circumstances:

- The desirable separation distance is 300 feet. This dimension provides queue storage space for vehicles on the approaches to the reverse frontage roads and enables turning movements to be made from the main roadway onto the cross roads without disrupting traffic flow on the main roadway. Even greater distances may be needed to provide sufficient left-turn storage on the cross road and to separate operations between an intersection on the main roadway and an adjacent intersection on the reverse frontage road.

CHAPTER 14: DESIGN EXCEPTIONS

14.1 Overview

The access management guidelines described in this document are intended to promote safe and efficient access and mobility along roadways at Port Authority facilities. The Port Authority strives to maintain the desirable balance between mobility on Port Authority roadways and access to those roadways, with sensitivity to the needs of the agency's tenants. These goals are consistent with the agency's policy objectives as well as other factors such as environmental constraints and the objectives of neighboring agencies. Tenants should work with Port Authority Engineering to identify access solutions that meet the guidelines described in this document to provide reasonable access. However, where the guidelines cannot be met and a degree of greater flexibility is needed, a "design exception" ─ a deviation from the access management guidelines authorized by the Port Authority ─ may be requested.

Design exceptions provide the Port Authority with the flexibility necessary to create reasonable solutions in unique situations, when there are special considerations such as conflicts between competing policy goals and environmental constraints. The ultimate goal is to reach a solution that the Port Authority can approve for the specific location and that all involved parties can "live with."

For these reasons, establishing a fair, consistent, and systematic process to address design exceptions is a key element of the Port Authority's approach to access management. This chapter presents the design exception procedure established for the Port Authority and the general criteria for the approval of design exceptions. Two examples illustrating the application of the design exception process and criteria are also provided.

14.2 General Design Exception Approval Criteria

When conditions warrant, a design exception may be granted by the Port Authority. A design exception may be approved by the Port Authority when it can be documented that a lesser design value is the best practical alternative. Given the added time and associated costs involved when pursuing an access management design exception, tenants should explore all possible alternatives prior to pursuing a design exception and work with Port Authority Engineering to understand the general circumstances under which a design exception would be approved. Port Authority Engineering will only approve a design exception when all reasonable alternatives[45] that meet the access management guidelines have been evaluated and determined to be infeasible, and the design exception would not result in a condition that would jeopardize the safety of the public or have a significant adverse impact on traffic operations or safety.

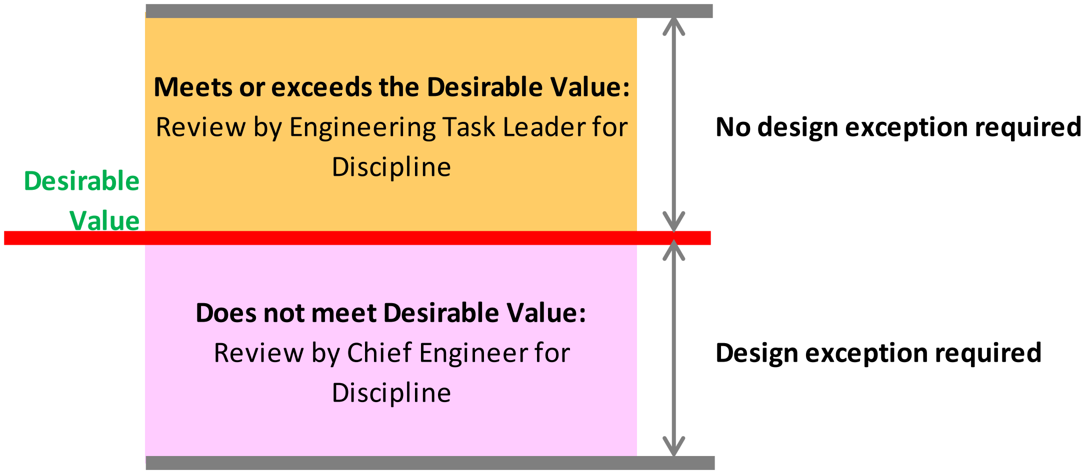
14.3 Design Exception Procedure

A request to the Chief Engineer for the relevant discipline shall be submitted. The reason for the design exception should be clearly stated and all supporting and necessary documentation to substantiate the design exception should be included.

Figure 14-1 is a conceptual illustration of when a design exception is needed at the Port Authority.

[45] Including redrawing the leasehold boundaries.

Figure 14-1: Conceptual Illustration of When an Access Management Design Exception is Needed



The design exception procedure at the Port Authority is as follows:

- If the desirable value stated in the guidelines is met or exceeded, a review by the Port Authority Engineering task leader for the relevant discipline is needed, but no design exception is needed.
- If the desirable value cannot be met, an access management design exception is needed for the associated value as stated in the guidelines. Access management design exceptions are reviewed by the Port Authority Chief Engineer for the relevant discipline. In most instances, the relevant lead discipline is Port Authority Traffic Engineering, but the discipline may be Port Authority Civil Engineering, Electrical Engineering, or other disciplines, based on the nature of the design exception needed. (See *Table 2-1* for the proper Port Authority point-of-contact within the Engineering Department.)

14.4 Examples

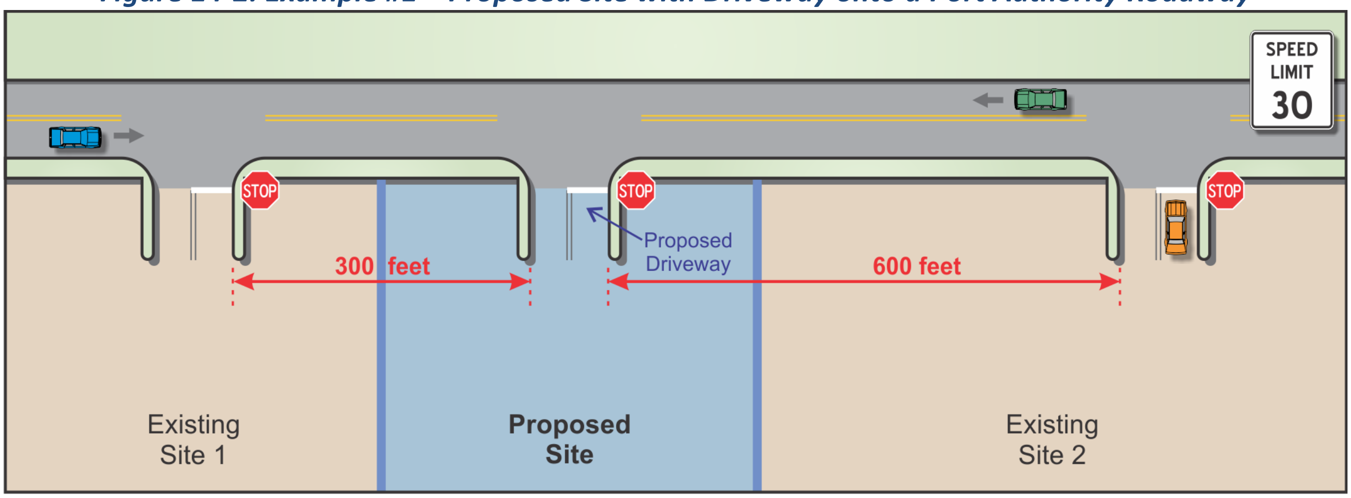
The following two examples illustrate the application of the design exception procedures to specific access management guidelines described in this document.

14.4.1 Example #1: Unsignalized Driveway Spacing

Given: An undivided Port Authority roadway with a collector access classification and a posted speed of 30 mph. A stop-controlled driveway is proposed to be located between two existing stop-controlled driveways, as shown in *Figure 14-2*.

Problem: Determine if the proposed driveway location meets the unsignalized driveway spacing guidelines given in *Chapter 5*.

Figure 14-2: Example #1 – Proposed Site with Driveway onto a Port Authority Roadway



Solution:

- Use *Table 5-1* to identify the desirable driveway spacing distance as shown below.

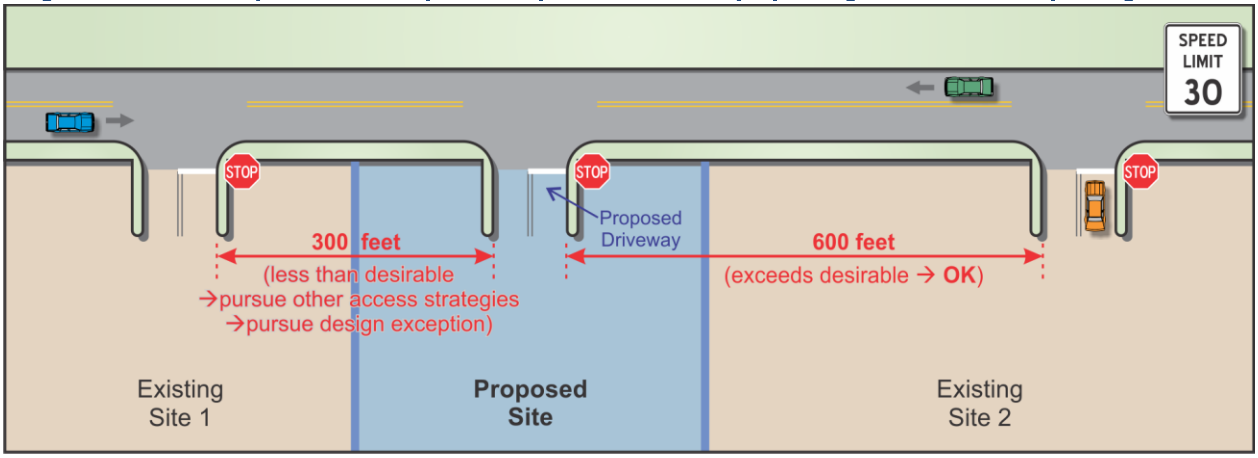
Posted Speed (mph)	Desirable Driveway Spacing	
	Undivided Roadways (feet)	Divided Roadways (feet)
20	260	245
25	370	340
30	**500**	450
35	640	570

As shown in *Table 5-1*:

Desirable driveway spacing distance = 500 feet

- Compare the desirable spacing distance to the distances between the proposed driveway and the two existing driveways from the site plan (see *Figure 14-3*).

Figure 14-3: Example #1 – Compare Proposed Driveway Spacing to Desirable Spacing



The distance between the proposed driveway and the existing driveway for Site 2 (600 feet) exceeds the desirable spacing guideline (500 feet); therefore, according to *Figure 14-1*, no design exception is needed for the proposed spacing to Site 2.

The distance between the proposed driveway and the existing driveway for Site 1 (300 feet) does not exceed the desirable spacing guideline (500 feet). Therefore, further analysis is needed, relative to the spacing between the proposed driveway and the existing driveway for Site 1. Applicable questions to ask at this point include the following:

1) Would any of the property access strategies presented in Chapter 13 be applicable to the subject site?

2) Would a design exception be needed for the proposed access driveway?

- Consideration of property access strategies in *Chapter 13* would involve "zooming out" from the initial area shown in *Figure 14-3* to consider other ways of providing access to the proposed site. Because this is an example problem to illustrate the design exception process, the strategies in *Chapter 13* will not be provided here.
- Because the spacing between the proposed driveway and the existing driveway at Site 1 (300 feet) is less than the desirable spacing (500 feet), a design exception is needed (refer to *Figure 14-1*) if no other access solution can be identified. Approval from the Port Authority Chief Traffic Engineer is needed. As part of the Chief's review, it is expected that he/she will ask to review the investigations of the property access strategies described in *Chapter 13* (that were not provided in this solution).

14.4.2 Example #2: Access in the Vicinity of Interchanges

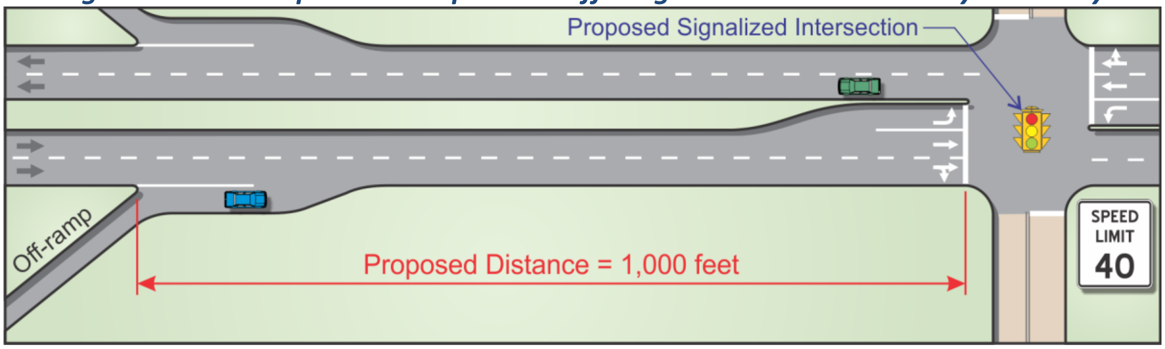
Given:

- A new traffic signal is proposed on a four-lane divided Port Authority roadway with a posted speed of 40 mph (see *Figure 14-4*).
- The new traffic signal is proposed to be located 1,000 feet downstream of an existing interchange off-ramp.

- No other traffic signals are located along the roadway.

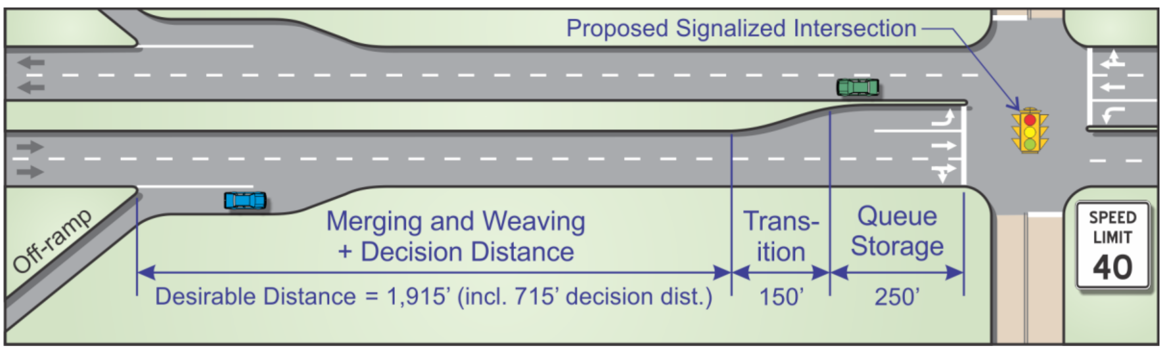
Problem: Determine if the proposed intersection meets the guidelines for access in the vicinity of interchanges given in *Chapter 8*.

Figure 14-4: Example #2 – Proposed Traffic Signal on a Port Authority Roadway



Solution:

- Calculate the desirable spacing distance (see procedures in *Chapter 8* for access in the vicinity of interchanges).



Desirable spacing distance = 2,315 feet

- Compare the proposed spacing (1,000 feet) to the desirable spacing distance (2,315 feet).
- Because the spacing between the proposed traffic signal and the interchange off-ramp (1,000 feet) is less than the desirable spacing (2,315 feet), a design exception from Port Authority Traffic Engineering would be needed. The design exception would need approval from the Port Authority Chief Traffic Engineer (refer to *Figure 14-1*).

REFERENCES

The following documents, with the specific editions noted below, were consulted in the preparation of these *Guidelines*:

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- *Access Management Manual, Second Edition*, Transportation Research Board, National Research Council, Washington D.C., 2014.
- *Active Design Guidelines: Promoting Physical Activity and Health in Design*, City of New York, 2010.
- *Port Authority Airport Roadway Sign Design Manual*, Port Authority of NY&NJ, January, 2013.
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- Mason, J. M. Jr. (Senior Editor), *Urban Street Geometric Design Handbook*, Institute of Transportation Engineers, 2008.
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- *Port Authority Environmental Sustainability Policy*, The Port Authority of NY & NJ, March 27, 2008.
- [Port Authority] *Intersection Signalization Procedures*, The Port Authority of NY & NJ, Traffic Engineering, December 2012.
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- Potts, I., et. al., *NCHRP Project 3-72: Lane Widths, Channelized Right-Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas – Final Report*, National Cooperative Highway Research Program, Transportation Research Board, National Research Council, August 2006.
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GLOSSARY

The following words and phrases, when used in these *Guidelines*, have the following meanings:

- **85th Percentile Queue Length:** The distance that would not be exceeded by a queue of vehicles 85 percent of the time during the analysis period.
- **95th Percentile Queue Length:** The distance that would not be exceeded by a queue of vehicles 95 percent of the time during the analysis period.
- **Access Classification System (ACS):** A hierarchy of access categories that forms the basis for the application of access management to all roadways. Each access category sets forth criteria governing the access-related standards and characteristics for corresponding roadways. These access categories ultimately define where access can be allowed between the roadway system and abutting properties, and where it should be denied or discouraged.
- **Access Management:** The coordinated planning, regulation, and design of access between roadways and land development. It involves the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway, as well as roadway design applications that affect access, such as median treatments and auxiliary lanes, and the appropriate separation of traffic signals.
- **Access Window:** The distance along the lateral length of a roadway – located outside the functional area of adjacent intersections – where a driveway may be located. The access window is identified by determining the upstream and downstream corner clearance distances at the adjacent intersections. The longer the access window, the more flexibility exists with respect to locating the driveway along the roadway.
- **Arterial:** An interrupted-flow roadway primarily used for the movement of through traffic. Access to abutting land uses is subordinate to through traffic movement. Arterials are distinct from Principal Arterials, which serve a high percentage of trucks.
- **Auxiliary Lane:** An exclusive right-turn or left-turn lane.
- **Backage Road:** An interrupted-flow roadway constructed at the rear of properties that front a major roadway for purposes of providing access to those properties. Also known as a **Reverse Frontage Road**.
- **Bandwidth:** The amount of time available, in seconds, for vehicles to travel through a series of traffic signals along a corridor at a specific progression speed. Bandwidth is a quantitative measurement of the through-traffic capacity of a signal progression system: the greater the bandwidth, the higher the capacity for progressing through-traffic along the corridor. The length of the bandwidth is the time elapsed between the passing of the first vehicle and the last vehicle that moves without impedance through a traffic signal system at the progression speed. Bandwidth may also be expressed as a percentage of the cycle length. For example, a 40-second green band along a corridor operating at cycle lengths of 80 seconds can be expressed as a "bandwidth of 50 percent."
- **Clear Zone:** The total roadside border area, starting at the edge of the traveled way, available for use by errant vehicles. This area may consist of a shoulder, a recoverable slope, and/or a clear run-out area. The desired width is dependent upon traffic volumes, speeds, and roadside geometry.
- **Collector Road:** An interrupted-flow roadway that provides both land access and traffic circulation functions by collecting traffic to/from local and private roadways and channelizing it to/from arterial roadways.
- **Complete Street:** A roadway that is comfortable, convenient, and safe for travel by motorists, pedestrians, bicyclists, and transit users of all ages and abilities, as well as sensitive to the context of its surrounding land uses and environment.
- **Conflict Point:** An area where intersecting traffic merges, diverges, or crosses.

- **Corner Clearance:** The distance from an intersection to the nearest access driveway.
- **Cross Slope:** The slope (or grade) of a roadway perpendicular to the direction of travel.
- **Crosswalk:** A crosswalk may be "marked" or "unmarked." A "marked crosswalk" is defined as any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by pavement marking lines on the surface, which might be supplemented by contrasting pavement texture, style, or color. An "unmarked crosswalk" is defined as that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the center line.
- **Curb Return Radius:** A circular pavement transition at the entrance of a driveway that facilitates turning movements.
- **Design Exception:** A deviation from the access management guidelines authorized by the Port Authority.
- **Developed Area:** An urbanized area characterized by one or more of the following features: (a) dense roadside development, (b) a substantial number of existing intersecting roadways, (c) limited right-of-way available for roadway improvements, (d) existing environmental and/or topographic constraints, and/or (e) significant pedestrian or transit considerations.
- **Developing Area:** An area that is (or will be) undergoing changes related to roadside development activity. These areas are typically characterized by one or more of the following features: (a) roadside development that is planned, imminent, or already taking place, (b) a growing number of driveways and intersecting roadways, (c) increasing pedestrian activity, and/or (d) a need to consider transit.
- **Divided Roadway:** A roadway on which traffic traveling in opposite directions is physically separated by a non-traversable (i.e., raised) median.
- **Driveway:** Any at-grade connection that provides access between a Port Authority roadway and activities or buildings on abutting properties or leaseholds.
- **Easement:** A right-of-way granted by the Port Authority to a tenant, utility company, or other party for specific and limited use of land. Within the easement area, specific tenant uses of the land may be limited or prohibited.
- **Egress:** The act of leaving or exiting a place, or the exit for vehicular traffic from abutting properties to a roadway.
- **Engineering Judgment:** The evaluation of available pertinent information and the application of appropriate principles, provisions, and practices as contained in these *Guidelines* and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device or roadway characteristic. Engineering judgment is exercised by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer in consultation with Port Authority Engineering. This consultation should be documented.
- **Engineering Study:** The comprehensive analysis and evaluation of available pertinent information and the application of appropriate principles, provisions, and practices as contained in these *Guidelines* and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device or roadway characteristic. An engineering study is performed by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. An engineering study is documented and prepared in consultation with Port Authority Engineering at the team conceptual planning meeting or subsequent coordination meetings.
- **Freeway:** A roadway designed for uninterrupted mobility and used exclusively for the movement of through traffic, without serving any direct property access function (i.e., no driveways). Access to and

from freeways is limited to grade-separated interchanges.

- **Frontage Road:** An access roadway that generally parallels a main roadway and is located between the right-of-way of the main roadway and the front building setback line. The frontage road provides direct access to properties, segregates through-traffic from local access-related traffic (thereby protecting the through-traffic lanes from conflicts and delays), and reduces the frequency and severity of conflicts along the main roadway.
- **Functional Area (of an Intersection):** The area beyond the physical intersection of two or more roadways that comprises the decision and maneuver distance, plus any needed vehicle storage length. It is desirable that the functional area be protected by the application of corner clearance and driveway spacing guidelines.
- **Ingress:** The act of entering into a place, or the entrance for vehicular traffic into abutting properties from a roadway.
- **Intersection:** Any at-grade connection with a roadway, including the connection of two roads or the connection between a driveway and a road.
- **Local Roadway:** An interrupted-flow roadway primarily intended to provide direct access to abutting land uses and accommodate a very low level of through traffic movement. At Port Authority facilities, local roadways are generally owned, operated, and maintained by the Port Authority.
- **Loon:** An extension of the pavement adjacent to the outer travel lane of a roadway for purposes of accommodating the U-turning path of vehicles, typically trucks and other large vehicles with large turning radii.
- **Master Plan (or Transportation Master Plan):** A system-wide transportation plan for an entire Port Authority facility, prepared to accommodate projected changes in land development patterns and provide a supporting transportation system. The plan provides the framework for the consistent application of access management throughout the facility.
- **May:** Indicates a statement of practice that is a permissive condition.
- **Median:** That portion of a roadway that separates opposing traffic flows, not including two-way left-turn lanes. A median can be traversable or non-traversable.
- **Median Opening:** An opening in a non-traversable median that provides for crossing and turning traffic. A "full" median opening allows all turning movements, whereas a "partial" median opening allows only specific movements and physically prohibits all other movements.
- **Non-Traversable Median:** A physical barrier in the roadway that separates traffic traveling in opposite directions, such as a concrete barrier or curbed island. The curbed island may or may not be landscaped.
- **Open Frontage:** A property frontage that consists of a large driveway lacking a defined lane arrangement; vehicles may enter and exit the property at any point along the frontage. Open frontages do not provide positive guidance to drivers entering and leaving the property and, thus, create additional conflict points relative to a standard driveway. As such, they are undesirable and should be avoided.
- **Port Authority Redevelopment Program:** A coordinated set of capital projects that reflect a major enhancement, upgrade, and/or improvement to a specific Port Authority facility. A redevelopment program contrasts with a "state of good repair" program that involves replacement-in-kind of existing infrastructure. Examples include the "JFK 2000 Airport Redevelopment Program," the "Newark Airport Redevelopment Program" (constructed between 2000 and 2003), the "LaGuardia Terminal Building Redevelopment Program" (under planning in 2011 and 2012), the "Downtown Restoration Program" (to rebuild the World Trade Center Site after 9/11), "Newark Airport Terminal A Redevelopment Program" (under planning in 2010 – 2012), and the "Lincoln Tunnel Helix Replacement" (under planning in 2011).
- **Pathway:** A general term denoting a traveled way for pedestrians and non-motorized vehicles outside of the roadway. Pathways are physically separated from the roadway by an open space or barrier, either

within the roadway right-of-way or within an independent alignment. Pathways include shared-use paths but do not include sidewalks.

- **Positive Offset:** A lateral shift in the left-turn lane alignment to improve the ability of left-turning drivers to see oncoming traffic.
- **Principal Arterial:** An interrupted-flow roadway primarily used for the movement of through traffic. Access to abutting land uses is subordinate to through traffic movement. Principal Arterials are distinct from Arterials, which serve a lower percentage of trucks.
- **Private Road Open for Public Travel:** An interrupted-flow roadway (including any adjacent sidewalks that generally run parallel to the roadway) within the tenant leasehold boundary, but on Port Authority property, where the public is allowed to travel without access restrictions. Private roadways are primarily intended to provide direct access to abutting land uses and accommodate a very low level of through traffic movement. They are also typically designed, operated, and maintained in accordance with negotiated lease agreements.
- **Ramp Terminal:** The intersection of a freeway ramp (entrance or exit ramp) and a surface street.
- **Retrofit:** A project or action taken to improve the transportation system to correct one or more identified operational or safety deficiencies. In some cases, retrofit projects are necessary based on a lack of proactive access management planning practices over long periods of time.
- **Reverse Frontage Road:** An interrupted-flow roadway constructed at the rear of properties fronting a major roadway for purposes of providing access to those properties. Also known as a **Backage Road**.
- **Right-of-Way (ROW):** A strip of land occupied, or intended to be occupied, by a roadway, sidewalk, crosswalk, or other feature.
- **Roadside Buffer:** The area, starting at the edge of the shoulder and extending away from the roadway centerline a horizontal distance specified in *Table 10-1* of these *Guidelines*. When no shoulder is present, the roadside buffer begins at the edge of traveled way. The purpose of the roadside buffer is to provide space for placing and maintaining utilities, locating roadside guide signs, and having a recovery area for errant vehicles.
- **Shall:** Indicates a required or mandatory action.
- **Shared Access:** A single access driveway serving two or more ad**jacent propert**ies or tenant leaseholds.
- **Should:** Indicates guidance of recommended practice, with deviations allowed by the Chief Engineer of the relevant discipline.
- **Sidewalk:** That portion of a street between the curb line, or the lateral edge line of a roadway, and the adjacent tenant lease line that is paved or improved and intended for use by pedestrians.
- **Sight Distance:** The unobstructed distance along which a driver can see an object or oncoming vehicle of a specified height.
- **Sight Triangle:** A desired area of unobstructed sight distance adjacent to the approach of an intersection or driveway along a roadway. Unobstructed sight triangles are typically needed from the approach in both directions along the roadway.
- **Signal Progression:** The progressive movement of traffic, at a planned rate of speed without stopping, through adjacent signalized intersections within a traffic control system.
- **Signal Spacing:** The distance between signalized intersections along a roadway. Signal spacing is typically measured between the points of intersecting centerlines at adjacent signalized intersections.
- **Sub-Area Plan:** A plan addressing mobility and access needs for a specific area of a Port Authority facility. The sub-area may include one or more tenant leaseholds within a Port Authority facility and/or one or more roadways. Preparation of a sub-area plan helps implement access management by providing

a framework for the consistent application of access management to accommodate potential changes in land development patterns.

- **Team Conceptual Planning Meeting:** A meeting taking place at project inception, prior to the preparation or submittal of any formal studies, reports, design drawings, or other such documents. This meeting is intended to provide an early opportunity for the PA Line Department staff, PA Engineering staff, tenants and tenant representatives, and other affected stakeholders to meet and discuss the framework for required deliverables and future coordination efforts with the PA as part of TAA projects, new leases, lease renewals, and Port Authority projects.
- **Throat Length:** The storage length available that is free of conflicts for vehicles entering and exiting a driveway. The throat length is measured from the outer edge of the traveled way of the intersecting roadway to the first point at which there are conflicting traffic movements on the subject property or leasehold served by the driveway.
- **Time-Space Diagram:** A graph on which the distance between signals and signal timing is plotted against time, and indicating the bandwidth and speed of traffic.
- **Traffic:** Pedestrians, bicyclists, motorized vehicles, streetcars, and other conveyances either singularly or together used for purposes of travel.
- **Transportation Master Plan:** See **Master Plan**.
- **Two-Way Left-Turn Lane (TWLTL):** A continuous lane located between opposing traffic streams on a roadway that provides a refuge area for vehicles to complete left-turns from both directions.
- **Undeveloped Area:** An area characterized by: (a) little to no roadside development, (b) few, if any, intersecting driveways and roadways, (c) right-of-way available for roadway improvements, and/or (d) little to no pedestrian activity.
- **Undivided Roadway:** A roadway that has no directional separator, natural or structural, to separate traffic moving in opposite directions. For example, a roadway cross-section containing a traversable median or a two-way left-turn lane are considered undivided.

LIST OF COMMON ABBREVIATIONS

AASHTO ....American Association of State Highway and Transportation Officials

ACS.................Access Classification System

ADA.................Americans with Disabilities Act

AADT ....Annual Average Daily Traffic

ADT ....Average Daily Traffic

EWR.................Newark Liberty International Airport

FHWA..............Federal Highway Administration

HCM ....Highway Capacity Manual

HCS..................Highway Capacity Software

ITE ....Institute of Transportation Engineers

JFK...................John F. Kennedy International Airport

LGA ....LaGuardia Airport

mph ....miles per hour

MUTCD...........Manual on Uniform Traffic Control Devices for Streets and Highways

NCHRP ....National Cooperative Highway Research Program

PATH...............Port Authority Trans-Hudson

SWF ....Stewart International Airport

TAA ....Tenant Alteration Application

TCAP ....Tenant Construction and Alteration Process

TEB..................Teterboro Airport

TRB..................Transportation Research Board

APPENDIX B

PA AIRPORT ROADWAY SIGN DESIGN MANUAL

Airport Roadway Sign Design Manual

April 15, 2022

Prepared by: Traffic Engineering, Design Division, Engineering Department

For External Use

THE PORT AUTHORITY OF NY & NJ

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1. Overview

1A. Introduction

The Port Authority of New York and New Jersey (Port Authority) operates five airports in the New York and New Jersey region:

- John F. Kennedy International Airport (JFK)
- Newark Liberty International Airport (EWR)
- LaGuardia Airport (LGA)
- Stewart International Airport (SWF)
- Teterboro Airport (TEB)

Facility maps of these airports are included in *Appendix A – Facility Maps*.

Airport roadways are designed to perform functions and operate in ways that are often different from the functions and operation of a typical highway. The complex highway systems and terminals of the airport facilities present challenges to travelers accustomed to typical highways and their operational characteristics. The goal of airport signing is to enable travelers to navigate into, through, and out of its airport facilities. To achieve that goal, the sign design process involves overcoming unique challenges, including:

- Many destinations within the limited area of the airport;
- Travelers who are unfamiliar with the airport and its roadways;
- Reduced speeds, restricted geometry, and frequent decision points on airport roadways;
- Transitioning between off-airport highways and arterials and on-airport roadways;
- Travelers who are late, uncertain about the location of their destination, or both;
- Travelers from other countries and cultures who may not be able to read sign text or who may be unfamiliar with American signing practices; and
- Occasional changes in airlines and other service providers at each terminal and airport.

1B. Purpose

The purpose of this Manual is to establish standards and guidelines to be used in developing comprehensive, clear, consistent, and conspicuous signing at all Port Authority airports.

- Comprehensive: Signs include all the information necessary and no extra information.
- Clear: Signs are easily understandable.
- Consistent: Signs look the same and sign messages are arranged and worded in the same manner at each facility and across all facilities.
- Conspicuous: Signs are properly located and readable from the appropriate angles and distances.

Following these signing principles is essential in conveying airport highway and terminal information to the traveling public. The design criteria and text presented herein provide guidance to the designer by referencing a recommended range of values for critical dimensions. For this purpose, this Manual offers numerous illustrations that reflect the products of its signing standards. However, one set of signing standards and guidelines cannot resolve every signing situation, and variations from design criteria may be required for special or unusual conditions such as space restrictions. The Port Authority reserves the right to make or allow modifications to the standards based on lessons learned, and always applying sound engineering judgment.

1C. Compliance with this Manual

This document supersedes the previously published *1994 Airport Signing Standards Manual*.

Any sign erected on the Port Authority's airport roadway system must be approved by the Chief Traffic Engineer or his designated representative.

Graphic design of airport roadway directional and informational signs shall conform to this Manual, including temporary (e.g., construction) signs. When design criteria presented in this Manual differ from criteria presented in other sources, this Manual shall take precedence. In the absence of direction given by this Manual, signs shall conform to the latest edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) published by the Federal Highway Administration. Airport-related messages to be placed on signs located outside of Port Authority jurisdiction shall be coordinated with the controlling agency. This Manual does not apply to Port Authority signs located away from airport facilities, such as trailblazers.

Signs may be replaced through one of several processes:

- Tenant requests for new signing, changes to sign messages, or sign changes necessitated by physical airport improvements (such as terminal reconstruction) must be coordinated with the Tenant Facility Office (TFO) through the Tenant Alteration Application (TAA) process.
- Tenant requests for other changes (such as airline name, terminal, or level number) are coordinated directly with the facility's Landside Operations. Landside Operations may also initiate or request sign replacements, such as for operational changes, in coordination with Port Authority Traffic Engineering.
- The Aviation Department may initiate facility-wide or agency-wide changes to signing, such as parking toll rate changes, in coordination with Port Authority Traffic Engineering.
- Port Authority Traffic Engineering may also initiate replacement for routine sign maintenance and upgrades.

Except for the TAA process, signs may be replaced by sending a Sign Service Request (SSR) to the Port Authority's Sign Shop, by initiating a work order, or through a contract.

1D. Design Process

Throughout the design process, the designer should keep in mind that the purpose of roadway signing is to give motorists clear directions to their desired destination. Before a highway sign can be designed for airport usage, other factors such as the sign's location, messages, text height, etc. must be determined by a traffic engineer.

At the beginning of the design process, the sign message and location must be established. The location is just as important as the message in determining sign layout based on whether the sign is overhead or ground mounted and whether height or width may be restricted. The sign design process generally follows the outline of this Manual:

- The color coding scheme and message hierarchy to be followed are established (Sections 2 and 3).
- Terminology is verified and text, overlays, and graphic elements are placed and appropriately sized (Sections 4 through 6).
- Arrows are located on the sign (Section 7).
- Borders and other panel design elements are added, and the final sign size and layout are determined (Section 8).

Sections 9 through 13 cover the design of various types of landside roadway guide signs. Sections 14 through 17 each apply to particular signing situations (frontages, parking facilities, parking entry and exit plazas, and airside).

The only pedestrian signs included in this Manual are those in mixed-mode locations such as frontages, parking lots, and garages. For design of pedestrian signs in terminal buildings and other locations, refer to the *Airport Standards Manual for Pedestrian Signing & Wayfinding* published by the Port Authority's Aviation department, hereafter referred to as the *Manual for Pedestrian Signing & Wayfinding*.

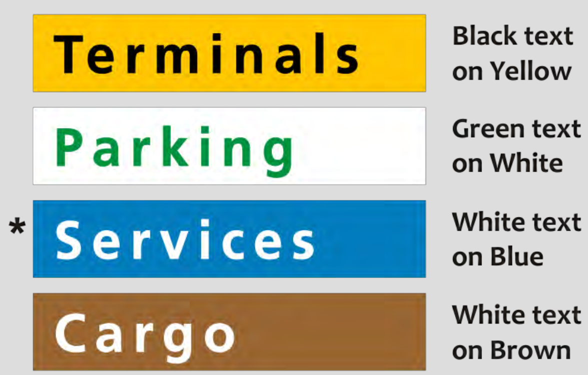
2. Color Coding System

The Port Authority uses a system of color coding according to function at all of its airports. Color coding requires that similar destination types utilize a single color, which allows road users to identify exactly which signs are relevant to their need. This provides for earlier recognition by travelers as the sign color will be visible before the message. The concept utilizes distinct and highly visible color combinations to visually organize messages by information type.

At JFK Airport, the Port Authority also uses a system of color coding according to location.

2A. Color Coding According to Function

In this system, similar functions are assigned the same color regardless of their location within the airport facility, as shown in **Figure 2-1**.



* Airport Services shall include but are not limited to all on-airport rental car companies, hotels, and gas stations.

Figure 2-1

All on-airport roadway signs shall start with a white message and border on a green background. Color overlays in accordance with the color coding system shall then be added to the sign. All messages not assigned to a function listed in **Figure 2-1** shall be directly applied to the sign without use of an overlay. Any regulatory or warning messages within the sign shall adhere to the standards for color as provided in the *MUTCD* and as discussed in *Section 12 – Regulatory and Warning Signs*.

Typical applications of color coding according to function on guide signs are shown in **Figures 2-2, 2-3, 2-4,** and **2-5** at Newark, LaGuardia, Stewart, and Teterboro Airports respectively. Signing for functions related to general aviation, such as all functions at Teterboro Airport (which does not accommodate scheduled commercial flights), is discussed in *Section 11A – General Aviation*.

2B. Color Coding According to Location (JFK Only)

At JFK Airport, the Central Terminal Area is divided into 5 distinct zones. Each zone is assigned a color regardless of the functions being served within the zone. Details of the terminals located in a particular zone and the color assigned are given in **Table 2-1**.

Table 2-1 Color Coding According to Location

Zone	*Terminals*	*Sign Colors*	
		Legend	*Background*
Green	1, 2, and 3	White	Green
Blue	4	White	Blue
Yellow	5	Black	Yellow
Orange	7	Black	Orange
Red	8	White	Red

All signs exclusively related to a particular zone that display messages exclusive to that zone shall use the zone's color for sign background. All of these signs shall be designed according to the color coding listed in **Table 2-1,** without the use of overlays. Any regulatory or warning messages within the sign shall adhere to the color standards as provided in the *MUTCD* and as discussed in *Section 12 – Regulatory and Warning Signs*.

Figure 2-6 shows typical applications of color coding according to location on guide signs at JFK Airport.

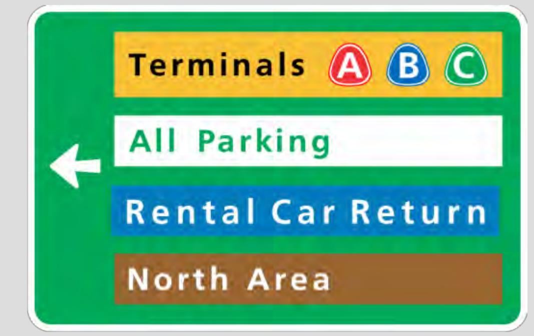


Figure 2-2

Figure 2-3

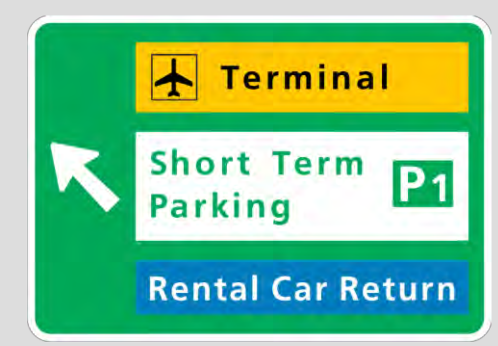


Figure 2-4

Figure 2-5

The standards described in Sections 2B.1 and 2B.2 shall apply at JFK Airport when signs do not belong exclusively to a particular zone.

2B.1 Inbound Roadways

On signs that display messages related to multiple zones, a gray background shall be used. Logos following color coding according to location shall be applied to the gray background. Color coding according to function and the use of overlays shall not be permitted. A typical example is shown in **Figure 2-7**.

On signs that display messages not related to any zone, color coding according to function shall be used. A typical example is shown in **Figure 2-8**.

2B.2 Other Roadways

Other than inbound roadways, signs may appear on terminal roadways, outbound roadways, and airport roadways not associated with terminals. On signs that display messages not related to any zone, color coding according to function shall be used as shown in **Figure 2-9**.

On signs that display messages related both to zones and functions, signs shall start with a white message and border on a green background. On these signs, overlays shall be applied according to the following rules:

- When an overlay displays a message related to a single location (zone), the overlay shall use the color coding as specified in **Table 2-1**. A typical example is shown at the bottom of **Figure 2-10**.
- When an overlay displays a message related to an airport-wide function, the overlay shall use the color coding as defined in *Section 2A – Color Coding According to Function*. Typical examples are shown in **Figures 2-8** and **2-9**.
- When multiple overlays are grouped with a single arrow orientation or directional message, they shall all be related either to location or to function, as shown in **Figure 2-10**.

All messages not assigned to an overlay function as described in this section or as listed in **Figure 2-1** shall be directly applied to the sign without use of an overlay.

Figure 2-6a

Figure 2-6b

Figure 2-6c

Figure 2-6d

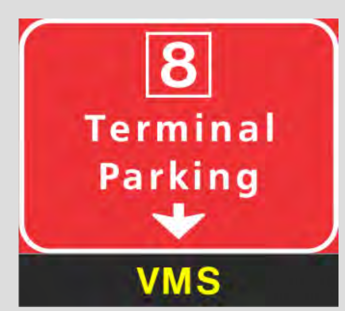


Figure 2-6e

Figure 2-7

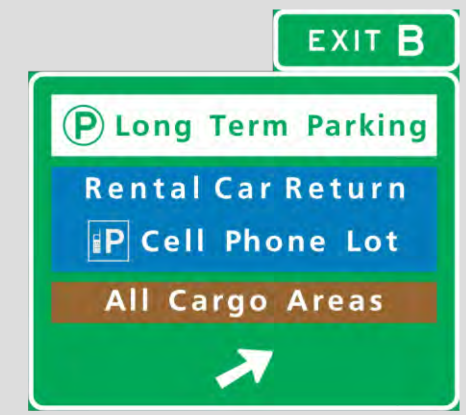


Figure 2-8

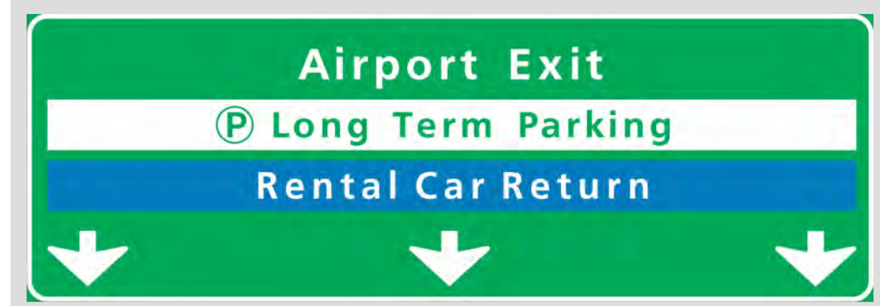


Figure 2-9

Figure 2-10

3. Message Hierarchy

Consistent placement and arrangement of messages on a sign panel is important. Messages shall be placed on guide signs in accordance with the Port Authority's message hierarchy. The message hierarchy allows one to determine which messages are most important.

Except as otherwise stated in *Section 3D – Exceptions to Hierarchy*, guide signing within airport facilities shall list messages according to the following message hierarchy:

1. Terminals
2. Parking
3. Services
4. Cargo
5. Other messages that do not belong to the above categories

Figures 3-1 and **3-2** show signs illustrating message placement according to the message hierarchy. The message hierarchy shall apply to signs following either of the two systems of color coding discussed in *Section 2 – Color Coding System*. Directional messages such as "KEEP RIGHT" shall be located below all related messages.

3A. Message Groups

When a sign has messages relating to more than one direction of travel, messages shall be divided into message groups according to the related arrow or directional message. Message groups, including the related arrow or directional message, shall be separated by message separator lines. To determine the order of message groups on a sign:

- In each message group, determine which message is listed first based on the message hierarchy.
- Use the message hierarchy to compare the first-listed messages.
- The order of first-listed messages according to the message hierarchy determines the order of message groups.

Figure 3-3 shows an example of message groups sorted by hierarchy.

3B. Hierarchy of Message Groups

When determining the order of messages or message groups on a sign, there may be two or more messages belonging to the same message hierarchy level. The following rules shall apply to determine the order of messages within each level of hierarchy:

1. Terminals: "A" or "1" shall be listed first, followed by other terminals in ascending order. General messages such as "Return to Terminals" shall be listed last.
2. Parking:
   a. Parking listed by terminal facility logo shall be listed first in the same order as Terminals.
   b. Parking listed by lot number logo shall be listed next. "P1" shall be listed first, followed by other lots in ascending order, except for Long Term Parking Lot P3 at LaGuardia Airport.
   c. At Newark Airport, Valet Parking shall be listed after Daily Parking Lots P1, P3, and P4 and before Economy Parking Lot P6.
   d. At JFK and LaGuardia Airports, Long Term Parking shall be listed last.
3. Services:
   a. Within the same message group, rental car messages shall be listed first in alphabetical order. If other service messages are preceded by building numbers, they shall be listed in ascending order starting with the lowest number; otherwise, they shall be listed in alphabetical order.
   b. When the first-listed messages in different message groups are service-related or when all messages are service-related, use the *MUTCD* arrow hierarchy defined in *Section 3C – Arrow Hierarchy*.
4. Cargo:
   a. Within the same message group, cargo messages shall be listed in alphabetical order.
      - At JFK Airport, cargo areas shall be listed in order from A to D.
      - At Newark Airport, the North Area shall be listed before the South Area.
      - Within each cargo area, building numbers shall be listed in numerical order.
   b. When the first-listed messages in different message groups are cargo-related or when all messages are cargo-related, use the *MUTCD* arrow hierarchy defined in *Section 3C – Arrow Hierarchy*.
5. Other messages that do not belong to the above categories:
   a. Within the same message group, if messages are preceded by building numbers, they shall be listed in ascending order starting with the lowest number; otherwise, they shall be listed in alphabetical order.
   b. When different message groups have no messages related to terminals, parking, services, or cargo, use the *MUTCD* arrow hierarchy defined in *Section 3C – Arrow Hierarchy*.

Figure 3-1

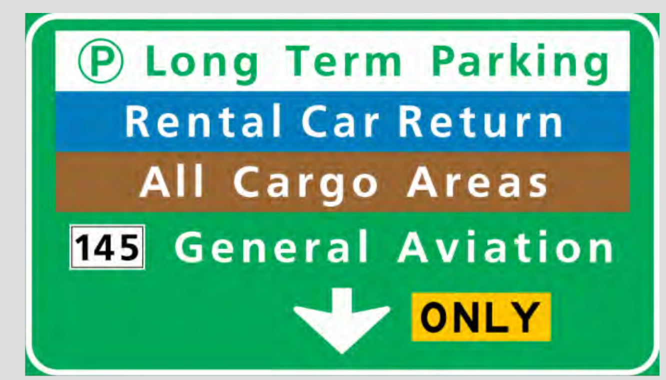


Figure 3-2

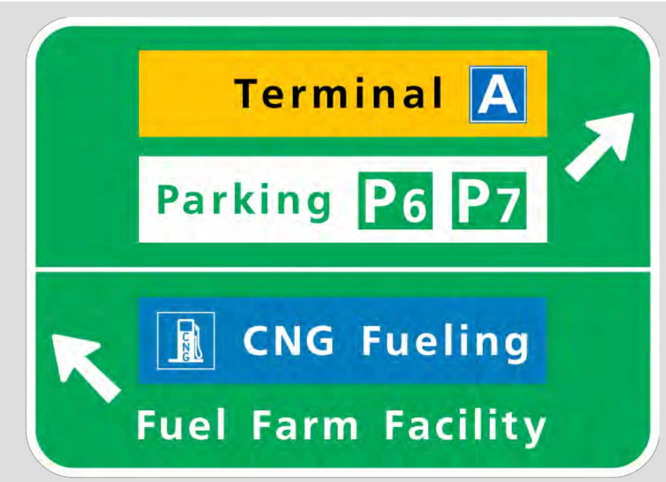


Figure 3-3

Figure 3-4 shows an example of sorting messages when two messages belong to the same hierarchy level. The message "Terminal A" is the only one associated with the directional message "NEXT LEFT," so it forms one message group. The messages "Terminals B, C" and "Daily Parking P1, P3" are both associated with the up arrow, so they form a second message group. The rules for Terminals are applied because both message groups have terminal messages (hierarchy level 1), so the "Terminal A" message group is listed first.

3C. Arrow Hierarchy

The arrow orientation hierarchy, as defined in the *MUTCD*, is up, left, right, down, directional message only. The arrow hierarchy shall be used to sort between message groups in the following circumstances, as described in *Section 3B – Hierarchy of Message Groups*:

- When the first-listed messages in two or more message groups are related to services, or when all messages on the sign are service-related as described in *Section 9 – Service Signs*.
- When the first-listed messages in two or more message groups are related to cargo areas (including building numbers), or when all messages on the sign are cargo-related as described in *Section 10 – Cargo Areas*.
- When two or more message groups on a guide sign have no messages related to terminals, parking, services, or cargo.

3D. Exceptions to Hierarchy

3D.1 Exit Signs

On signs leading to or immediately prior to an exit, such as a parking lot exit or the airport exit, the message related to the exit shall take precedence over the established hierarchy and the associated message group shall be placed first on the sign. Any remaining messages shall adhere to the basic hierarchy rules. A typical example is shown in **Figure 3-5**.

3D.2 Cargo Area Signs

On signs entering or within cargo areas along roadways away from terminal and parking areas, cargo-related messages should take precedence over the established hierarchy and the associated message group should be placed first on the sign. Any remaining messages shall adhere to the basic hierarchy rules. Typical examples are shown in **Figure 3-6**.

3D.3 Parking Facility Signs

Refer to *Section 15A.2 – Parking Facilities – Message Hierarchy* for the hierarchy of parking facility signs.

Figure 3-4

Figure 3-5

Figure 3-6a

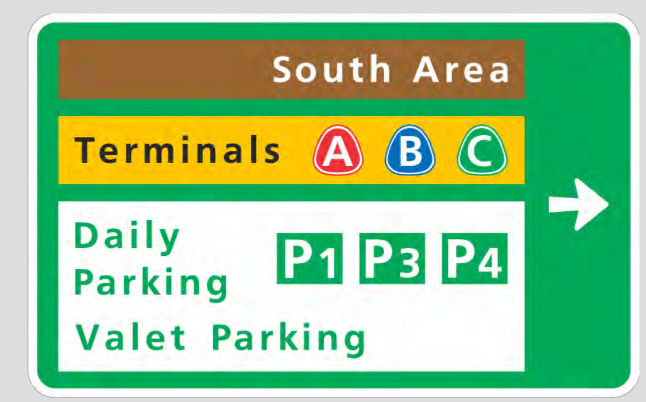


Figure 3-6b

4. Text

All airport roadway signs shall use only the English language. Roadway signs must be read, understood, and acted upon by the driver of a moving vehicle within a short time span. The Port Authority has implemented the criteria in this section to maintain a balance between readability and sign size.

4A. Terminology

The acceptable terminology that may appear on Port Authority signs is limited in order to establish clear and consistent messages across all facilities. Each facility has unique signing requirements, including different buildings and locations within the facility, but all airport facilities share common elements. A list of approved sign terminology general to all facilities and specific to each facility is included in *Appendix B – Sign Terminology*. Sign messages shall be selected from the approved terminology.

Signing should avoid using abbreviations whenever possible. If it is necessary to include abbreviations after all other options have been considered, only those abbreviations listed in the approved terminology shall be used. The use of punctuation and symbols such as periods, commas, hyphens, colons, semicolons, apostrophes, etc. should be avoided unless otherwise shown in *Appendix B – Sign Terminology*.

A logical progression of terminology shall be employed on signs leading to any given destination. Consecutive signs should employ the same terminology. For example, the term "Exit" is used on signs within parking facilities because it refers to both the parking facility exit and the airport exit. After leaving the parking facility, the term "Airport Exit" is used on signs on airport roadways. Because it may be confused with the airport exit, the term "Exit" is not used in other contexts. Therefore, instead of using "EXIT ONLY" panels on overhead lane assignment signs, only the word "ONLY" should be used, as shown in Section 3, **Figure 3-2**.

4B. Typeface

In the interest of keeping a uniform, consistent look to on-airport signing, only Frutiger 65 with +150% inter-letter spacing shall be used on roadway guide signs in Port Authority airports. **Figure 4-1** shows Frutiger 65 letters and numbers. **Figure 4-2** shows a comparison of text with +0% and +150% inter-letter spacing.

- The Frutiger typeface has several numbered variants based on character weight, width, and position (such as Frutiger 75, 56, etc.), but the Port Authority will only accept Frutiger 65.
- Inter-letter spacing for Frutiger 65 should be increased to +150% to maintain a balance between readability and sign size while still keeping a uniform appearance to all signs.
- All roadway guide sign figures in this Manual use the Frutiger 65 typeface with +150% inter-letter spacing unless otherwise specified.
- A typeface other than Frutiger 65 may only be used in the following circumstances:
  - Street name signs, which shall adhere to the *MUTCD* as discussed in *Section 11F – Street Name Signs*
  - Regulatory and warning messages, which shall adhere to the *MUTCD* as discussed in *Section 12 – Regulatory and Warning Signs*
  - Variable message signs
- The only exceptions to the inter-letter spacing requirement are as follows:
  - Facility identification signs as described in *Section 11C – Facility Identification*
  - Frontage signs as described in *Section 14 - Frontages*
  - Signs within parking lots and garages as described in *Section 15A.1 – Parking Facilities – General Rules and Guidelines*
  - Pedestrian signs as described in *Section 15B – Pedestrian Signing*
  - Aisle and row markers as shown in *Appendix D – Aisle and Row Markers*
- Otherwise, if message width is limited, reductions in spacing shall occur in 5% increments and shall require the approval of the Port Authority.

Except for directional messages, all guide sign messages shall be written such that the beginning of the word will start with an upper case letter, and the remainder will be in lower case. This provides simplicity in appearance and improved readability. Directional messages such as "KEEP RIGHT" shall be written only in upper case.

Frutiger 65

Upper case:

A B C D E F G H I J K L M N O P Q
R S T U V W X Y Z

Lower case:

a b c d e f g h i j k l m n o p q
r s t u v w x y z

Numbers:

1 2 3 4 5 6 7 8 9 0

Figure 4-1

Text with additional +150% interletter spacing: (required spacing)

8" **T e r m i n a l s**
64.4"

8" **E c o n o m y P a r k i n g**
114"

8" **K E E P L E F T**
64.3"

Text with additional +0% interletter spacing: (spacing not permitted)

8" **Terminals**
51.2"

8" **Economy Parking**
92.8"

8" **KEEP LEFT**
53.5"

Figure 4-2

4C. Text Height

Table 4-1 shall be used for design of roadway guide signs. The provisions of this section apply to all text, whether or not the text is contained within an overlay.

Table 4-1 - Text Height

Sign Type	*Text Height (Upper Case)*
Overhead	16" Recommended 12" Standard Minimum 10" Absolute Minimum
Ground Mounted	8" Recommended 6" Minimum

The text heights shown in **Table 4-1** are based on upper case letters that are not rounded, such as "A" or "E." Rounded letters and numbers may slightly exceed the specified text height. Lower case text height is defined as part of the font relative to the upper case text height.

Text height is based on the time required to both read and react to the message displayed. Additionally, the size of lettering on adjacent signs, the number of competing signs that must also be processed, and the regulatory speed of the roadway shall be considered.

The designer shall make every effort to adhere to the recommended text height shown in **Table 4-1**. If height or width restrictions limit the size of the sign, text shall be no smaller than the minimum text height shown. On overhead signs, the standard minimum text height should be used in design before considering the absolute minimum text height. More than one text height may be used on the same sign as warranted by factors such as message priority. These rules and guidelines are shown in Section 2, **Figure 2-10** and Section 3, **Figure 3-5**.

Text height on parking lot and garage signs is discussed in *Section 15A.1 – Parking Facilities – General Rules and Guidelines*. Text height on small guide signs is discussed in *Section 11H – Small Guide Signs*.

4D. Text Placement

The unit measurement for spacing is the height of the largest upper case letter as defined in *Section 4C – Text Height*, and is referenced in figures in this section as the letter "Y." Spacing for signs in parking lots and garages is described in *Section 15A.4 – Parking Facilities – Text Placement*.

Directional messages shall always be placed at the bottom of the sign. Rules regarding placement of fractions within directional messages are described in the *MUTCD*, including the alignment of numerals within the fraction and the size and alignment of the solidus. An example of a directional message with a fraction is in Section 2, **Figure 2-3**.

Horizontal alignment refers to the positioning of text to the left, center, or right. Vertical alignment refers to the positioning of text to the top, center, or bottom.

4D.1 Horizontal Alignment

The following rules govern horizontal spacing of text:

- As shown in **Figure 4-3**, spacing between the leftmost or rightmost letter and the border or message separator line should be a minimum of the upper case text height.
- As shown in **Figure 4-4**, spacing from the edge of the overlay to the leftmost or rightmost letter in the overlay shall be a minimum of 4 inches.
- As shown in **Figure 4-5**, spacing between words shall be equal to the upper case text height.
- As shown in **Figure 4-6**:
  - Spacing between two letters used as initials (e.g., NJ or US) shall be equal to ½ the upper case text height.
  - Spacing between a letter and a number shall be equal to the upper case text height.
  - Spacing between two letters or numbers with a hyphen in between shall be 1¼ times the upper case text height.
  - Spacing between a letter and a punctuation mark or symbol shall be equal to the upper case text height.

As stated in *Section 4A – Terminology*, the use of punctuation marks and symbols should be avoided whenever possible.

Figure 4-3

Figure 4-5

Figure 4-6

Figure 4-4

Directional messages shall be horizonally centered on the sign. The placement of text, including text within an overlay, is contingent on the location of the arrows, if any:

- If an arrow is present on the left side of the sign, the related messages shall be left justified. If an arrow is present on the right side of the sign, the related messages shall be right justified. These rules are shown in **Figure 4-4** and apply except in the following circumstances:
  - When two lines of text are part of the same message, the longer line shall be right justified and the shorter line shall be left justified to the longer line, as shown in Section 3, **Figure 3-6a**.
  - Parking messages may be left justified based on sign design considerations, as shown in Section 3, **Figure 3-6b**.
- If no arrow is present (i.e., there is a directional message) or if arrows are located on the bottom of the sign, overlay messages and general text should be horizontally centered, as shown in **Figures 4-7a** and **4-7b**. However, the presence of logos and symbols or other considerations will ultimately dictate the alignments of the messages, such as left justifying multiple messages with logos or symbols as shown in **Figure 4-7c**.

When overlays and general text are left or right justified on the same sign, the following rules apply:

- When they share an arrow, the general text should be aligned with the text inside the overlay as shown in **Figure 4-8**.
- When they do not share the same arrow, the general text shall be aligned with the edge of overlay closer to the arrow belonging to the general text as shown in **Figure 4-9**.

Horizontal spacing between logos or symbols and the message is discussed in *Section 6 – Graphic Elements*.

4D.2 Vertical Alignment

Spacing between lines of text that are not related should be a minimum of the upper case text height. Lines of text that are related should always be perceived by drivers as belonging together, not as two separate messages. Therefore, spacing between related lines of text should be ¾ times the upper case text height, rounded to the nearest whole number. These guidelines are shown in **Figure 4-10**.

As shown in **Figure 4-3**:

- Spacing between the top line of text and the border should be a minimum of the upper case text height.
- If the bottom line of text contains only word messages, spacing between the bottom line of text and the border should also be a minimum of the upper case text height.

As shown in **Figure 4-4**:

- Spacing between the edges of an overlay and the top or bottom of the message in the overlay should be equal to the height of the upper case letter and shall be a minimum of 4 inches.
- When a line of text includes a letter with a descender (e.g., the letter “g” in Parking), the spacing below that line of text may be increased by 1 inch for every 6 inches of text height, rounded to the nearest inch. This applies to spacing between two related lines of text, between two unrelated lines of text, or between the last line of text on an overlay and the bottom of the overlay.

Figure 4-7a

Figure 4-7b

Figure 4-7c

Figure 4-8

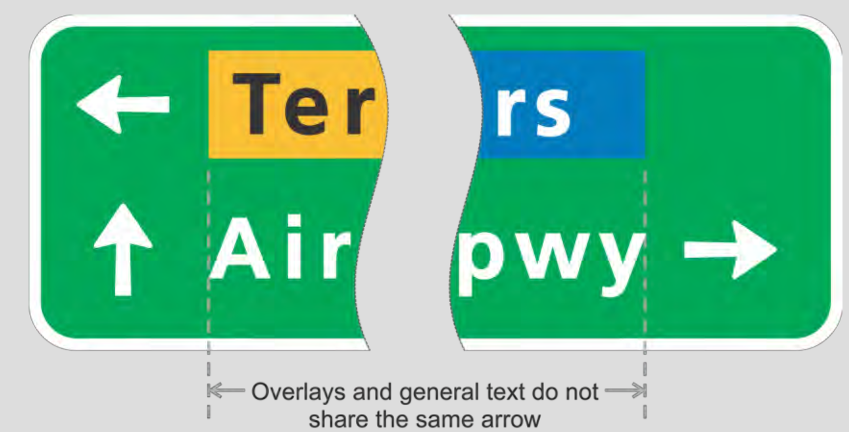


Figure 4-9

Figure 4-10

5. Placement of Overlays on Signs

The following rules apply to overlay placement. Typical examples of overlay placement are shown in **Figures 5-1** to **5-5**.

- The width of all overlays within an individual sign shall be the same, and shall be dictated by the longest message.
- The width of a line of text applied directly to the sign shall be equal to or less than the overlay width.
- The height of each overlay may vary based on the number of lines of text or the height of the logo.
- All overlays shall have square corners. The edges of all overlays on an individual sign shall be horizontally aligned.
- Arrows are the only graphic element that may be placed on the left side and right side of the overlays.

Horizontal alignment refers to the positioning of the overlay to the left, center, or right. Vertical alignment refers to the positioning of the overlay to the top, center, or bottom.

5A. Horizontal Alignment

The horizontal alignment of overlays on the sign panel differs based on sign type:

- **Overhead Signs:** Overlays shall be horizontally centered on the panel. The bottom portion of overhead signs shall be limited to arrows or directional messages. Horizontal spacing between the edge of the overlay and the inner edge of the border or an arrow should be 8 inches and shall be a minimum of 4 inches. **Figure 5-2** shows a typical example of overlay alignment on overhead signs.
- **Ground Mounted Signs:** Arrows on ground mounted signs may be placed on either the right or left side of the sign panel as shown in **Figure 5-3**. Overlays shall be aligned to the right of the panel if an arrow is placed on the left side of the sign and aligned to the left of the panel if an arrow is placed on the right side of the sign. Overlays shall be horizontally centered on the panel if an arrow is placed on the bottom of the sign or if there is no arrow (directional message only). Horizontal spacing between edge of the overlay and inner edge of border or an arrow shall be 4 inches minimum. **Figures 5-1** and **5-4** show typical examples of overlay alignment on ground mounted signs.

Horizontal alignment of text within overlays is discussed in *Section 4D.1 – Text Placement – Horizontal Alignment*.

5B. Vertical Alignment

Vertical alignment of overlays on guide signs is independent of sign type. Spacing between the inner edge of the border or arrow and top or bottom of an overlay shall be 4 inches minimum, not including the width of the border. Vertical spacing between overlays shall be 4 inches minimum. **Figure 5-1** shows vertical spacing requirements. In limited circumstances, the vertical spacing may be eliminated to overcome height restrictions as shown in **Figure 5-5**. Under no circumstances shall a vertical spacing between 0 inches and 4 inches be allowed.

When general text is placed above or below an overlay, the spacing from the overlay to the general text should be at least equal to the height of the adjacent line of text as shown in **Figure 5-5**.

Figure 5-1

Figure 5-2

Figure 5-3

Figure 5-4

Figure 5-5

6. Graphic Elements

Graphic elements, including symbols, logos, and highway shields, are incorporated on signs throughout the Port Authority airport roadway system.

- **Symbols** are graphic designs that are generic and can be used at any facility. Symbols used on Port Authority signs include on-airport services and permittee hold areas.
- **Logos** are graphic designs that are unique to a business or service facility, including designs used for brand identification. Logos used on Port Authority signs include specific terminals and parking lots.
- **Highway shields** are graphic designs that indicate numbered or named highways in accordance with the *MUTCD* or the controlling agency. Highway shields are used on Port Authority guide signs, including airport exit signs.

The logos and symbols shown in this Manual were designed to be easily recognized and understood. Where applicable, they are based on standards developed by the U.S. Department of Transportation and the International Organization for Standardization (ISO). To produce sign layouts in accordance with this Manual, the logos and symbols are available in electronic format from Port Authority Traffic Engineering.

Detailed dimensions and specifications of logos and symbols are provided in *Appendix C – Logos and Symbols*. Different logos and symbols, found only in the *Manual for Pedestrian Signing & Wayfinding*, may be used on signs at frontages as discussed in *Section 14 – Frontages* and on pedestrian-oriented signs in parking lots as discussed in *Section 15B – Pedestrian Signing*. No logo or symbol may be altered or added without formal approval. A request for a new logo or symbol must be initiated through Port Authority Traffic Engineering.

The placement of graphic elements shall be in accordance with guidelines listed in *Section 6H – Placement of Graphic Elements*.

6A. Airports

Newark Airport has a custom rounded triangle logo that has developed extensive recognition. All other Port Authority airports use the *MUTCD* airport symbol (I-5). **Figure 6-1** shows the logos used at each airport.

Airport logos and symbols placed on off-airport signs and on signs entering the airport follow certain guidelines. The Newark Airport logo is placed on a brown background with the message ("Newark Airport," "North Area," etc.) in white text. All other Port Authority airports have the *MUTCD* airport symbol placed on a green background followed by the appropriate airport name in white text. The logo or symbol should be followed by the name of the airport. **Figure 6-2** shows typical signs erected off-airport by other agencies.

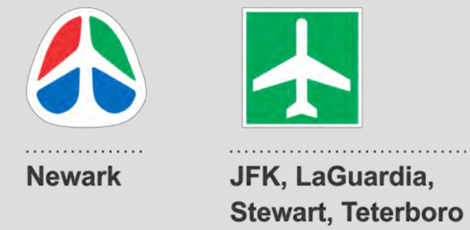


Figure 6-1

Figure 6-2a

Figure 6-2d

Figure 6-2b

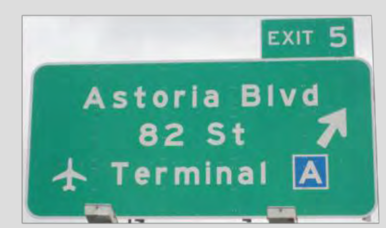


Figure 6-2e

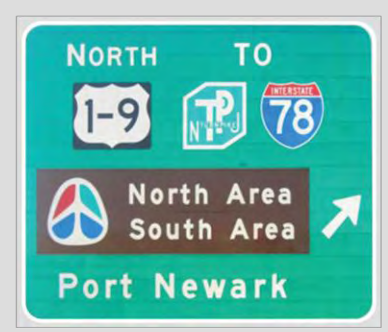


Figure 6-2c

Figure 6-2f

6B. Terminals

The terminal designation on roadway signs shall be represented by a square logo at JFK and LaGuardia Airports and by a rounded triangle logo at Newark Airport in the shape of the airport logo. Each terminal or group of terminals at each airport is assigned a specific background color so that travelers may easily identify their terminal by both designation and color. The terminal logos at each airport are shown in **Figure 6-3**, and colors, detailed dimensions, and other specifications are provided in *Appendix C – Logos and Symbols*. Note that JFK Terminals 5 and 7 have an alternate logo with an inset black border, to be used only on signs with gray backgrounds.

Stewart Airport's passenger terminal is identified with the *MUTCD* airport symbol (I-5) in black legend on a yellow background, accompanied by the message "Terminal." Teterboro Airport has no passenger terminal and therefore has no terminal logo or symbol.

All messages related to terminals in general, such as "Return to Terminals," shall be written in text with no logo or symbol. Logos related to terminal functions on frontages are discussed in *Section 14 – Frontages*. When messages include terminal level numbers, the word "Level" and the level number shall be shown in yellow text on a black background within the yellow overlay, as shown in **Figure 5-2**.

Figure 6-3

6C. Parking

Each airport has a unique system of different types of parking facilities, requiring appropriate messages based on the different rates and locations relative to the terminals. This section discusses the different signing situations encountered when directing motorists to the correct parking facilities in each airport. Signing within parking lots and garages is described in *Section 15 – Parking Facilities*. Teterboro Airport is not included because it does not have public parking facilities.

In the special condition where space constraints do not permit use of a standard guide sign for a parking facility, a small guide sign with logo or symbol and text may be employed. Design considerations are discussed in *Section 11H – Small Guide Signs*.

6C.1 JFK Airport

There are two kinds of public parking at JFK Airport:

- Short Term Parking is available in each zone adjacent to the corresponding terminal or terminals in the Central Terminal Area (CTA). The terminal logo with the message "Parking" is used to identify Short Term Parking, and there is no parking logo. An example of a sign for Short Term Parking is in Section 2, **Figure 2-6**.
- Long Term Parking serves all terminals and is located outside the CTA. Long Term Parking is identified by a symbol consisting of the letter P inside a circle with green legend on a white background. The symbol shall be followed by the message "Long Term Parking." **Figure 6-4** shows the Long Term Parking symbol at JFK Airport. Examples of signs for Long Term Parking are in **Figures 2-8** and **2-9**.

6C.2 Newark Airport

There are four kinds of public parking at Newark Airport:

- Short Term Parking is available adjacent to each terminal. Short Term Parking is identified by the message "Parking" or "Short Term Parking" followed by the terminal logo for its respective terminal. An example of a sign for Short Term Parking is in Section 4, **Figure 4-7b**.
- Daily Parking serves all terminals and is located outside the terminal area. Daily Parking is designated as Lots P1, P3, and P4 and is identified by logos consisting of the lot designation with the number in a subscript. The message "Daily Parking" shall precede the parking logos.
- Economy Parking serves all terminals and is located outside the terminal area. Economy Parking is designated as Lot P6 and is identified by a logo consisting of the lot designation with the number in a subscript. The message "Economy Parking" shall precede the parking logos.
- Valet Parking serves all terminals and is located at Daily Parking Lot P4. It does not have a logo and it is identified by the message "Valet Parking."

Employee Parking is designated as Lot F, but the associated logo is only used on signs at the parking lot entrance.

Figure 6-4 shows logos related to parking at Newark Airport. An example of a sign for Daily, Valet, and Economy Parking is in Section 5, **Figure 5-1**.

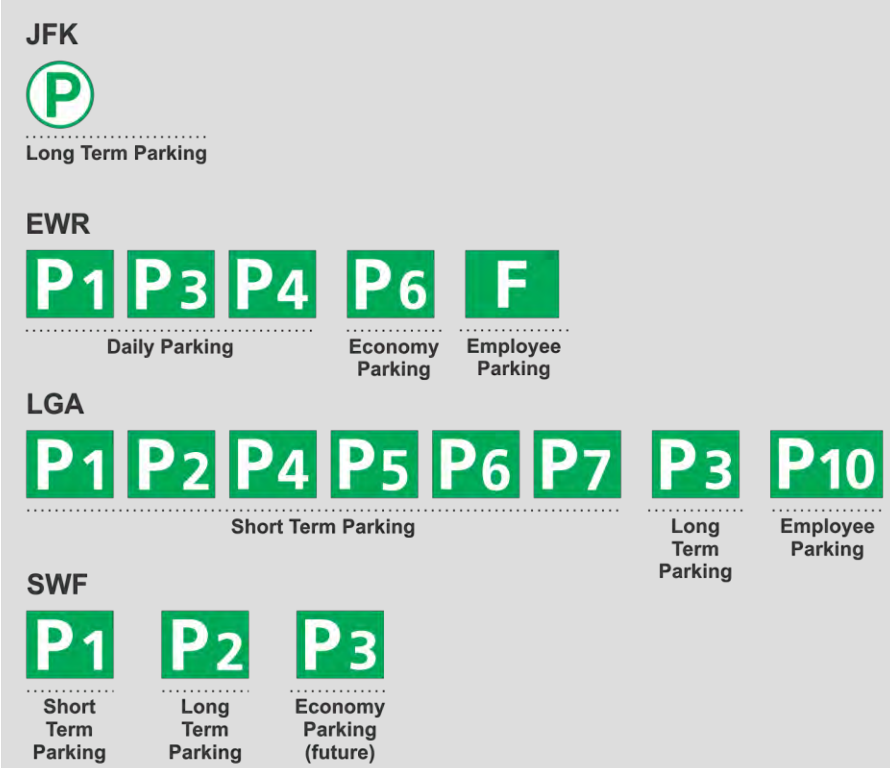


Figure 6-4

6C.3 LaGuardia Airport

There are two kinds of public parking at LaGuardia Airport:

- Short Term Parking is available adjacent to each terminal as identified in **Table 6-1** (Terminals A and B have more than one associated parking lot). Short Term Parking is identified by logos consisting of the lot designation with the number in a subscript. The message "Parking" shall precede the parking logos. The related terminal logos shall only be shown before the word "Parking" if there are terminal messages on the same sign unrelated to those lots. An example of a sign for Short Term Parking is in Section 2, **Figure 2-3**.
- Long Term Parking is centrally located and is designated as Lot P3. Long Term Parking is identified by a logo consisting of the lot designation with the number in a subscript. The message "Long Term Parking" shall precede the parking logo. An example of a sign for Long Term Parking is in Section 3, **Figure 3-1**.

Employee Parking is designated as Lot P10, but the associated logo is only used on signs at the parking lot entrance.

Figure 6-4 shows logos related to parking at LaGuardia Airport.

Table 6-1 - Short Term Parking at LaGuardia

Terminal	*Short Term Parking Designation*
A	P6, P7
B	P1, P2
C	P4
D	P5

6C.4 Stewart Airport

There are two kinds of public parking at Stewart Airport: Short Term Parking (Lot P1) and Long Term Parking (Lot P2). In the future, Economy Parking is planned to open as Lot P3. Parking lots are represented by logos consisting of the lot designation with the number in a subscript. Logos shall be preceded by the name of the parking lot.

Figure 6-4 shows logos related to parking at Stewart Airport. An example of a parking sign at Stewart Airport is in Section 2, **Figure 2-4**.

6C.5 Motorcycle Parking

Motorcycle parking is only allowed in designated sections of designated parking lots. Signs directing motorcyclists to motorcycle parking shall use the symbol shown in **Figure 6-5** in white legend on a green background. The symbol and message shall be placed directly on the sign with no overlay.

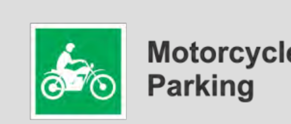


Figure 6-5

6D. On-Airport Services

All graphic elements associated with services are considered symbols with the exception of specific rental car companies. Not all services have associated symbols. Service symbols shall be placed on signs or overlays with blue backgrounds. Where signing directs a motorist to a specific building for a service, the building number may be used in the same manner as a symbol, as discussed in *Section 9B – Service Signs – General Services*.

6D.1 Rental Car Companies

When specific on-airport rental car company names are displayed on service signs, the company name shall be displayed on a demountable nameplate with its associated colors as listed in **Table 6-2**. The nameplates shall be as shown in **Figure 6-6** and no corporate logo shall be used. The colors shall be as defined in *Appendix F – Color and Material Specifications* and no other color, including any corporate colors, shall be used. Layout details are discussed in *Section 9A – Rental Car Messages*. Except as otherwise described in this Manual, rental car nameplates should follow the same rules as logos.

Table 6-2 - Rental Car Company Nameplates

Company	Colors
Avis	White on Red
Budget	Blue on White
Dollar	Blue on Yellow
Enterprise	White on Green
Hertz	Black on Yellow
National	White on Green

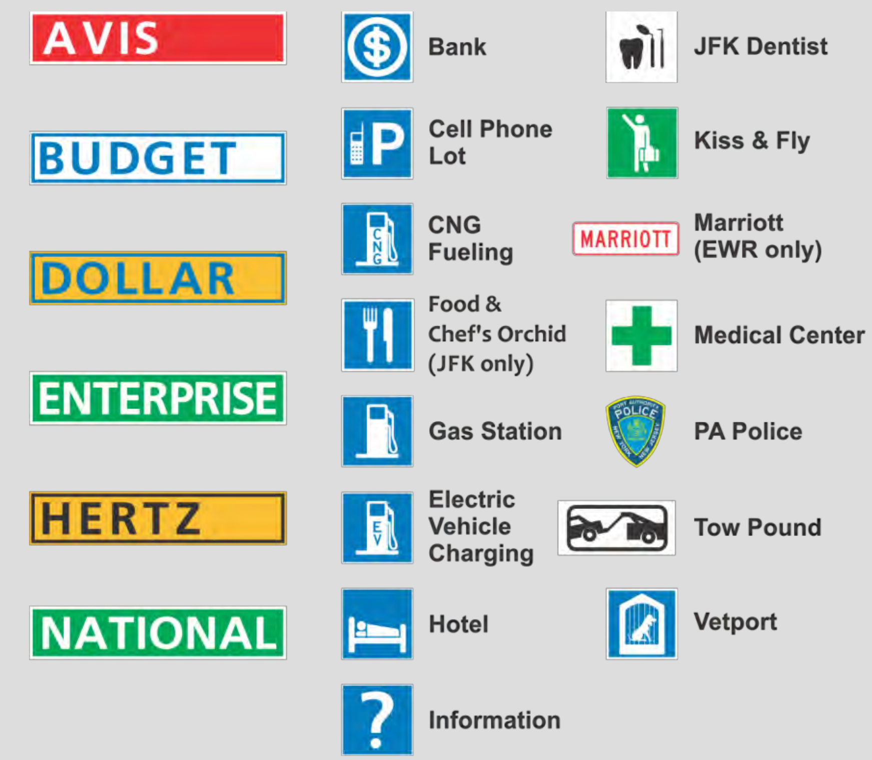


Figure 6-6

6D.2 General Services

General on-airport services include, but are not limited to, those shown in **Figure 6-6**. The related message shall follow the symbol in white text.

- The symbols for Kiss & Fly and Tow Pound shall be placed on signs with green backgrounds followed by the message in white text. No overlay shall be used.
- For the Marriott hotel at Newark Airport, the Marriott logo is used on roadway guide signs with no accompanying message. On frontage signs only, the general hotel symbol is used, followed by the word "Marriott."

The use of any symbol to represent a particular service must be approved by the Port Authority. It shall only apply to the particular service, location, and provider as approved. **Figure 6-6** shows symbols used to represent services. *Section 9B – Service Signs – General Services* includes more information on service-related guide signs.

In the special condition where space constraints do not permit use of a standard guide sign for a service, a small guide sign with logo or symbol and text may be employed, as detailed in *Section 11H – Small Guide Signs*. At Newark Airport, the Port Authority Police are located in the PA Administration Building in Building 1. *Section 11H – Small Guide Signs* describes a special guide sign that is used to direct traffic to Building 1.

6E. Permittee Hold Areas

The symbols shown in **Figure 6-7** shall only be used to designate the Central Taxi Hold and the Permittee, Bus & Limo Staging at JFK Airport. The symbol and text shall have a white legend on a green background and shall be placed directly on the sign with no overlay.

Figure 6-7

6F. Cargo Areas

JFK Airport has four designated cargo areas: Cargo Areas A, B, C, and D. Newark Airport has two designated cargo areas: North Area and South Area. These areas are shown in *Appendix A – Facility Maps*. Only JFK Airport uses logos, as shown in **Figure 6-8**, to designate cargo areas. The logos shall have a white legend on a brown background, and detailed dimensions and other specifications are provided in *Appendix C – Logos and Symbols*.

Figure 6-8

6G. Building Numbers

Building numbers shall be displayed in logos, which may be included on general airport roadway signs or on cargo area signs as discussed in *Section 10 – Cargo Areas*. Building number logos shall follow these rules:

- Logos shall have a black legend on a white background as shown in **Figure 6-9**.
- The logo for a one-digit building number is narrower than the logos for two- and three-digit building numbers. *Appendix C – Logos and Symbols* includes detailed dimensions and specifications of building number logos.
- The horizontal and vertical positioning of building number logos shall be as described in *Section 6H – Placement of Graphic Elements*.
- In most cases, building number logos shall be placed directly on the sign with no overlay. There are two exceptions:
- When logos are included as part of a service-related message, they shall be placed as described in *Section 9B – Service Signs – General Services*.
- When a cargo area message is included on a brown overlay, building number logos related to that cargo area should be placed within the same overlay as shown in Section 3, **Figure 3-6a**.
- Except on directory signs, each row of building number logos shall be aligned to the other messages on the sign and the associated arrow or directional message.

Whenever possible, each building number should be displayed in a separate logo as shown in **Figure 6-9a**. If multiple building numbers must be displayed on a sign but the resulting sign design would exceed height or width constraints, the building numbers may be separated by commas in a single extended logo as shown in **Figure 6-9b**, with detailed dimensions and specifications in *Appendix C – Logos and Symbols*. Building numbers in an extended logo may be on one or more lines depending on sign design constraints. The minimum building number text height in extended logos shall be 10 inches on overhead signs and 6 inches on ground mounted signs.

6H. Placement of Graphic Elements

Special rules on the size, positioning, and spacing of logos and symbols on small guide signs are described in *Section 11H – Small Guide Signs*. Horizontal alignment refers to the positioning of graphic elements to the left, center, or right. Vertical alignment refers to the positioning of graphic elements to the top, center, or bottom.

Figure 6-9a

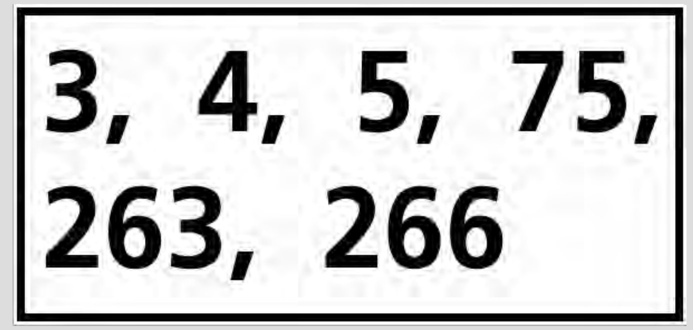


Figure 6-9b

6H.1 Size

The size of a logo or symbol is dependent on the text height:

- On overhead signs without text, the standard size of the logo or symbol shall be 36 inches.
- On ground mounted signs without text, the standard size of the logo or symbol shall be 12 inches.
- For all signs with text, the standard size of the logo or symbol shall be at least 2 times the height of the text.
- The minimum height for a logo or symbol shall be 12 inches.

All logos and symbols on the same sign should be the same height.

6H.2 Positioning

A logo or symbol and its accompanying message should always be perceived by drivers as belonging together, not as two separate elements.

A symbol shall always be placed before the associated text on the same line. The symbol and text shall be horizontally centered.

A logo may be placed on the same line or on a separate line from the associated text. When a logo is placed on the same line as text, the following rules apply:

- Terminal logos at Newark and LaGuardia Airports shall be placed after the word "Terminal" or "Terminals," and otherwise shall be placed before the associated text.
- Terminal and cargo area logos at JFK Airport shall be placed before the associated text.
- Parking lot logos shall be placed after the associated text.
- All logos and text shall be vertically centered.

Figure 6-10 shows examples of signs with terminal logos and **Figure 6-11** shows examples of signs with other logos and symbols.

When there are space restrictions, logos and the associated text may be placed on separate lines, as shown in **Figure 6-12**. The following rules apply:

- The text shall be horizontally centered with respect to the associated logos.
- Terminal logos at Newark and LaGuardia Airports and all parking lot logos shall be placed on the second line, in which case text shall be placed on the first line.
- All other logos shall be placed on the first line, in which case text shall be placed on the second line.
- The vertical spacing between logos and text shall be no greater than the text height. The minimum vertical spacing between logos and text shall be 8 inches for overhead signs and should be 4 inches for ground mounted signs. The minimum vertical spacing for ground mounted signs may be reduced to 3 inches if sign dimensions are constrained.

When multiple lines of text are associated with one or more logos, the following rules apply:

- When one or more logos appear to the left of two or more lines of text that form a single message, the logos shall be top justified to the first line of text, as shown in **Figure 6-10a**.
- When the first line of text is the level number, the logos shall be vertically centered on the first line of text, as shown in **Figure 5-2**.
- In all other cases, the logos shall be vertically centered on the lines of text as shown in **Figure 6-11a**. This includes when the logos appear to the right of the text or when each line of text is a distinct message.

Parking lot logos on different lines shall be horizontally aligned to each other as shown in Section 4, **Figure 4-4**.

When multiple overhead guide signs are next to each other, it may be desirable to configure the signs to look similar (i.e. all terminal logos on top, regardless of message) instead of adhering to the rules in this section. Any such exception for the sake of driver readability shall be approved by Port Authority Traffic Engineering.

Figure 6-10a

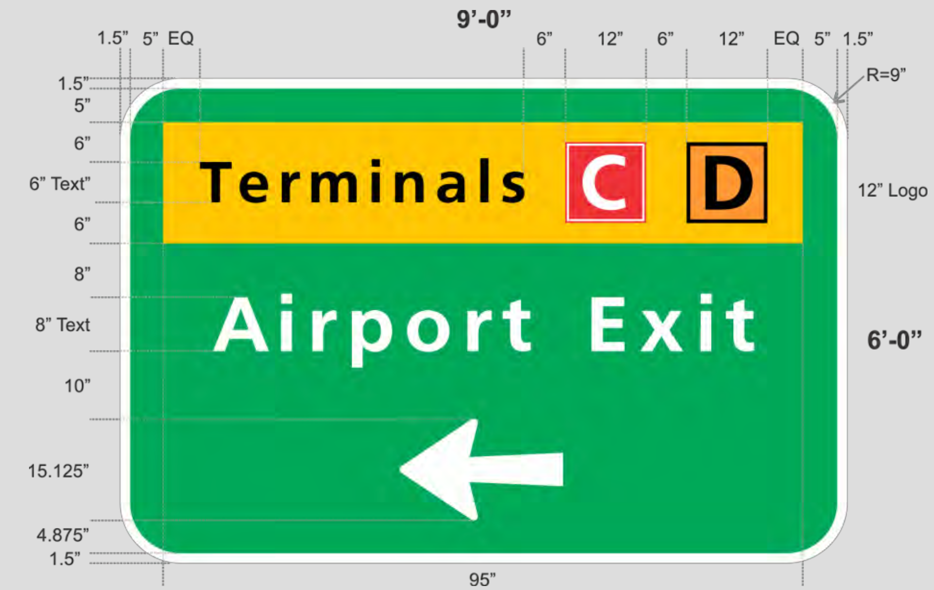


Figure 6-10b

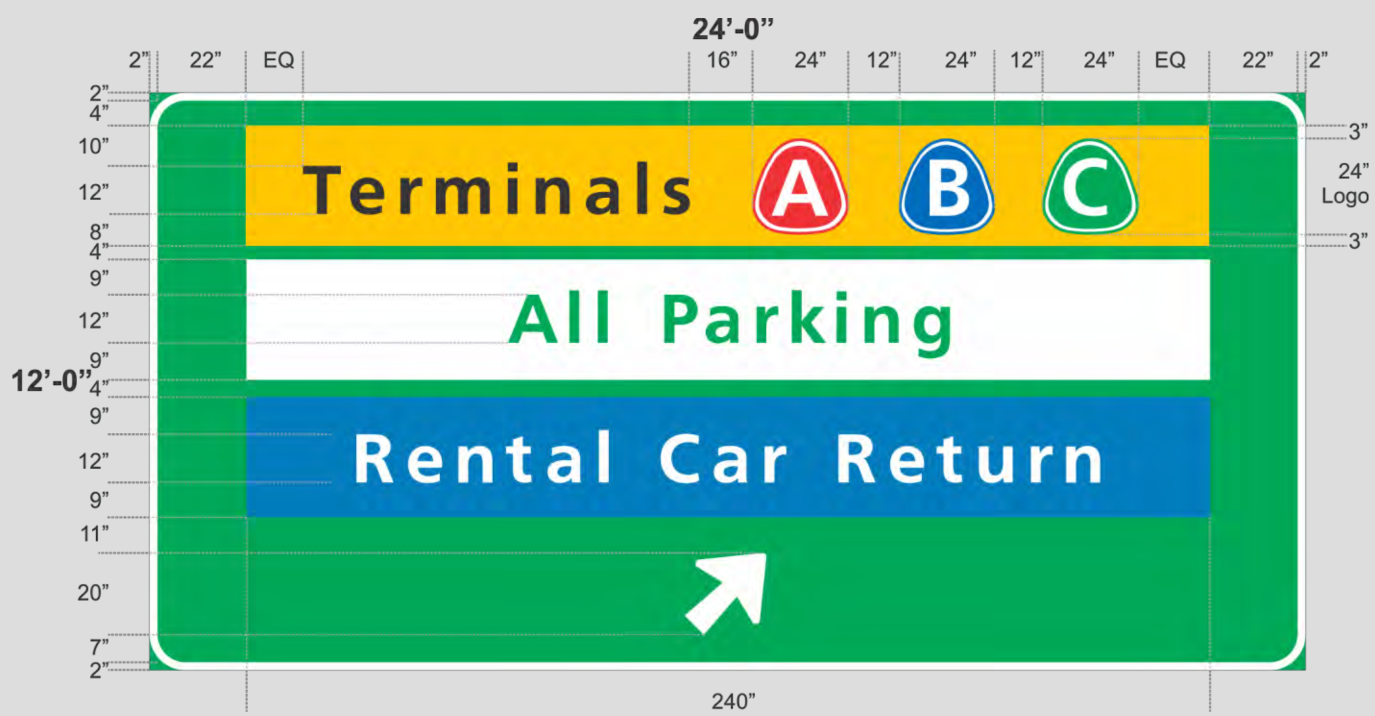


Figure 6-10c

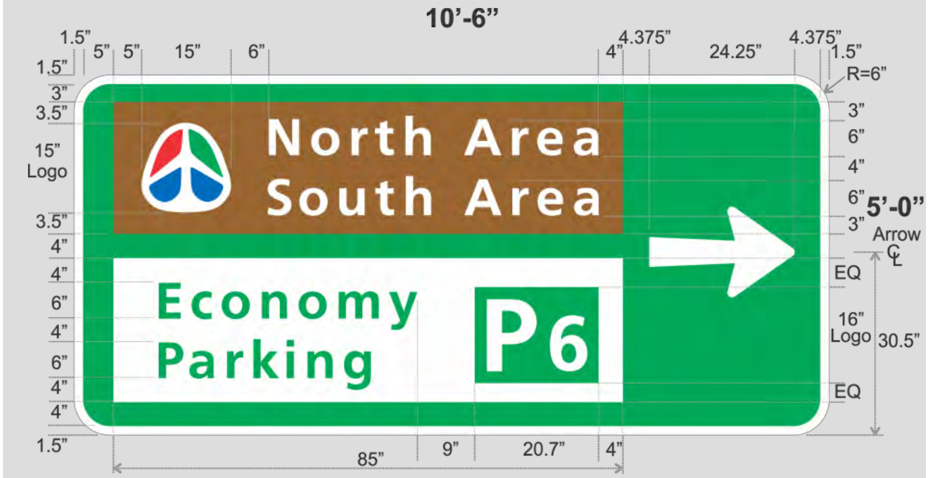


Figure 6-11a

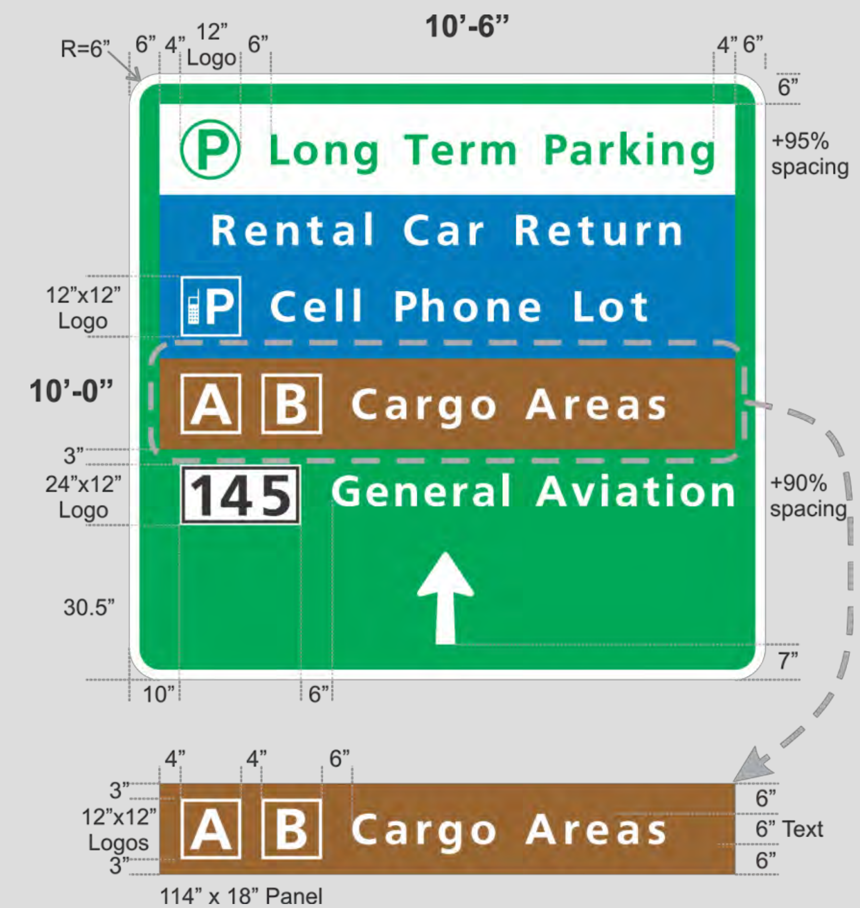


Figure 6-11b

Figure 6-12a

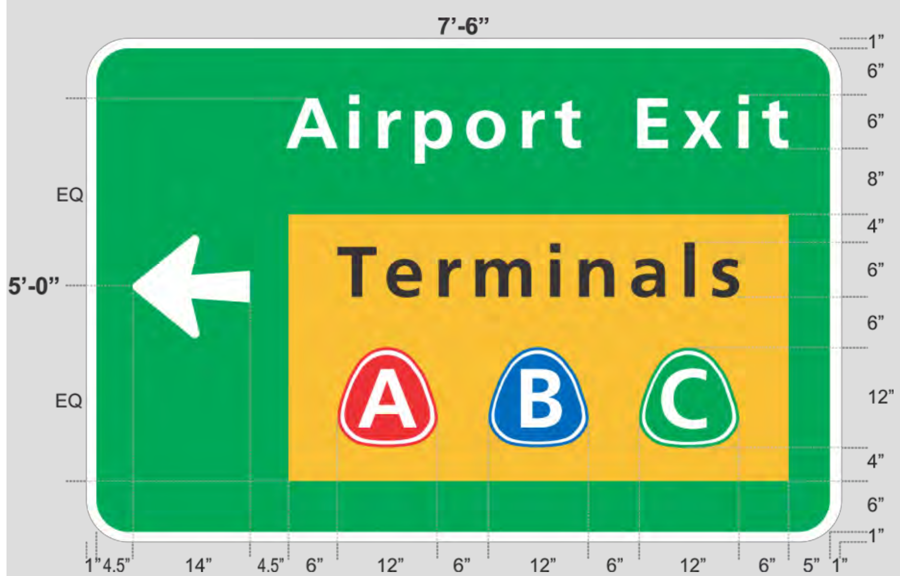


Figure 6-12b

6H.3 Spacing

Figures 6-13 and **6-14** provide an overview of horizontal and vertical spacing requirements. The following spacing rules apply:

- The logo or symbol shall be placed a minimum of 4 inches horizontally from the right or left edge of the overlay and a minimum of 3 inches vertically from either edge of the overlay.
- When the logo or symbol is placed to the left of text, the horizontal spacing to the text shall be a minimum of 4 inches and should be a maximum of the upper case text height. Larger spacing may be warranted on some overhead signs.
- When the logo is placed to the right of text, the horizontal spacing to the text shall be a minimum of the text height.
- There shall never be more than one symbol on any one line, but there may be multiple logos on one line.
- Horizontal spacing between logos depends on the overall size of the sign and the logos.
  - When there is more than one logo on a line, there shall be a 4 inch minimum spacing between the logos.
  - When logos are at least 24 inches tall or on overhead signs, spacing between the logos may be ½ the height of the logos.
- The vertical spacing between logos or symbols should be ½ the height of the logo or symbol, and the minimum spacing shall be 3 inches.

Figures 6-10, **6-11**, and **6-12** show examples incorporating these spacing rules.

Figure 6-13

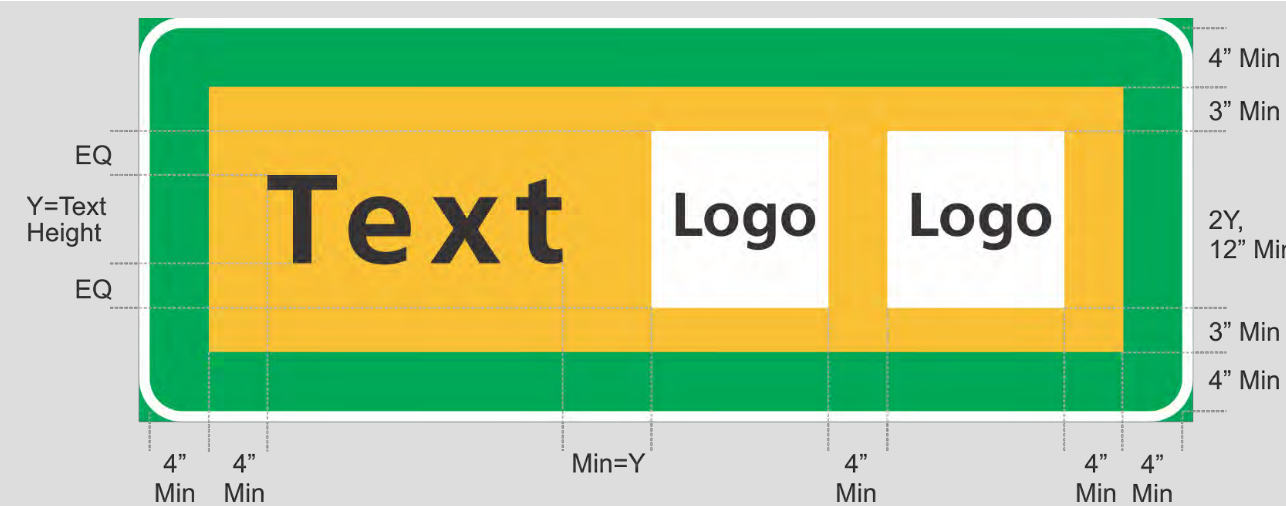


Figure 6-14

7. Arrows

Arrows are used on guide signs to indicate the direction a motorist must take when following the indicated messages.

- Arrows used on small guide signs are discussed in *Section 11H – Small Guide Signs*.
- Arrows used on regulatory and warning signs are discussed in *Section 12 – Regulatory and Warning Signs*.
- Arrows used in parking facilities are discussed in *Section 15A.6 – Parking Facilities – Arrows*.

There are five types of arrows used on guide signs at Port Authority airports: Type A and Type B (up arrows), Type A Extended, Type C (advance turn arrow), and the down arrow. These arrows are described in the *MUTCD*, shown in **Figure 7-1**, and used as described below:

- Type A and B arrows are the primary types used throughout Port Authority airports as described in *Section 7C – Placement*.
- Type A Extended arrows may optionally be used instead of Type A and B arrows where the amount of legend on the sign requires added emphasis on the direction.
- Type C arrows are used at least 200 feet in advance of a turn to pre-position turning vehicles in the correct lanes. Sign location shall follow the guidance given in the *MUTCD*.
- Down arrows shall only be used on overhead signs to indicate one or more lanes to be followed.

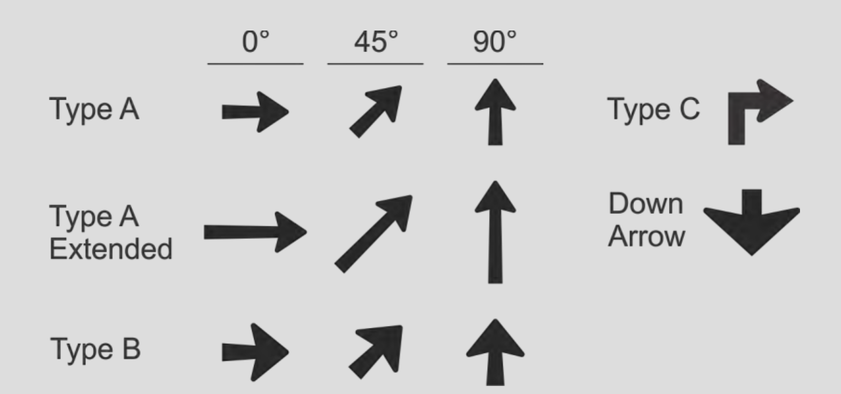


Figure 7-1

Detailed dimensions for these standard arrows are provided in the FHWA's *Standard Highway Signs*.

Arrows shall be pointed at the appropriate angle to clearly convey the direction to be taken. Type A and Type B arrows are typically rotated in increments of 45 degrees, but may be rotated at other angles depending on considerations such as roadway geometry and sign location. Type A and Type B arrows shall always point left, right, or at an upward angle. Type C arrows shall always point upward and either left or right. Down arrows shall always point directly down.

7A. Color

All arrows shall be the same color as the legend.

- Arrows are white when placed on a green, blue, brown, or other dark background.
- Arrows are black when placed on a white, yellow, or orange background.
- Arrows on regulatory and warning signs are designed according to *Section 12 – Regulatory and Warning Signs*.

7B. Size

Arrow sizes shall conform to the dimensions shown in **Table 7-1** for each type. "Width" refers to the width across the arrowhead, while "length" measures from the base of the arrow stem to the point of the arrow.

Table 7-1 - Arrow Sizes

Upper Case Letter Height	Arrow Types and Sizes (Width x Length)				
	Type A	Type A Extended	Type B	Type C	Down
6"	11.25" x 18.25"	11.25" x 22"	8.44" x 9.56" 12.25" x 14"	8.44" x 10.88"	32" x 22"
8"	15.13" x 24.25"	15.13" x 28"	14.25" x 17.25"	14.25" x 18.25"	
10" to 10.67"	18.25" x 29.25"	18.25" x 38"	17.25" x 20.25"	17.25" x 22.38"	
12" to 16"	22.25" x 35.63"	22.25" x 48"	21.88" x 25"	21.88" x 28"	
20"	27.88" x 45"	27.88" x 60"	—	—	

The selection of the appropriate arrow type for a sign depends on several considerations including but not limited to arrow placement, text height, sign location, use of overlays, and dimensions of the sign. In general, the arrow size should be selected from **Table 7-1** based on a width across the arrowhead that is approximately 1.75 times the upper case text height of the major messages on the sign, subject to aesthetic considerations and engineering judgment. Section 6, **Figures 6-10a** and **6- 10b** show the dimensions of arrows and their relationship to text height. The same size arrow shall be used for all messages on one sign as shown in **Figure 7-2**.

For the purpose of sign layout only, the dimensions given in **Table 7-1** may be rounded to the nearest ½ inch. For all other purposes including sign manufacturing, arrow sizes shall conform to this section.

Figure 7-2

7C. Type and Placement

Type A arrows should be used except in the following circumstances:

- Type B arrows should be used for arrows at any angle to the left or right of a single line of text, for vertical up arrows underneath text, or for horizontal left or right arrows to the side of multiple lines of text.
- Type B arrows may be used when Type A arrows do not fit within sign dimension constraints.
- Type A Extended, Type C, and down arrows are used in the circumstances described in paragraph 2 of *Section 7 – Arrows*.

Type A arrows and Type B arrows shall not be used on the same sign.

When two or more signs are next to each other, the same arrow types should be used on all of those signs and the signs should be arranged with a similar layout.

Horizontal centering refers to the positioning of the arrow relative to the left and right. Vertical centering refers to the positioning of the arrow relative to the top and bottom.

7C.1 Overhead Signs

Down arrows shall be located at the bottom of the sign and shall point vertically downward within one foot (plus or minus) of the center of the lane. The arrows should be horizontally centered on the sign if possible.

Down arrows shall only be used on a sign if one arrow points to the center of each lane indicated by the destinations on the sign. These rules and guidelines are shown in **Figure 7-3**.

Up arrows and down arrows shall not both be used on the same sign.

Type A and Type B arrows should be located at the bottom of the sign and horizontally centered on the sign, as shown in **Figure 7-4**. If there are restrictions on the height of the sign:

- The arrow may be placed on the same line of text as the message, to the same side of the text as the arrow direction (either side for an up arrow pointing straight ahead) and vertically centered on the message, as shown in **Figure 7-5**.
- The arrow may be placed on the same side of the overlays as the direction of the arrow (either side for an up arrow pointing straight ahead), vertically centered between the top and bottom edges of the overlays, as shown in **Figure 7-6**.

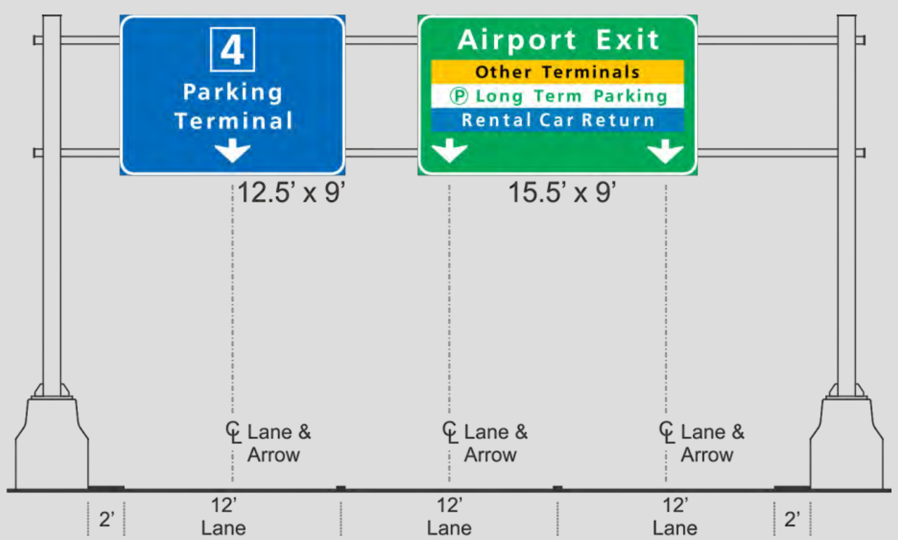


Figure 7-3

Figure 7-4

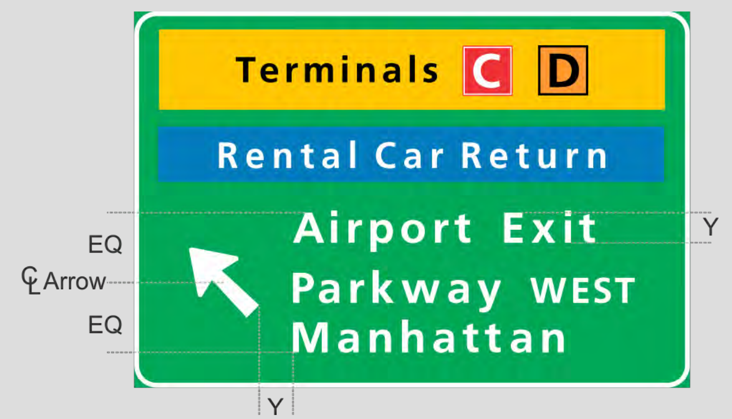


Figure 7-5

Figure 7-6

7C.2 Ground Mounted Signs

The following rules apply to ground mounted signs:

- Arrows should be located in the green space on either or both sides of the sign. The arrow shall be placed at the side of the sign that will reinforce the movement of exiting traffic. For a straight-through movement, the arrow should be placed on the side of the sign closest to the driver.
- When arrows are placed on the side of the sign, each arrow shall be vertically centered on the related lines of text or overlays.
- Signs should never have more than one arrow pointing in any single direction.
- Down arrows shall not be used.

Figures 7-2 and **7-7** show positioning and vertical alignment of arrows.

Figure 7-7

The placement of arrows pointing different directions on the same sign follows the message hierarchy discussed in *Section 3 – Message Hierarchy*, as shown in **Figure 7-8**.

In some cases, the width of ground mounted signs may be restricted due to location, placement, proximity of other signs, etc. In these limited circumstances, the arrow may be placed horizontally centered at the bottom of the sign, as shown in **Figure 7-9**.

7D. Spacing

Spacing is defined in terms of the upper case text height used on the sign. The upper case text height is shown as "Y" in the figures referenced in this section.

7D.1 Overhead

Spacing from the last line of text, bottom of the overlay, or bottom of the logo to the near edge of the arrow should be a minimum of ¾ of the largest upper case text height used on the sign as defined in *Section 4B – Text Height*. Spacing from the edge of the border or message separator line to the near edge of the arrow should be approximately ¾ of the largest upper case text height. **Figure 7-10** shows spacing of arrows on overhead signs.

7D.2 Ground Mounted

Spacing from the edge of arrow to the inner edge of the border, message separator line, logo, or overlay should be a minimum of 4 inches. A minimum space equal to the upper case text height should be maintained from the edge of arrow to a directly applied (not on an overlay) line of text. **Figure 7-11** shows spacing of arrows on ground mounted signs.

Figure 7-8

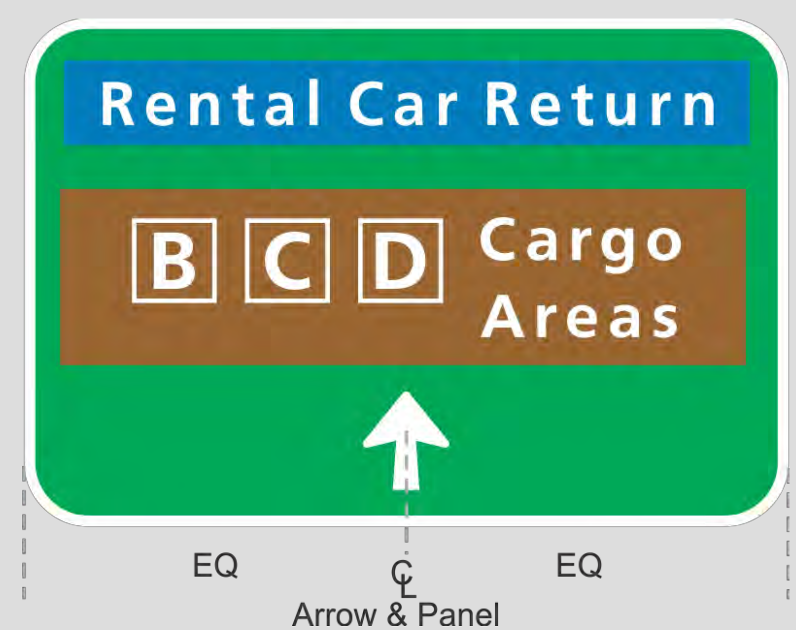


Figure 7-9

Figure 7-10

Figure 7-11

8. Panel Design

Panels for guide signs shall be sized in 6-inch increments. All ground mounted signs shall have rounded corners and all overhead signs shall have square corners with no rounding.

8A. Borders

Borders are used on signs to give them target value, particularly at night. Accordingly, all on-airport roadway signs shall have borders except Facility Identification signs, as discussed in *Section 11C – Facility Identification Signs*. On both ground mounted and overhead signs, all borders shall have rounded corners as defined in *Section 8B – Corner Radii*.

The border shall be the same color as the legend:

- The border is white on signs with a green, blue, brown, or other dark background.
- The border is black on signs with a white, yellow, or orange background.
- The border on regulatory and warning signs is designed according to *Section 12 – Regulatory and Warning Signs*.

When the border is black, it shall be inset from the edge of the sign, and the space between the border and the edge of the sign shall be the same color as the sign background.

The border dimensions shown in **Table 8-1** shall be used for all overhead and ground mounted roadway signs.

Table 8-1 - Border Width

Location and Sign Area		*Border Width*	*Black Border Inset*
All overhead signs		2”	1.5”
Ground mounted signs	< 20 ft^2	1”	0.625”
	$20\ ft^2 – 40\ ft^2$	1.25”	0.75”
	> $40\ ft^2 – 60\ ft^2$	1.5”	1”
	> 60 ft^2	2”	1.5”

The stroke width of the lettering used for the primary sign message should be thicker than the border width.

Borders for parking lot and garage signs are as described in *Section 15A.1 – Parking Facilities – General Rules and Guidelines*.

8B. Corner Radii

The corner radius of airport guide signs shall be determined from **Table 8-2** except that the radius shall be no greater than the height of the primary sign message. The corner radius shall always be a multiple of 3 inches. Border widths and insets shall be maintained around the corners.

- On ground mounted signs (rounded corners), the corner radius is defined as the radius applied to the outside edge of the sign.
- On overhead signs (square corners) with a white border, the corner radius is defined as the radius applied to the outside edge of the border.
- On overhead signs (square corners) with a black border, the corner radius is defined as the radius applied to the outside edge of the inset.

Table 8-2 - Corner Radius

Length of Shortest Side	*Corner Radius*
36” or less	3”
42” – 60”	6”
66” – 84”	9”
90” or more	12”

Regulatory and warning signs shall have a corner radius in compliance with the latest edition of the *MUTCD*, as discussed in *Section 12 – Regulatory and Warning Signs*.

8C. Message Separator Lines

Message separator lines are used to separate different message groups as described in *Section 3 – Message Hierarchy* and to separate messages on overlays as described in *Section 8C.2 – Signs with Overlays*. Section 7, **Figures 7-7** and **7-8** show examples of signs with message separator lines. Message separator lines shall follow these rules:

- Message separator lines on guide signs shall be the same color as the border.
- Message separator lines on overlays shall be the same color as the text on the overlay.
- The width of the separator line shall be at least half the border width and no more than equal to the border width, and shall be rounded to the nearest 0.25 inches.
- Except as described in Sections 8C.1 and 8C.2, all message separator lines shall begin and end at the inside edge of the border or at the edge of another separator line.

8C.1 Signs with Headers

A header is a message at the top of the sign that applies to all of the messages on the sign. The header may or may not have a horizontal message separator line (header separator line) separating it from other messages on the sign. **Figure 8-1** shows examples of signs with headers.

- A header separator line shall be used if there are any other horizontal message separator lines on the sign and otherwise may be omitted.
- When it is used, the header separator line shall extend between the inside edges of the left and right border of the sign.
- Other horizontal message separator lines shall extend at least to the leftmost and rightmost edges of the message (including text, arrows, logos, and symbols). The ends of horizontal message separator lines should be at least 4 inches from the inside edge of the border.
- If there is a header separator line, vertical message separator lines shall extend between the header separator line and the inside edge of the bottom border of the sign.
- If there is no header separator line, vertical message separator lines should extend to the bottom and top edges of the message. The message includes text, arrows, logos, and symbols, but does not include descenders on lower case letters like "p" and "g." The separator lines may instead extend to the inside edge of the bottom border.

8C.2 Signs with Overlays

If an overlay has a header message, refer to *Section 8C.1 – Signs with Headers*. References to "inside edge of border" in that Section should be construed as "edge of overlay."

If an overlay does not have a header message, message separator lines on overlays should extend to the edges of the overlay. Separator lines may instead extend to the left and right edges or top and bottom edges of the message. The message includes text, arrows, logos, and symbols, but does not include descenders on lower case letters like "p" and "g."

Figure 8-1a

Figure 8-1b

9. *Service Signs*

Signs that include both service-related messages and other messages shall be designed as standard guide signs according to Sections 2 through 8 of this Manual. Signs that include only service-related messages shall follow the principles in Sections 2 through 8, modified by the rules and guidelines given in this Section.

All signs that include only service-related messages shall use the arrow hierarchy described in *Section 3C – Arrow Hierarchy*. Messages associated with the up arrow shall be listed first, followed by messages associated with the left, right, and down arrows. Messages associated with a directional message shall be listed last.

9A. Rental Car Messages

"Rental Car Return" shall be the message used on all inbound roadway signs and any other signs directing traffic between the airport entrance and rental car lots. "Rental Cars" shall be the message used on signs displaying company nameplates, such as on roadways primarily serving rental car lots, to direct motorists between different rental car businesses.

Service signs that include only rental car-related messages shall be designed according to the following rules. A typical example is shown in **Figure 9-1**.

- The sign shall have white legend on a blue background and no overlays shall be used.
- The sign shall have a header message of "Rental Cars" with a separator line below.
- The only graphic elements that shall appear on the sign are rental car company nameplates, arrows, and directional messages.

Rental car company nameplates are demountable panels with allowable colors and company names as listed and described in *Section 6D.1 – Graphic Elements – On-Airport Services – Rental Car Companies*. As shown in **Figure 9-1**, the following rules and guidelines apply to nameplate layouts:

- Nameplates on ground-mounted signs should measure 48 inches wide and 10 inches tall. The Port Authority will provide modified nameplate dimensions if application to an overhead sign is required.
- Nameplates should follow the same layout criteria as logos and symbols as described in *Section 6H – Placement of Graphic Elements*, except the minimum spacing on any side of a nameplate to any other sign panel element (including other nameplates, text, edge of overlay, border, etc.) may be reduced to 3 inches.
- Nameplate specifications are detailed in *Appendix C – Logos and Symbols*.

The dimensions shown in **Figure 9-2** shall only be used if the smaller nameplates result in a beneficial reduction in sign size. The same dimensions shall be used for all nameplates on a sign.

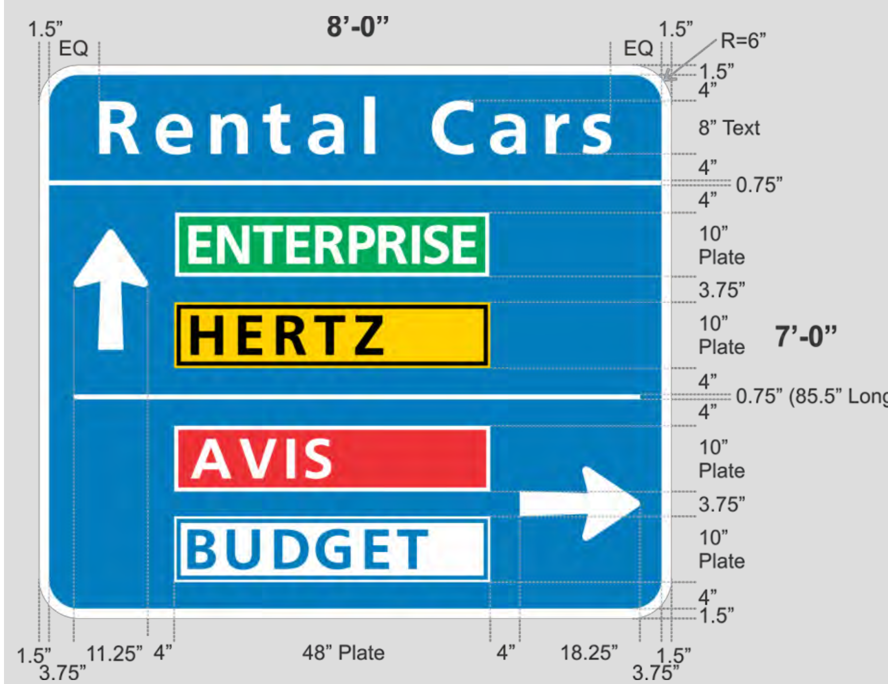


Figure 9-1a

Figure 9-1b

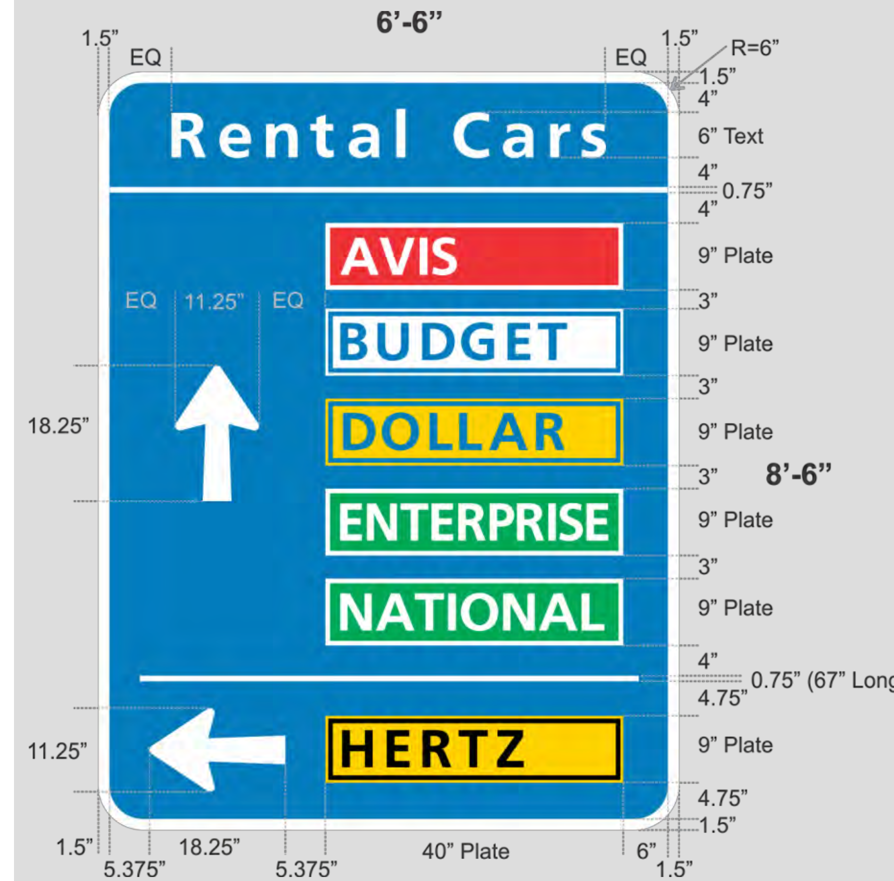


Figure 9-2a

Figure 9-2b

9B. General Services

Appendix B – Sign Terminology includes a list of approved service message terminology. The use of any symbol or terminology representing a particular service must be approved by the Port Authority.

Symbols related to on-airport services are described in *Section 6D.2 – Graphic Elements – On-Airport Services – General Services* and shown in Section 6, **Figure 6-6**. The application of these symbols to guide signs is shown in **Figures 9-3** and **9-4**:

- **Figure 9-3a** shows an example where the service has an associated symbol.
- **Figure 9-3b** shows an example where the service has no associated symbol but the associated building number is used for navigation.
- **Figure 9-4** shows examples where the service has both an associated symbol and building number used for navigation.
    - When a service has an associated symbol, the building number is also displayed when other signs used for navigation to the building display only the building number.
    - The symbol shall appear before the name of the service and the building number shall appear after as shown in **Figure 9-4a**, unless there are other services listed only with building numbers.
    - When there are other services listed only with building numbers, the building number shall appear before the name of the service and the symbol shall appear after as shown in **Figure 9-4b**.

In the special condition where space constraints do not permit use of a standard guide sign for a service, a small guide sign with symbol and text may be employed. Design considerations are discussed in *Section 11H – Small Guide Signs*.

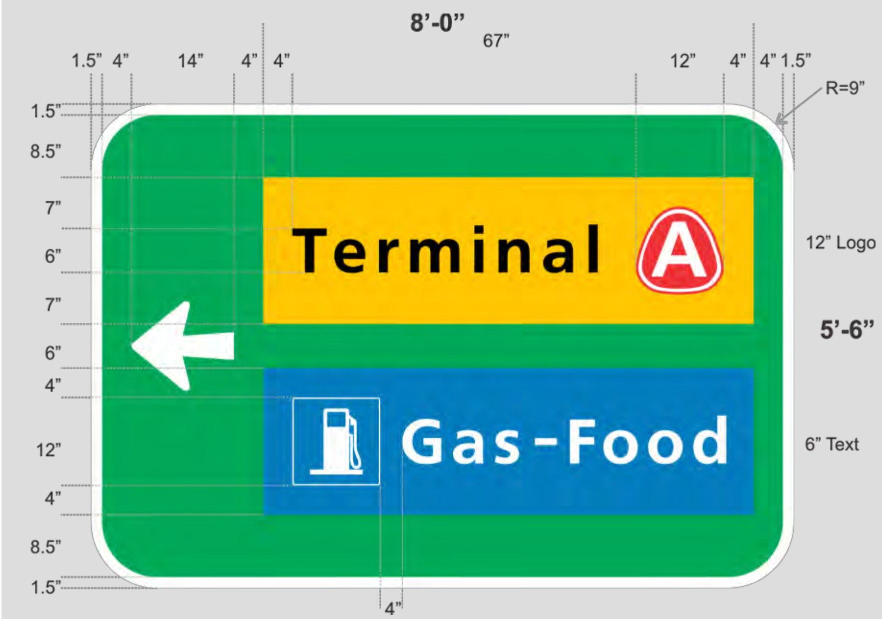


Figure 9-3a

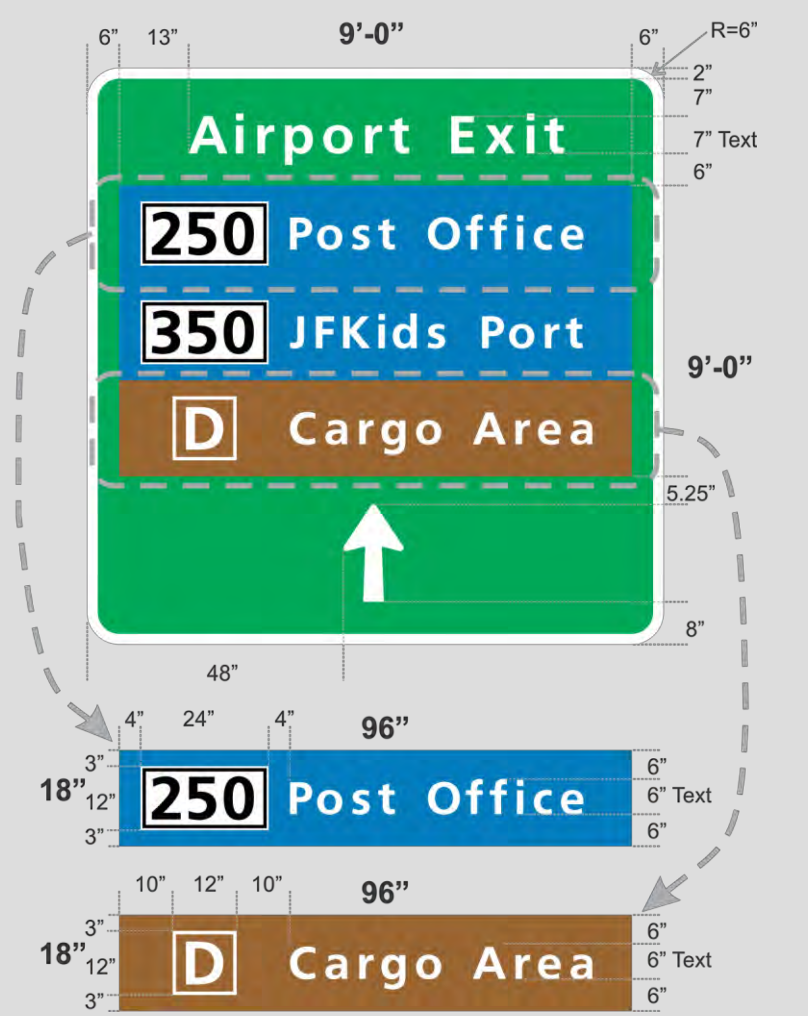


Figure 9-3b

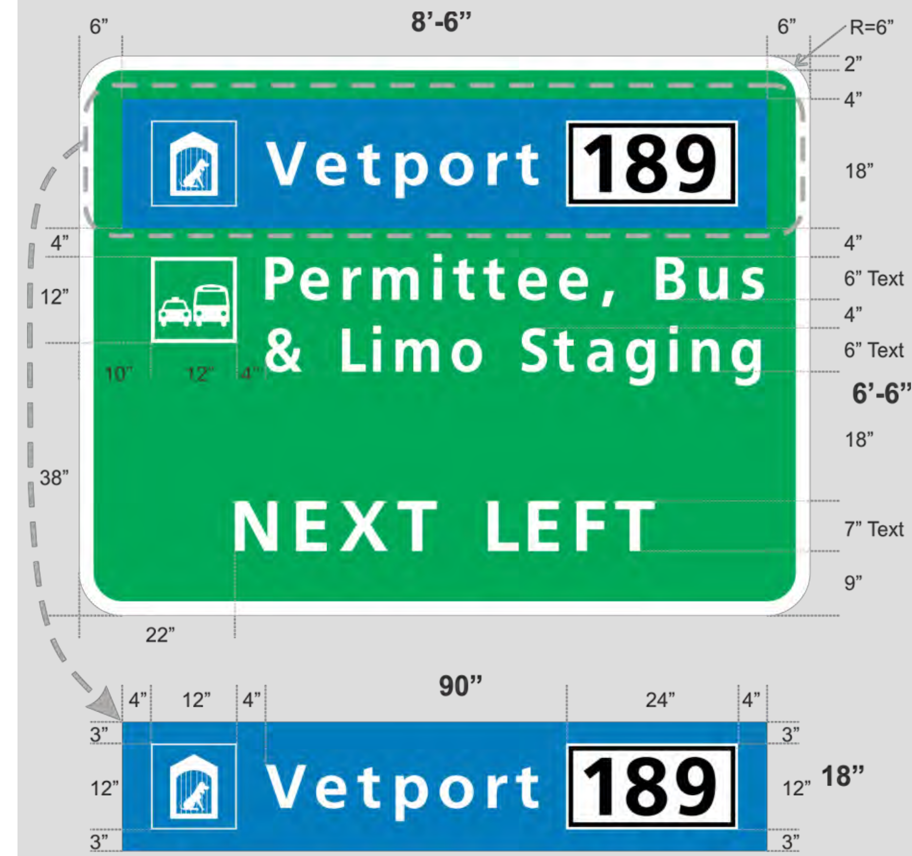


Figure 9-4a

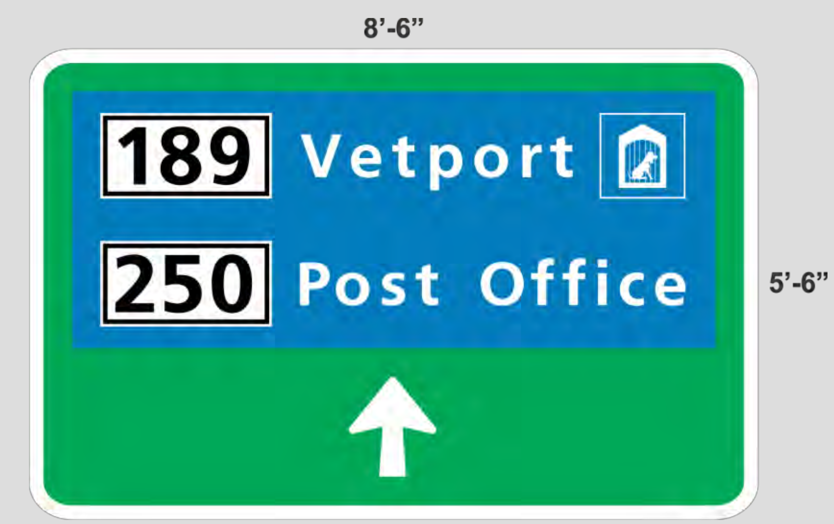


Figure 9-4b

10. Cargo Areas

JFK Airport has four designated cargo areas: Cargo Areas A, B, C, and D. Newark Airport has two designated cargo areas: North Area and South Area. These areas are shown in *Appendix A – Facility Maps*.

- All guide signs with cargo-related messages located outside these areas, including at other airports, shall be designed as standard guide signs according to Sections 2 through 8 of this Manual.
- Inside or entering designated cargo areas, signs that include both cargo-related messages and other messages shall be designed as standard guide signs according to Sections 2 through 8 of this Manual.
- Signs that include only cargo-related messages shall follow the principles in Sections 2 through 8, modified by the rules and guidelines given in this Section.

All signs that include only cargo-related messages shall use the arrow hierarchy described in *Section 3C – Arrow Hierarchy*. Messages associated with the up arrow shall be listed first, followed by messages associated with the left, right, and down arrows. Messages associated with a directional message shall be listed last.

Cargo areas at JFK Airport are represented by logos consisting of the letter designation in white legend on a brown background. These logos are shown in Section 6, **Figure 6-8**.

There are three types of cargo area guide signs with only cargo-related messages:

- Signs with directional messages related to multiple cargo areas, as described below.
- Signs with directional messages related to one cargo area, which shall be designed according to *Section 10A – Directional Signs*.
- Building directory signs, which shall be designed according to *Section 10B – Building Directory Signs*.

Signs with directional messages related to multiple cargo areas shall be designed as standard guide signs according to Sections 2 through 8 of this Manual, except the word "Building(s)" or "Bldg(s)" and the associated building numbers are included on the brown overlay. A typical example is shown in **Figure 10-1**. The word "Building(s)" or "Bldg(s)" may be either:

- On the same line as the building number logos, vertically centered with the logos.
- On the line above the building number logos, left justified with the leftmost logo.

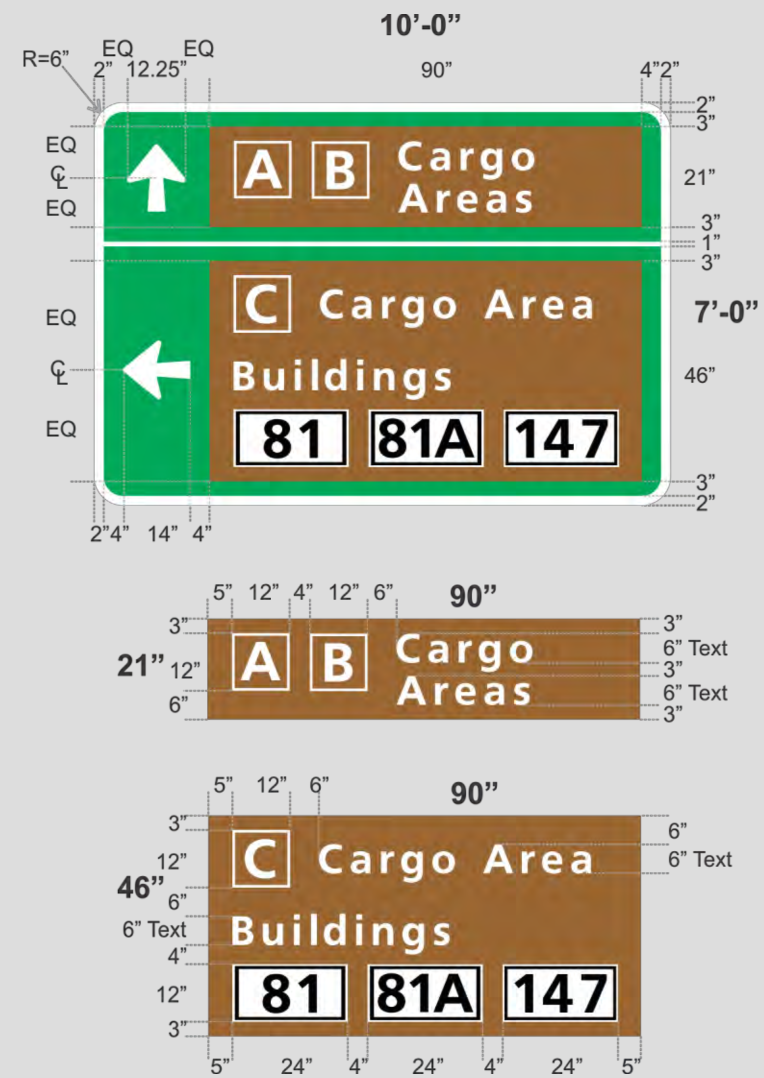


Figure 10-1

10A. Directional Signs

In the context of this Section, directional signs are defined as cargo area signs used to direct motorists to different buildings within a particular cargo area. A typical example is shown in **Figure 10-2**. Cargo area directional signs shall be designed according to the principles described in Sections 2 through 8 of this Manual. The sign shall comprise the following elements:

- A header consisting of the name of the cargo area (and logo if applicable) in white legend on a brown background with a separator line below.
- The building numbers preceded by "Building(s)" or "Bldg(s)" in white legend on a green background. Tenants shall not be listed, except Fixed Base Operators (FBOs) may be listed if they provide public services or operations. Building number logos shall be designed and arranged on the sign as described in *Section 6G – Building Numbers*.

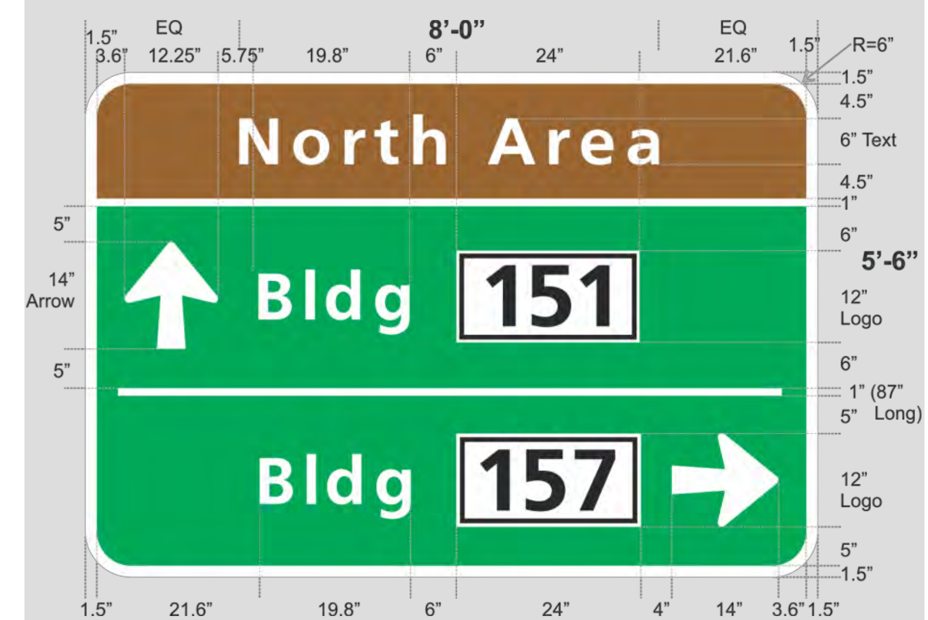


Figure 10-2

10B. Building Directory Signs

Building directory signs are only located at or along building driveways. Some buildings do not have directory signs.

Rules for airline names and capitalization are given in *Section 11D – Airline Directory Signs*. Tenants shall be listed in alphabetical order without providing any distinction for subtenants.

Building directory signs shall be sized to accommodate the maximum number of anticipated tenants. Depending on sign dimension constraints, tenants may be listed in more than one column.

Typical building directory signs are shown in **Figure 10-3**. Building directory signs shall be designed according to the principles described in Sections 2 through 8 of this Manual. The sign shall comprise the following elements:

- A header consisting of the name of the cargo area (and logo if applicable) in white legend on a brown background with a separator line below.
- The building numbers and arrow in white legend on a green background. Building number logos shall be designed as described in *Section 6G – Building Numbers*.
- Tenant listings consisting of demountable nameplates with white text on a green background and no border. The outlines in **Figure 10-3** are only shown for display purposes to represent the extents of the nameplates.

Building directory signs are designed according to the following rules and guidelines:

- The minimum text height of the tenant names shall be 6 inches.
- A minimum horizontal separation of 2 inches shall be maintained between columns of demountable tenant nameplates.
- Columns of demountable tenant nameplates should be separated by a message separator line horizontally centered between the edges of the nameplates. The message separator line should extend from the bottom of the bottommost nameplate to the top of the topmost nameplate.

The Port Authority desires to maintain consistency in nameplate dimensions between different signs so that nameplates may be reused if tenants move between buildings. Whenever possible, new nameplates should be designed to match the dimensions of existing nameplates on signs at that facility. Note that existing signs may reflect prior facility policies on indentation, font sizes, or color schemes, particularly in regard to distinguishing subtenants. These policies shall not be followed on new signs, including the consideration of reusing existing nameplates.

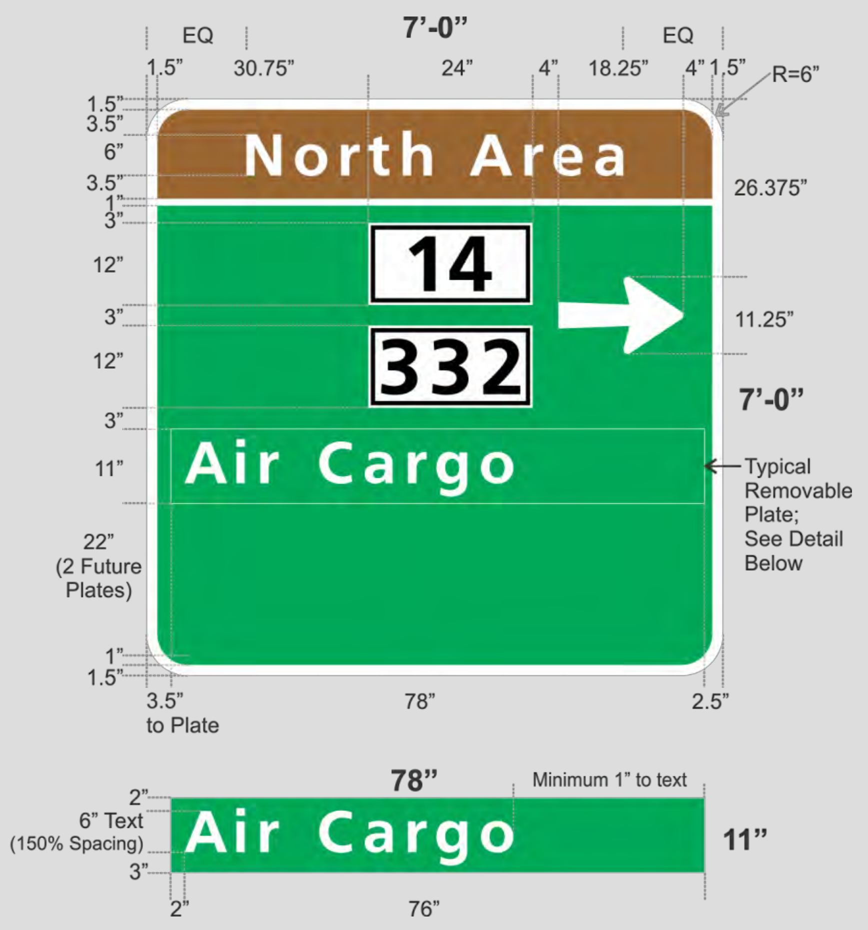


Figure 10-3a

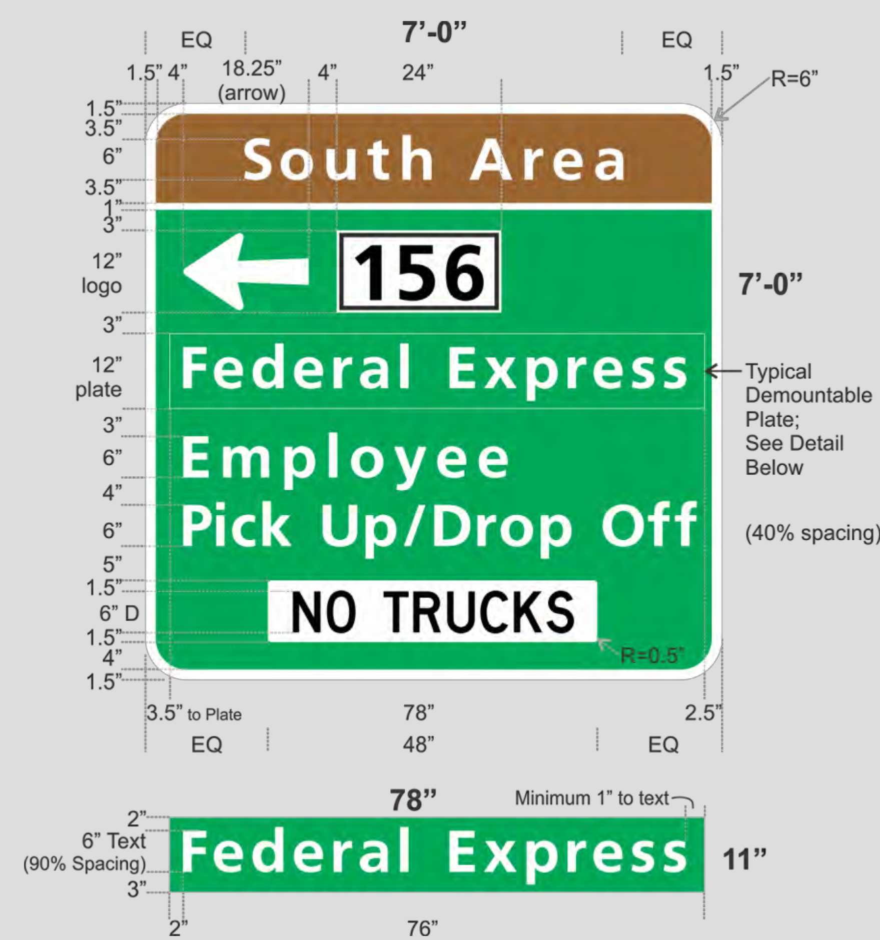


Figure 10-3b

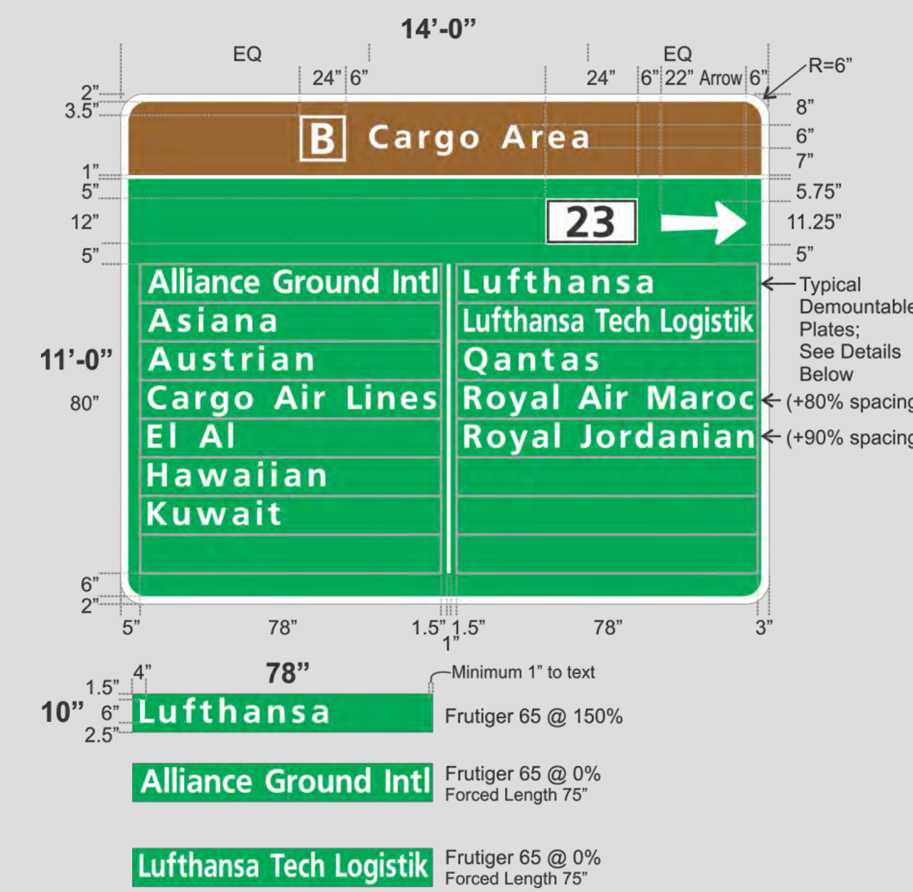


Figure 10-3c

11. Specialized Guide Signs

This section discusses cases of guide signs found throughout airport property that follow special design rules and guidelines. Each subsection discusses a particular type of sign and the particular rules associated with it. Unless otherwise described in this section, signs are designed according to the same principles as regular airport guide signs as described in Sections 2 through 8.

11A. General Aviation

General aviation includes private aircraft operations and various types of cargo and chartered aircraft services provided by Fixed Base Operators (FBOs). Unlike other building tenants, FBOs may be listed on relevant directional signs as well as building directory signs.

- Teterboro Airport functions as a general aviation airport and does not accommodate scheduled carrier operations. At Teterboro Airport, all FBOs shall be listed on guide signs, which shall be designed as standard guide signs according to Sections 2 through 8 of this Manual. The names of FBOs are considered terminal messages and shall therefore appear in black legend on a yellow overlay. All FBOs and other tenants shall be listed in alphabetical order on demountable nameplates. Section 2, **Figure 2-5** shows an example of a Teterboro general aviation guide sign.
- At all other airports, FBOs are only listed if they provide public services or operations. General aviation facilities are signed using building number logos as described in *Section 6G – Building Numbers*. FBOs shall be listed with white text on a green background.
    - FBOs may be listed on directional signs, which are designed according to *Section 10A – Directional Signs*.
    - FBOs listed on building directory signs should be listed the same way as tenants as described in *Section 10B – Building Directory Signs*.

11B. Building Façade Signs

Building façade signs are not strictly guide signs, but are relevant to this Manual because they are used by motorists to locate their destination. Therefore, the signs must be mounted to maximize visibility to approaching motorists:

- Signs should be located toward the top of the building and not at eye level.
- The recommended location is an offset of 2 feet from the top and side of the building, adjusted for visibility and physical obstructions.
- One sign shall be mounted on each side of the building that faces approaching traffic. Approaches from parking lots or dead end roads are excluded.
- Minor approaches to small buildings may also be excluded on a case by case basis with Port Authority approval.

Figure 11-1 shows a typical building façade sign installation.

Signs shall be designed with black legend on white background, indented borders and square corners as shown in **Figure 11-2**.

Because they are mounted to buildings, façade signs do not have the same limitations in sign size as guide signs:

- **Figure 11-2a** shows recommended sign dimensions for one-story buildings.
- **Figure 11-2b** shows recommended sign dimensions for multi-story buildings.
- Sign dimensions vary according to the height of the building and the number of digits (including letters) in the building number.
- Variation from the recommended dimensions is permissible to meet the sign visibility criteria established in the *MUTCD* depending on the mounting height, approaching roadway geometry, and speed of approaching traffic.

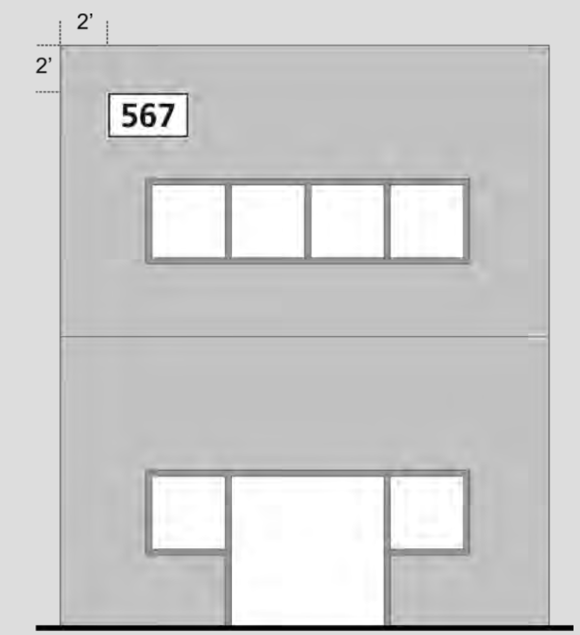


Figure 11-1

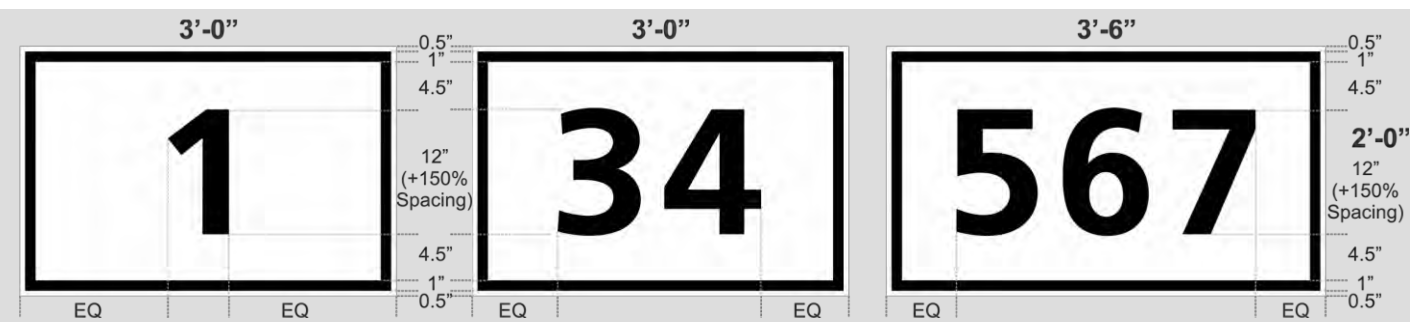


Figure 11-2a

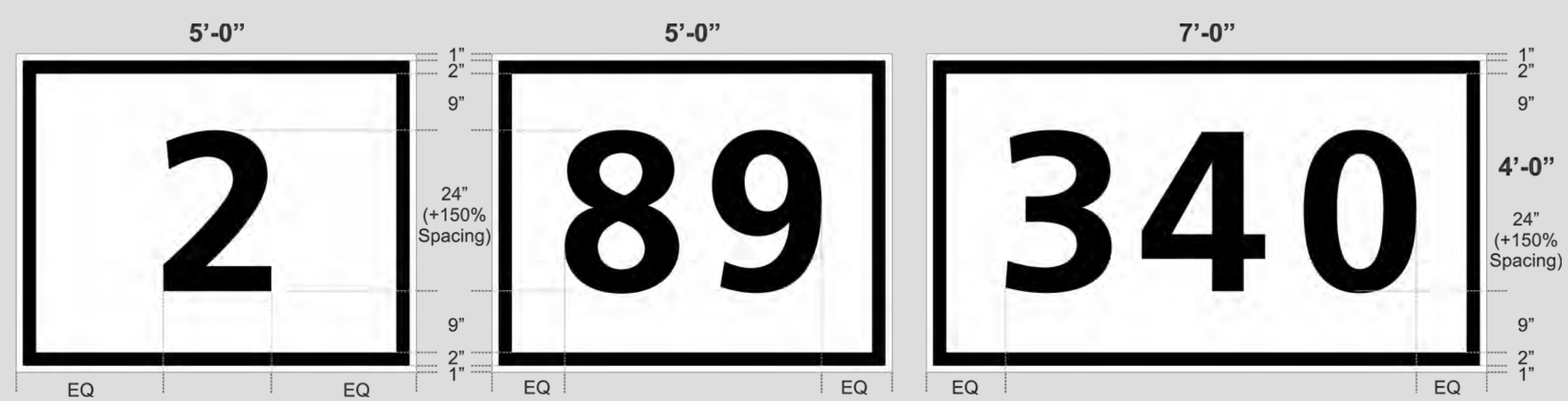


Figure 11-2b

11C. Facility Identification Signs

Facility identification signs are found at entrances to airport property. The locations and placement of the signs are subject to engineering judgment given that guide, regulatory and warning signs have priority to motorists. The dimensions of a facility identification sign depend on the constraints of location and placement, avoiding obstructing messages on other roadway signs.

As shown in **Figure 11-3**, the top of the sign is designed with the facility name in white legend on a light blue background, and the bottom of the sign consists of the Port Authority logo in white legend on a blue background. Inter-letter spacing shall be +0%. Additional rules, including text and logo placement and proportion requirements, are provided by Port Authority Marketing and Port Authority Aviation.

Figure 11-3a

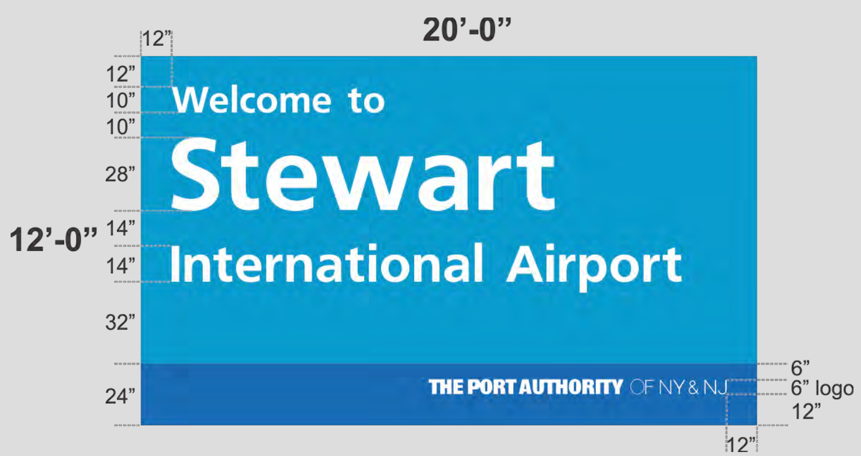


Figure 11-3b

11D. Airline Directory Signs

Airline directory signs are lists of airlines associated with each terminal, located along inbound roadways. Airline directory signs shall be located in ascending terminal order starting with "A" or "1." If there is insufficient advance distance to locate directory signs for all terminals in order, at a minimum the directory sign for each terminal shall be located in advance of the exit or roadway leading to that terminal.

Typical airline directory signs are shown in **Figures 11-4** to **11-6**:

- JFK Airport: **Figure 11-4** shows a ground mounted sign on an inbound roadway.
- Newark Airport: **Figure 11-5a** shows an overhead sign and **Figure 11-5b** shows a ground mounted sign on an inbound roadway.
- LaGuardia Airport: **Figure 11-6a** shows a ground mounted sign on an inbound roadway and **Figure 11-6b** shows a ground mounted sign on a recirculation roadway.
- Stewart Airport: There are no airline directory signs on roadways because there is only one passenger terminal.

11D.1 Airline Listing Criteria

Airline names follow these rules:

- Airline names shall be listed in alphabetical order.
- The first letter of each word within an airline name shall be capitalized and the remaining letters shall be lower case. All letters of an abbreviation shall be capitalized only if the abbreviation consists entirely of initials, such as "KLM." These rules are shown in **Figure 11-4**.
- The word "Air" shall be listed if it comes before the name of the airline, such as "Air India." The words "Air," "Airlines," or "Airways" are omitted if they come after the name of the airline, such as "Alaska." The Port Authority retains the sole discretion to list the words "Air," "Airlines, or "Airways" after the name of the airline if omission would cause confusion, such as "Jet Airways." These rules are shown in **Figure 11-5a**.
- The space between words in an airline name is omitted from the listing if it is omitted in the official airline name, such as "JetBlue," as shown in **Figure 11-5b**.
- Airline names shall not be displayed with corporate logos or other branding.

To reduce the number of airline names that must be read by motorists who enter the airport at moderate to high speeds:

- Codeshare partner airlines that do not operate aircraft at the terminal are not listed.
- Charter services are not listed.
- Subsidiaries operating in the same terminal as the parent airline may be omitted.

Only if approved by Port Authority Traffic Engineering, the listing for an airline may be subdivided to show specific operations. This may occur where one airline has different destinations, services, or operations located in different levels or terminals. An example is shown in **Figure 11-6a**.

11D.2 Sign Design Rules and Guidelines

Airline directory signs should be sized to accommodate the maximum number of anticipated airlines at the terminal, but if all of the airlines associated with a single terminal will not fit within a single sign, two or more consecutive signs may be used. Depending on sign dimension constraints, airlines may be listed in two columns. When there are physical constraints due to roadway configuration, listings for two terminals may be combined on one sign as shown in **Figure 11-6a**.

At JFK Airport, airline directory signs are designed as shown in **Figure 11-4**:

- Header with the terminal designation using the legend and background colors associated with that terminal's zone.
- White header separator line.
- Airline names listed on demountable nameplates in white legend on a gray background with no border. The outlines in **Figure 11-4** are only shown for display purposes to represent the extents of the nameplates.

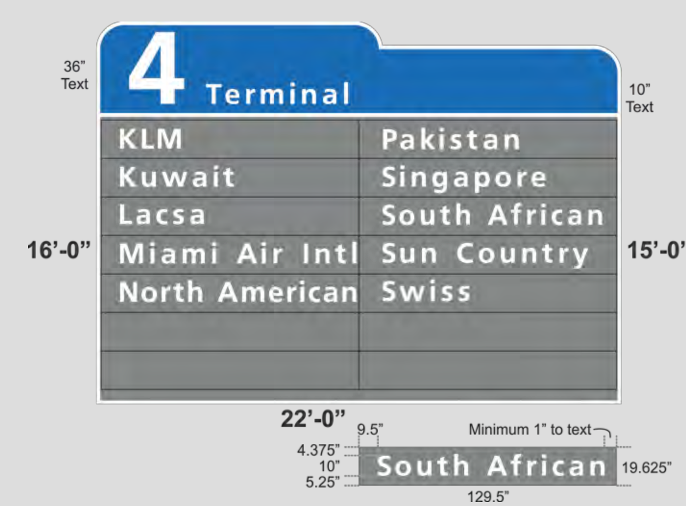


Figure 11-4

At Newark and LaGuardia Airports, airline directory signs are designed as shown in **Figures 11-5** and **11-6**:

- The sign shall start with white legend on a green background. Typically, the sign border is the only element of white legend on the sign, but there may be an arrow or directional message.
- Terminal messages, including airline names listed on demountable nameplates, shall be in black legend on a yellow overlay with no border. The outlines in **Figures 11-5** and **11-6** are only shown for display purposes to represent the extents of the nameplates.

Demountable airline listing nameplates shall match the color of the background or overlay on which they are placed. A message separator line shall be used to separate two columns of airline nameplates. The minimum text height of the airline names shall be:

- 10 inches on overhead signs
- 8 inches on ground mounted signs on inbound roadways
- 6 inches on ground mounted signs on other roadways (such as recirculation roadways)

Passenger drop-off frontages may be located on more than one level of a terminal to serve airline check-in facilities located on each level. The airline directory signs for these terminals shall list airlines associated with each level in separate columns, preceded by a header message listing the level number. The header message may span two columns.

The header message shall consist of the word "Level" and the level number in yellow text on a black background. **Figure 11-5a** shows an example of a level number message at Newark Airport.

When airline nameplates for a single terminal are listed in two columns and the columns are not associated with different levels, the message separator line shall be offset from the top and bottom of the background or overlay on which the nameplates are placed. When the two columns are associated with different levels or different terminals, the message separator line is not offset.

The Port Authority desires to maintain consistency in nameplate dimensions between different signs so that nameplates may be reused if airlines move between terminals. Whenever possible, new nameplates should be designed to match the dimensions of existing nameplates on signs at that facility. Note that existing signs may reflect prior facility policies on font sizes or color schemes. These policies shall not be followed on new signs, including the consideration of reusing existing nameplates.

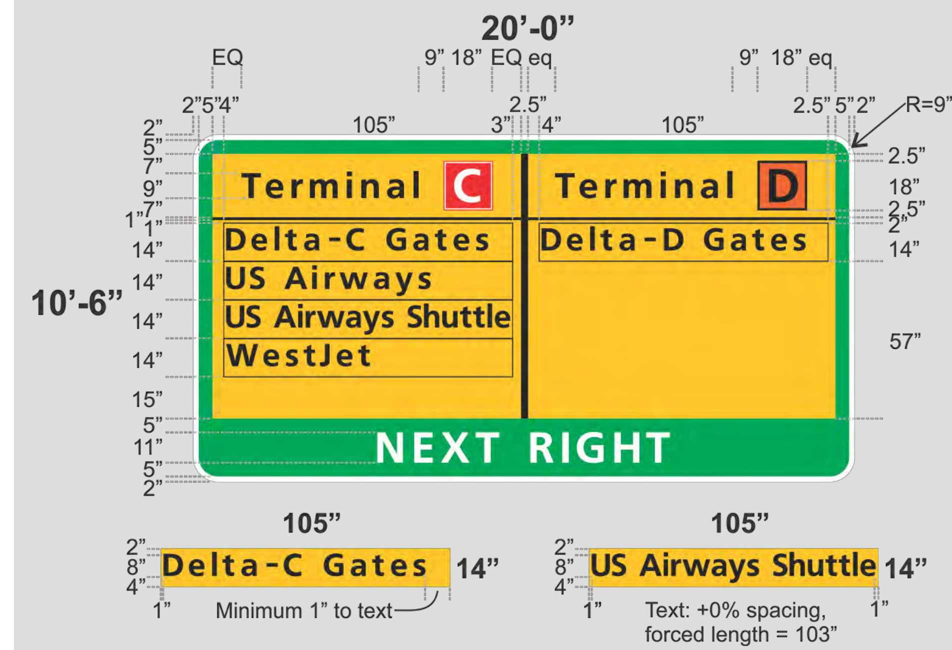


Figure 11-6a

Figure 11-6b

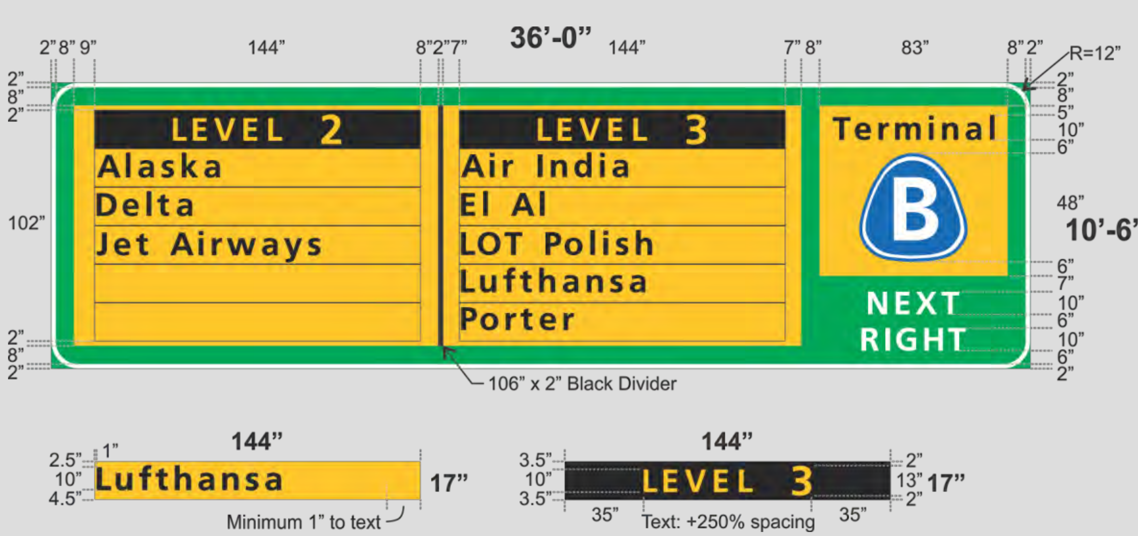


Figure 11-5a

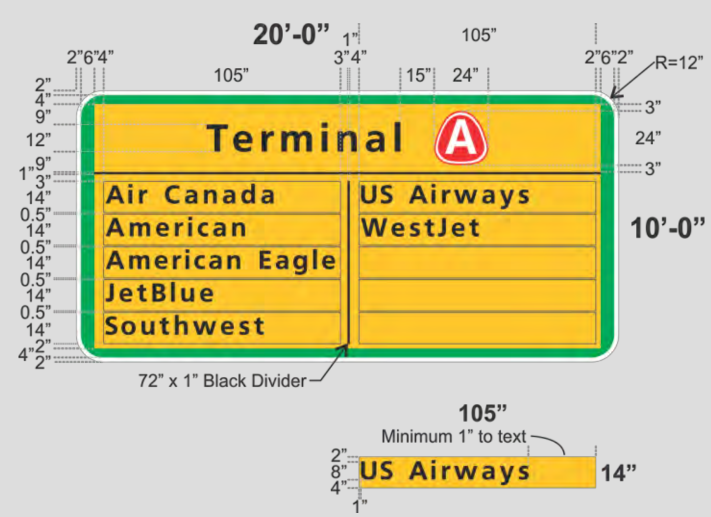


Figure 11-5b

11E. Parking Rate Signs on Inbound Roadways

Parking rate signs display different types of parking lots and their associated rates. They are located at airport entrances along inbound roadways. Examples are shown in **Figure 11-7**. Note that the Aviation Department may change rates and rate structures at each airport. Consult Port Authority Traffic Engineering for the current rates prior to designing the parking rate sign.

The parking rate sign consists of a header with the message "Airport Parking," a message separator line, parking facility designations, and the parking rates associated with each facility. Parking rate signs are designed with white legend on a green background as per Sections 2 through 8 of this Manual, except the minimum text size shall be 8 inches due to the amount of information presented on these signs. Because the text is applied directly to the green background with the exception of JFK Long Term Parking, parking lot logos are displayed using a reverse color scheme (green on white) as shown in **Figure 11-7a**.

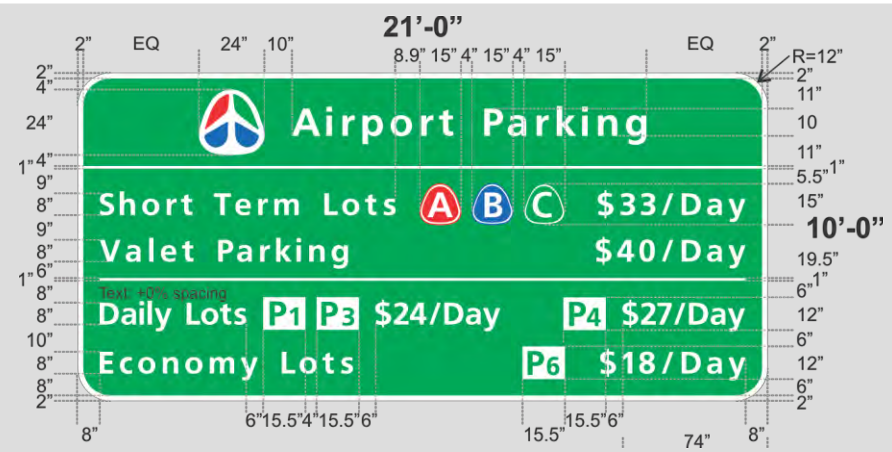


Figure 11-7a

Figure 11-7b

11F. Street Name Signs

Street name signs are located at airport roadway intersections and are generally double sided. They are designed according to the *MUTCD* with specific rules at some airports:

- JFK Airport signs have white legend on a blue background with the associated logo inside an arc as shown in **Figure 11-8a**.
- Newark Airport signs have white legend and the airport logo on a green background as shown in **Figure 11-8b**.
- LaGuardia Airport signs have white legend on a green background with the associated logo inside an arc as shown in **Figure 11-8c**.

Street name signs shall use the Federal Highway Administration "Highway" typeface. Signs mounted on traffic signal mast arms shall have minimum text heights of 8 inches for the street name and 6 inches for secondary text such as "Ave," "St," etc. Ground mounted signs shall have minimum text heights of 6 inches for the street name and 4 inches for secondary text. For a given sign width and text height, the widest typeface that fits should be used (for example, Highway 'C' instead of 'B').

Figure 11-8a

Figure 11-8b

Figure 11-8c

11G. Bus Stop Signs

Regardless of their location in the airport, bus stop signs follow the same design rules and guidelines as terminal frontage location signs. Refer to *Section 14C.1 – Frontages – Bus Stop Signs.*

11H. Small Guide Signs

Small guide signs may be used when a message cannot be accommodated on regular guide signs due to space or visibility constraints. Small guide signs direct motorists along a continuously signed route to destinations such as terminals, parking lots, and services. If a guide sign along this signed route is mounted overhead, it shall be designed according to Sections 2 through 8 of this Manual because additional legibility is required.

Examples of small guide signs are shown in **Figures 11-9** and **11-10**. Small guide signs are designed according to Sections 2 through 8 of this Manual with the following modifications:

- A minimum text height of 4 inches should be used. The absolute minimum shall be 3 inches.
- If a message cannot be written in Frutiger 65 due to sign dimensions, even with reduced inter-letter spacing, the Federal Highway Administration "Highway" typeface may be used as shown in **Figure 11-9c**.
- The edge of any overlay shall be offset a minimum of 1 inch from any other element on the sign, including the border, text, logos, symbols, or arrows. Overlay text shall also be offset a minimum of 1 inch from the edge of the overlay.
- The minimum logo or symbol height shall be proportionally larger than the message text height.
- When the arrow is part of the guide sign, it shall be Type A or Type C. The arrow size should conform to **Table 11-1**, subject to aesthetic considerations and engineering judgment. At a minimum, the width across the arrowhead should be at least equal to the text height on the sign. These arrows are described in the MUTCD and shown in Section 7, **Figure 7-1**.

Table 11-1 - Small Guide Sign Arrow Sizes

Upper Case Letter Height	Arrow Types and Sizes (Width x Length)	
	Type A	Type C
4" to 5"	7.25" x 11"	7" x 9"
6" or greater	See **Table 7-1**	See **Table 7-1**

- When the arrow is on a separate sign mounted immediately below the guide sign, it shall follow the MUTCD standard (M5 and M6 series signs) that incorporates a Type D arrow.
- The overall height and width of the sign shall be in multiples of 3 inches or 4 inches.
- The border width shall be a minimum of ½ inch.

Small guide signs are currently provided for Long Term Parking at JFK Airport and Daily, Valet, and Economy Parking at Newark Airport. **Figure 11-9** shows examples of small parking guide signs.

When small guide signs are provided for services, the sign shall have white legend on a blue background with no overlay. **Figures 11-10a** and **11-10b** show examples of small service guide signs.

The PA Police are considered a service, but there is a special guide sign for the PA Police at Newark Airport because they are located in historic Building 1. The Building 1 guide sign shown in **Figure 11-10c** has a unique design that does not necessarily conform to other design elements in this Manual. The electronic design file for this sign will be provided by Port Authority Traffic Engineering.

Figure 11-9a

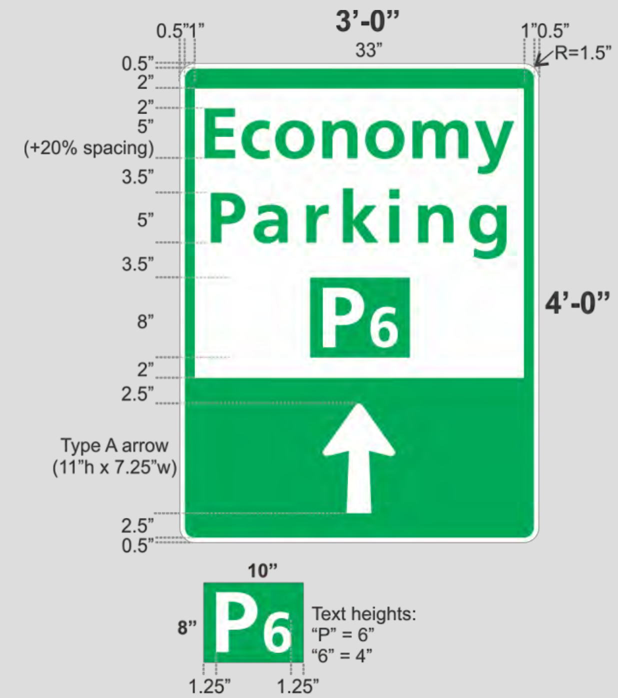


Figure 11-9b

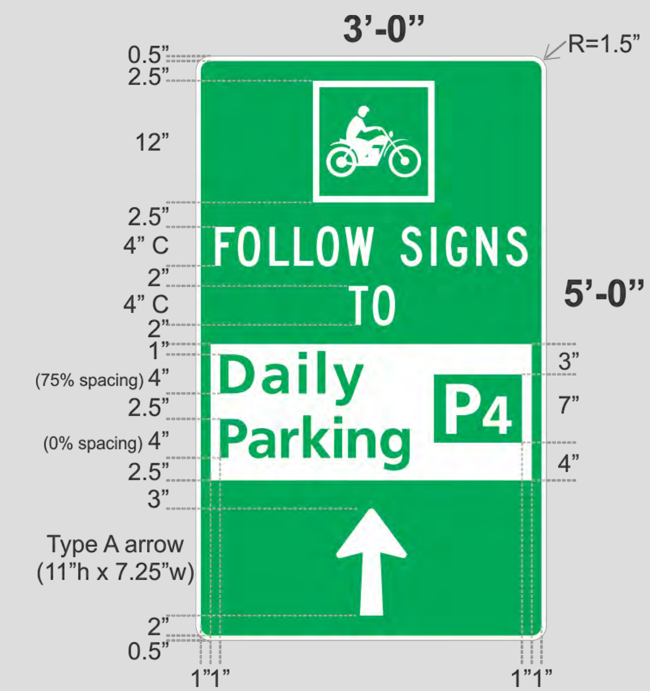


Figure 11-9c

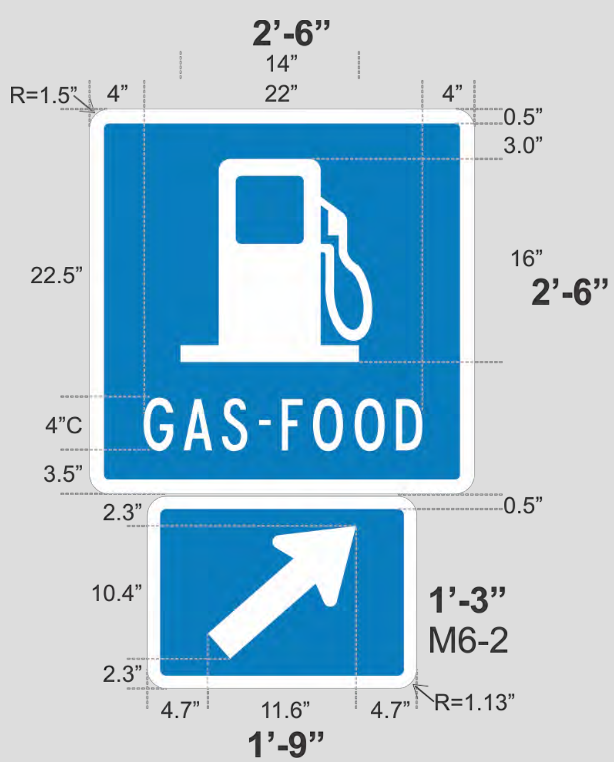


Figure 11-10a

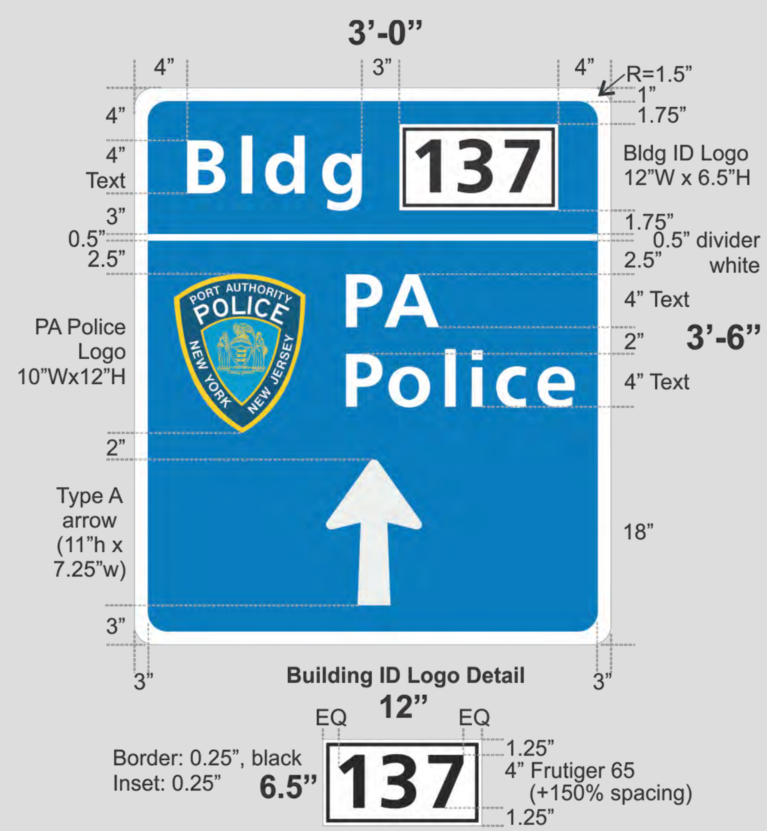


Figure 11-10b

Figure 11-10c

12. Regulatory and Warning Signs

Standard regulatory and warning signs shall use the colors, fonts, arrows, shapes, and dimensions specified in the *MUTCD*. Due to the unique conditions along airport roadways and differences between airports, it is often necessary to modify signs from the *MUTCD* or to create new signs, following *MUTCD* guidance. When a facility requests a new regulatory or warning sign, the sign designer should express the intended message in as few words as possible to communicate it efficiently and effectively to drivers.

Some signs have been adopted from other roadway agencies instead of designing a new sign. Signs in parking garages that are suspended from the ceiling may vary from the shapes and dimensions specified in the *MUTCD* as described in *Section 15A.9 – Parking Facilities – Regulatory and Warning Signs*.

A regulatory or warning message may be on a separate sign, included within a roadway guide sign, or on a panel mounted beneath a roadway guide sign. Section 10, **Figure 10-3b** shows a regulatory message within a roadway guide sign panel.

Examples of signs that are not found in the *MUTCD* are shown in this Section:

- **Figure 12-1** shows a sign posted on all roadways entering airport property.
- **Figure 12-2** shows signs prohibiting unauthorized access. Sign dimensions may vary based on location or other constraints.
- **Figure 12-3** shows terminal frontage signs:
  - Signs shown in **Figures 12-3a** and **12-3b** are found on passenger pick up and drop off frontages.
  - Signs shown in **Figures 12-3c** and **12-3d** are found along taxi lines.
  - The sign shown in **Figure 12-3e** is found on bus frontages.
- **Figure 12-4** shows parking signs; the sign shown in **Figure 12-4d** is only found in New Jersey, where it is required to be mounted underneath the reserved accessible parking sign (R7-8).
- Figures in *Section 16A – Parking Plaza Signs* show parking facility plaza signs.
- Figures in *Section 17A – Guard Posts* show guard post signs.
- **Figure 12-5** shows other regulatory and warning signs. The sign shown in **Figure 12-5d** is found in bus layover areas at Newark Airport, and shall include the text of the applicable statute in the lower right corner of the sign ("NJ 39:3 70-2" or superseding statute).

Note that some of the signs in **Figures 12-1** to **12-5** are designed to include arrows. Arrows may point in any direction, including bidirectional (left and right) arrows, or may be omitted depending on the location and message of the sign.

Figure 12-1

Figure 12-2a

Figure 12-2b

Figure 12-2c

1'-0" × 1'-6"

Figure 12-3a

1'-0" × 1'-6"

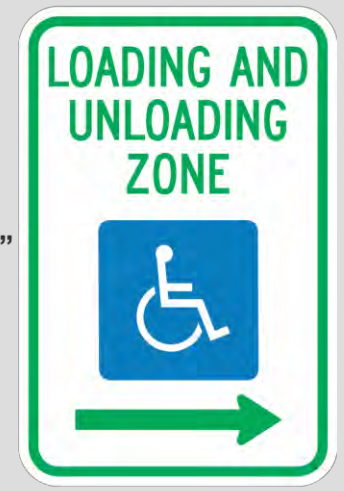


Figure 12-3b

1'-0" × 1'-6"

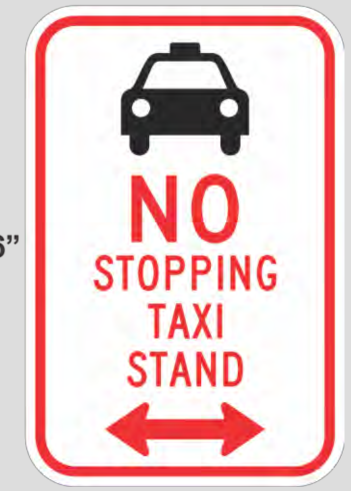


Figure 12-3c

4'-0" × 2'-6"

Figure 12-3d

1'-0" × 1'-6"

Figure 12-3e

3'-0" × 3'-6"

Figure 12-4a

1'-0" × 1'-6"

Figure 12-4b

1'-6" × 1'-3"

Figure 12-4c

0'-10" × 1'-0"

R(NJ)7-8a

Figure 12-4d

3'-0" × 3'-0"

Figure 12-4e

Figure 12-5a

Figure 12-5b

NYCDOT R3-13R

Figure 12-5c

Figure 12-5d

(All text: Frutiger 65)

Figure 12-5e

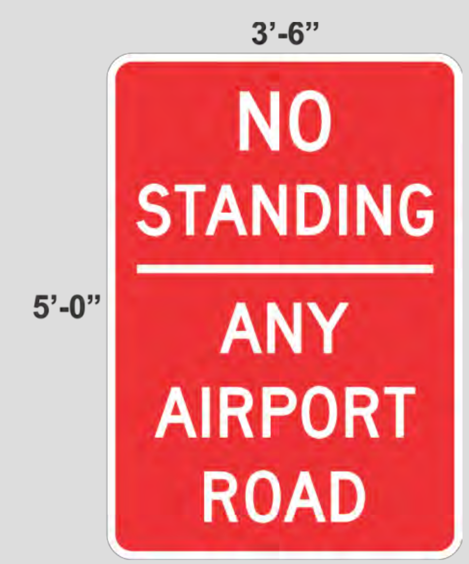


Figure 12-5f

13. Variable and Changeable Message Signs (VMS and CMS)

Variable Message Signs (VMS) and Changeable Message Signs (CMS) are used throughout Port Authority airports to display the appropriate messages to motorists in a wide variety of conditions.

- VMS have the capability to display any message that fits within the height and width of the sign matrix.
- CMS may display one of a limited set of fixed messages.

VMS and CMS are controlled centrally at each airport. They may also be controlled locally at each parking facility or at each individual sign.

A VMS or CMS may be either a standalone sign or a panel located within or below a fixed message sign. When located within a roadway sign, the VMS or CMS panel shall be located with the appropriate offsets to text, sign border, and other sign elements. These offsets should be the same as for logos as described in *Section 6 – Graphic Elements*. Any additional restrictions on the location of a VMS or CMS panel within the sign will be dictated by the sign message. Section 2, **Figures 2-3** and **2-6e** show examples of signs with VMS elements. **Figure 13-1** shows an example of signs with CMS elements.

All messages to be displayed on VMS and CMS require the approval of Port Authority Traffic Engineering. Sign messages shall be displayed using all upper case letters. VMS may remain static (displaying one message) or may cycle between two messages. Additional rules are given in the *MUTCD*.

The mechanical and electrical design of Variable and Changeable Message Signs (VMS and CMS) shall be according to a custom specification ("C spec") issued by the Port Authority for each project until a standard specification is issued. Text height, text color, and display type shall be as indicated in the specification.

Figure 13-1

14. Frontages

Frontages are the interfaces between vehicles and pedestrians, where passengers are picked up and dropped off by private cars, limousines, or permittees such as taxis, buses, and shuttles. Frontages may be found at the following locations and may either be dedicated to one function or serve multiple functions:

- Arrival frontage for passenger pick up at each terminal
- Departure frontage for passenger drop off at each terminal
- Taxi line frontage for passenger pick up by taxis
- Bus frontage for passenger pick up, drop off, or both by authorized permittees (buses, shuttles, and vans)
- Frontages for passenger pick up and drop off in some parking facilities

Guide signs on frontages are designed according to this section, incorporating the *Manual for Pedestrian Signing & Wayfinding*, which discusses requirements and guidelines on color coding, sign layout, dimensions, and other design parameters. The typeface for frontage guide signs shall be Frutiger 65 with +0% inter-letter spacing. Regulatory and warning signs on frontages shall be designed according to *Section 12 – Regulatory and Warning Signs*.

Frontage guide signs are usually mounted in sign boxes. Any sign not mounted in a sign box shall be sized in increments of 1 inch with a dark gray border of ½ inch. When a sign is mounted in a sign box:

- The sign box is typically suspended from a canopy (ceiling mounted) or mounted on poles (ground mounted).
- The overall dimensions of panels for sign boxes shall be determined by the dimensions of the sign box. The extent of material beyond the visible sign face, overlapping the sign box frame, shall be verified to fit the dimensions of the sign box and is typically a minimum of ½ inch. Note that sign box dimensions may vary by location or facility, but are typically the same for signs on each frontage.
- The sign shall have no border, and sign material beyond the visible sign face shall be the color of the sign background.

When a frontage sign is designed and positioned to be read by both vehicular and pedestrian traffic, the sign shall be sized to be readable by motorists:

- The minimum size of logos and symbols should be 12 inches. Only when sign dimensions are constrained, the size of logos and symbols may be reduced to an absolute minimum of 8 inches.
- The minimum text height shall be 4 inches, except the minimum height of secondary text listing destinations shall be 2 inches.

When a frontage sign is designed and positioned to be read by pedestrian traffic only, the sign shall be sized according to the *Manual for Pedestrian Signing & Wayfinding*. Signs mounted higher than an 8-foot vertical clearance should use logo, symbol, and text sizes greater than the minimum to provide sufficient visibility at an increased reading distance.

As shown in **Figure 14-1a**, many frontage guide signs are double sided to be read by pedestrians, with the same message on both sides or different messages on each side. On frontage signs mounted perpendicular to a roadway that include at least one roadway-related message, the logo or symbol and associated light gray band shall be located closer to the roadway than the rest of the message on both sides of the sign.

Because frontage signs are located outside, illumination must be provided for sign readability in any ambient lighting or weather condition, especially when the sign has greater than 8 feet of vertical clearance. Signs to be illuminated shall be mounted in sign boxes with sign panels made of translucent material and internally illuminated as described in the *Manual for Pedestrian Signing & Wayfinding*. Sign illumination shall be coordinated with Port Authority Electrical Engineering.

14A. Passenger Pick Up and Drop Off

Signs for passenger pick up and drop off are designed differently depending on the type of frontage:

- **Figure 14-1** shows signs on terminal frontages for passenger pick up.
- The *Manual for Pedestrian Signing & Wayfinding* shows signs on terminal frontages entirely dedicated to passenger drop off.

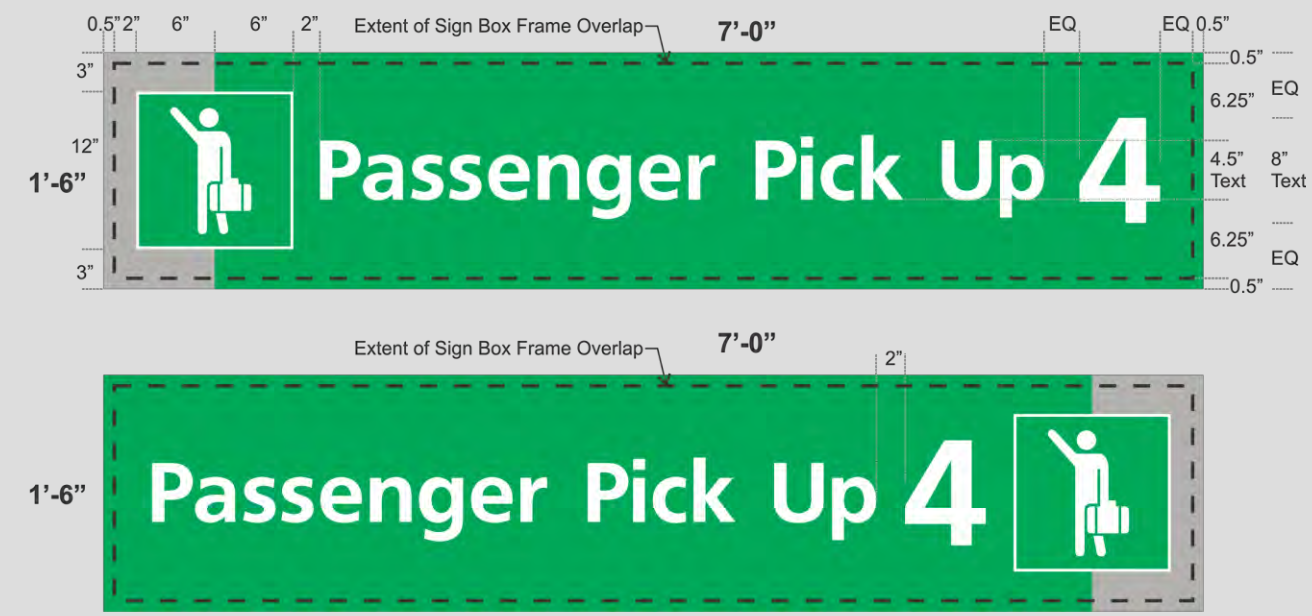


Figure 14-1a

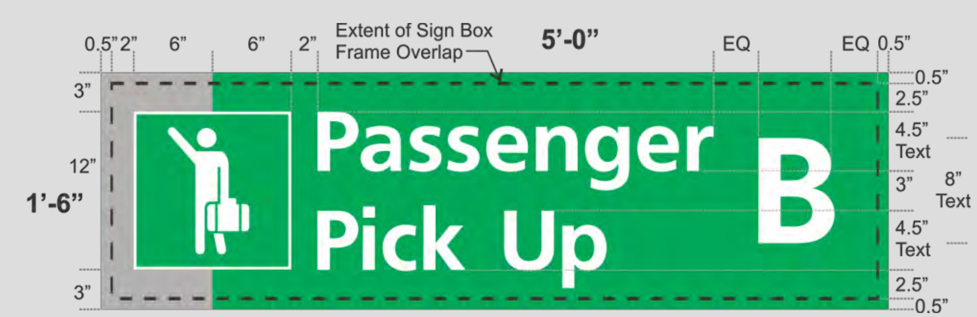


Figure 14-1b

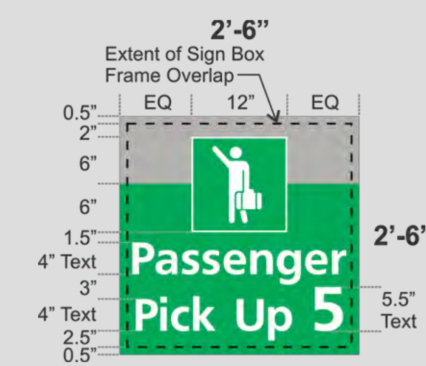


Figure 14-1c

- **Figure 14-2** shows signs on terminal frontages with some areas for passenger drop off.
- **Figure 14-3** shows signs on parking facility frontages for passenger pick up and drop off.

All symbols used on passenger pick up and drop off signs shall match the legend and background color of the sign. As stated in *Section 14A – Frontages*, symbols shall be located closer to the roadway than the rest of the message on both sides of the sign.

On terminal frontages for passenger pick up, signs shall use the passenger pick up symbol and shall read "Passenger Pick Up" with white legend on a green background. Typical examples are shown in **Figure 14-1a** (ceiling or canopy mounted), **Figure 14-1b** (ground mounted on poles), and **Figure 14-1c** (cantilevered from a wall or column). Long frontages are divided into designated pick up areas to assist drivers and passengers in finding each other. Pick up areas are designated by letter where terminals are numbered and by number where terminals are lettered, as shown in **Figure 14-1**.

Terminal frontages for passenger drop off are usually dedicated to that function, but some drop off areas may be located on terminal frontages that serve multiple functions. On frontages that are not dedicated to passenger drop off, signs indicating passenger drop off areas are designed with black legend on a yellow background. The message "Departures" is shown with the departing flight symbol as shown in **Figure 14-2a**. When the drop off area is for a particular airline, the name of the airline may be added as shown in **Figure 14-2b** but the airline logo shall not be used. Signs may have different layouts depending on how they are mounted, similar to **Figure 14-1**.

On parking facility frontages for passenger pick up and drop off, signs are typically ground mounted on poles. Signs shall use the passenger drop off symbol with the optional text "Passenger Drop Off" or "Alternate Drop Off" in white legend on a green background, as shown in **Figure 14-3**. Signs with different mounting types may have different layouts, similar to **Figure 14-1**.

14B. Taxi Lines

A typical sign identifying the location of a taxi line is shown in **Figure 14-4**. The sign is designed with white legend on a green background. Signs may have different layouts depending on how they are mounted, similar to **Figure 14-1**. Note that unlike other passenger frontages, dedicated taxi frontages may be located on the left side of the roadway, in which case the taxi symbol is on the right when facing approaching drivers. Regulatory signs located at taxi lines are discussed in *Section 12 – Regulatory and Warning Signs* and examples are shown in Section 12, **Figures 12-3c** and **12-3d**.

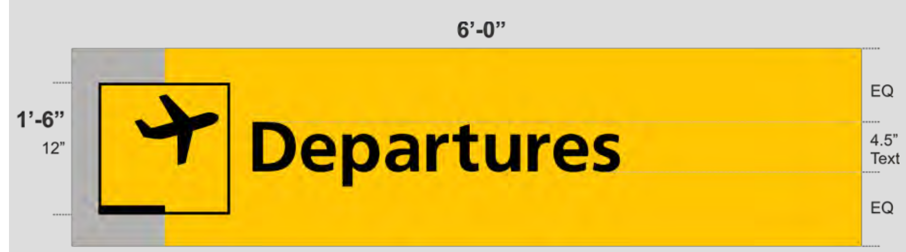


Figure 14-2a

Figure 14-2b

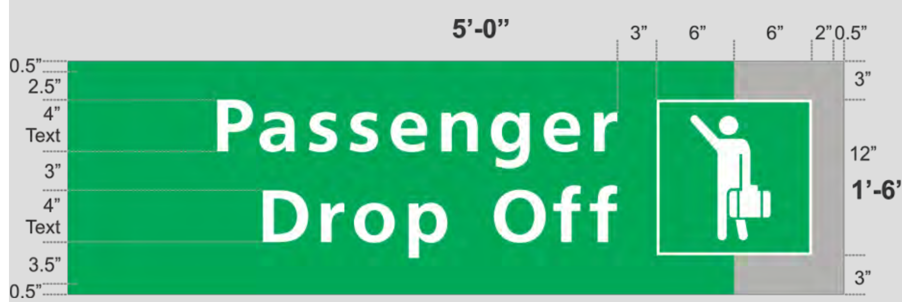


Figure 14-3

Figure 14-4

14C. Ground Transportation

This section addresses signs for areas designated for ground transportation permittees either on dedicated frontages (such as bus frontages) or on frontages serving multiple functions. Permittees may include the following categories:

- City and intercity buses
- Shared ride vans
- Free Port Authority parking facility and inter-terminal buses and shuttles
- Rental car and hotel shuttles
- Off-airport parking shuttles
- Employee buses

Ground transportation signs on frontages include bus directory signs, directional signs, and location signs. Each type of sign is described below, with examples shown in the *Manual for Pedestrian Signing & Wayfinding*:

- Bus directory signs are typically mounted on information kiosks facing the direction of pedestrians leaving the terminal. They provide a listing of bus company names and routes, stop location designations if applicable, and directions (arrows) to the stop locations, and may include destinations.
- Directional signs are typically canopy mounted, leading to but not yet at the stop locations. They provide bus or shuttle information pertaining to one or more stops and directions (arrows) to the stop locations.
- Location signs are found at the stop locations and are typically canopy mounted. They provide specific information for that stop that may include the company name, route designation, stop location, and destination. **Figure 14-5** shows additional examples of location signs.

Company names may appear on signs, but company logos or corporate colors shall not be used.

Ground transportation sign panels, logos and symbols shall be designed with white legend on a green background. Signs at or leading to designated permittee stop locations shall include either a bus or shuttle symbol as appropriate for the service provided. Although the Port Authority's free parking facility and inter-terminal services may be called "shuttles," they are run with full-size buses and therefore are designated by the bus symbol. On signs mounted perpendicular to a roadway, ground transportation symbols shall be located on the side of the sign closer to the roadway.

Ground transportation frontages may be divided into several designated stop locations. These locations are designated with letters where terminals are numbered and with numbers where terminals are lettered. Stop location designations shall be shown in square logos as shown in **Figures 14-5a, 14-5b,** and **14-5c** to help guide permittees and pedestrians to the proper stop locations. Where ground transportation signs on frontages are mounted perpendicular to a roadway, the stop location logo shall be located closer to the roadway than the rest of the message on both sides of the sign, including any other logo or symbol.

Secondary logos or symbols may also be included on the sign, as shown in **Figure 14-5d**. The secondary logo or symbol and associated text should be smaller than the primary message on the sign. Secondary logos and symbols may include:

- Rental car, hotel, or parking symbol for shuttles to these locations
- Train or subway symbol or AirTrain logo for buses or shuttles to stations

Figure 14-5a

Figure 14-5b

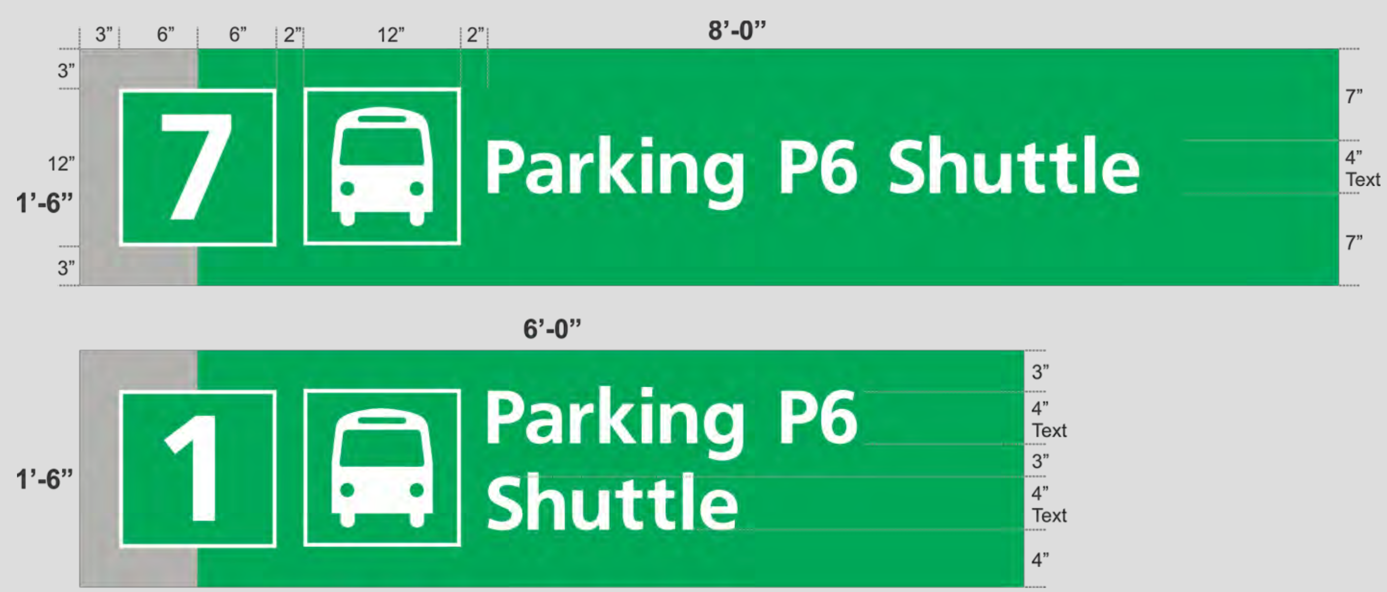


Figure 14-5c

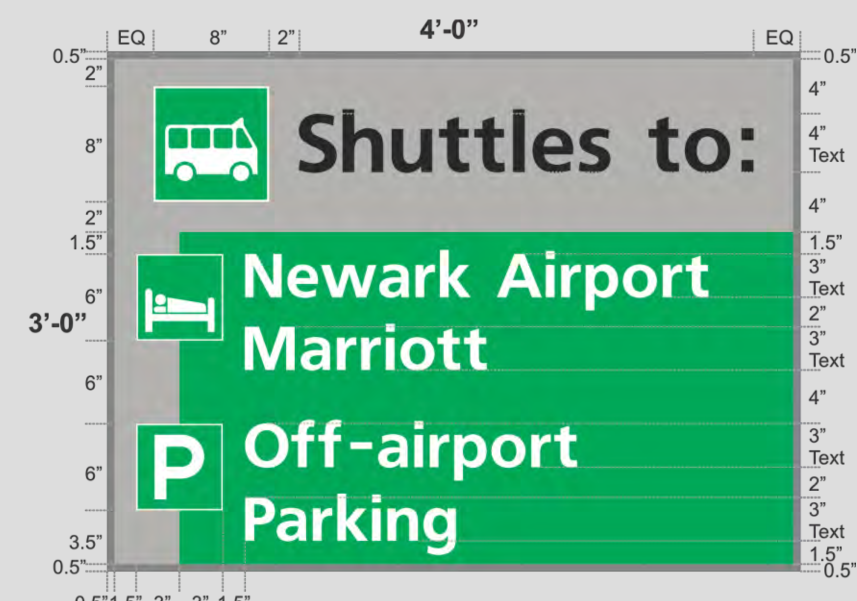


Figure 14-5d

14C.1 Bus Stop Signs

Bus stop signs are designed to the same specifications regardless of whether they are found on a frontage or elsewhere in the airport. Sign height may vary depending on the number of bus companies listed or the design of other bus stop signs on the same frontage.

A typical bus stop sign is shown in **Figure 14-6a**. Bus stop signs in parking lots are designed as shown in **Figure 14-6b**, and are typically pole mounted on the four sides of a cube. Bus stop signs in parking lots have no border, and the horizontal spacing from the edge of the sign to the text may be reduced to 2 inches when the bus stop number has two digits.

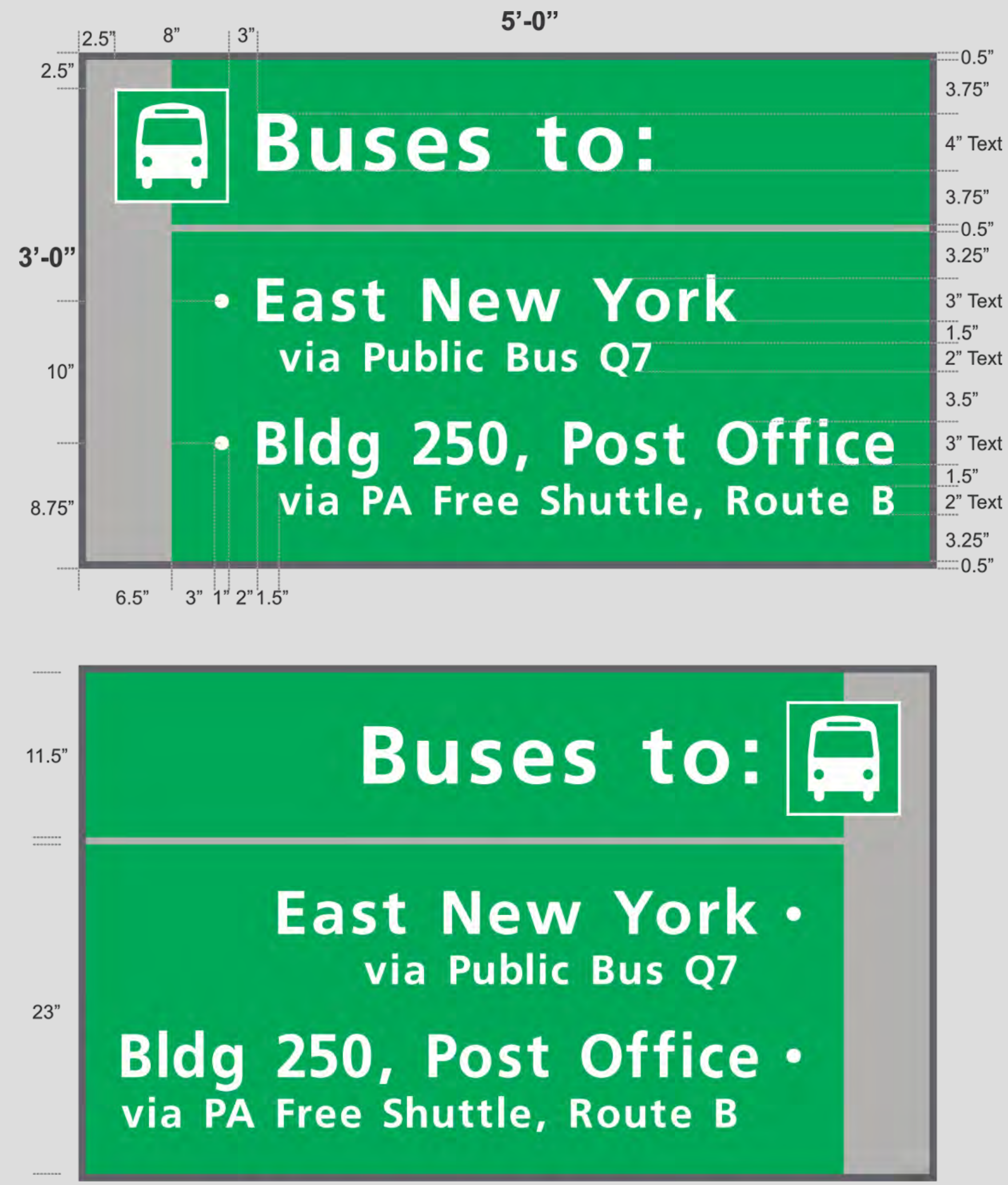


Figure 14-6a

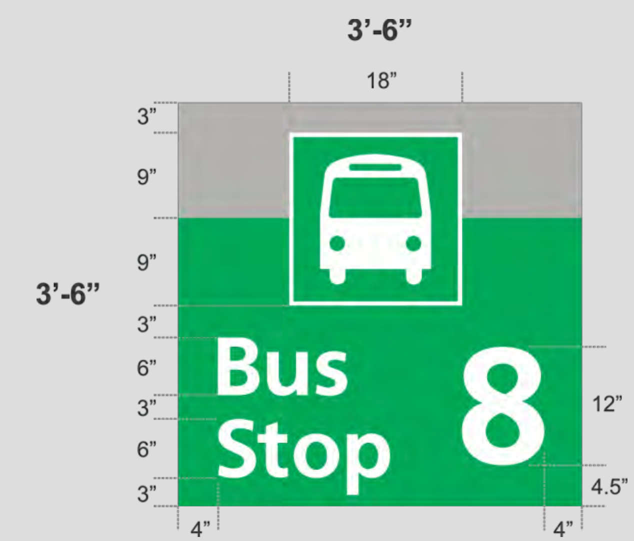


Figure 14-6b

15. Parking Facilities

Parking facilities include single-level surface parking lots and multi-level parking garages. Signing within parking facilities requires special attention because signs may apply to vehicles, pedestrians, or both (such as aisle and row markers) and yet must look consistent with other vehicular and pedestrian signs. When motorists and pedestrians may be able to view the same signs, the signs should be designed to clearly identify the intended audience and signs should be oriented toward the appropriate paths of travel.

Parking lot signs are typically ground mounted, while parking garage signs are typically suspended from the ceiling or mounted on walls, columns, or beams due to space and location restrictions. Sign boxes may be used for non-ground mounted signs, and signs mounted within sign boxes may be internally illuminated as described in *Section 15D – Illumination*.

When sign dimensions are constrained, such as when the sign must be retrofitted to an existing sign box or structure, the minimum criteria established in this section should be upheld to the greatest degree possible within the required dimensions. Spacing between text, logos, symbols, borders, etc. should be reduced before considering other methods to fit the message into the visible sign face.

Signs designating pedestrian drop off and pick up areas within parking facilities are discussed in *Section 14A – Frontages – Passenger Pick Up and Drop Off*. Signs directing motorists to those areas are considered parking guide signs and are covered in this section. Signs at parking lot entry and exit plazas are discussed in *Section 16 – Parking Entry and Exit Plazas*.

15A. Vehicular Signing

Vehicular signs in parking facilities are designed to help motorists search for available parking spaces or find the exit. Parking facility signs should be designed by considering the same factors as for airport roadway signs, such as letter and symbol size, arrangement of text, arrow placement, and the use of variable message sign panels. Due to the low speeds of motorists in parking lots, signs are generally placed only at decision points and advance signing is not used.

Parking facilities at Port Authority airports may provide different types of parking in different areas or levels and messages may include directions for limousines, motorcycles, or other specific users. These messages should be consistently indicated on signs leading to the proper area or level.

15A.1 General Rules and Guidelines

The following rules and guidelines apply to vehicular signs, as shown in **Figure 15-1** (ground mounted) and **Figure 15-2** (suspended from the ceiling).

- **Color Coding System:** All parking facility signs shall have a white message and border on a green background except regulatory and warning signs as described in *Section 15A.9 – Regulatory and Warning Signs* and overlays with the *MUTCD* accessibility symbol as described in *Section 15A.5 – Graphic Elements*.
- **Typeface:** Frutiger 65 shall be use as described in *Section 4B – Typeface*, except an inter-letter spacing of +100% shall be applied. If message width is limited, reductions in spacing shall occur in 5% increments and shall require the approval of the Port Authority.
- **Text Height:** The recommended text height on all signs is 6 inches and the minimum text height shall be 4 inches. Text height shall be increased or decreased in increments of 1 inch. When it is part of a sign with multiple messages, the "Exit" message should utilize a larger text height than the other text on the sign, depending on sign location and restrictions on sign height and width.

Figure 15-1

15A.2 Message Hierarchy

When a sign has messages relating to more than one direction of travel, messages shall be divided into message groups according to *Section 3A – Message Groups*.

Figures 15-2 to **15-5** show signs incorporating the message hierarchies for signs with message groups separated vertically and horizontally.

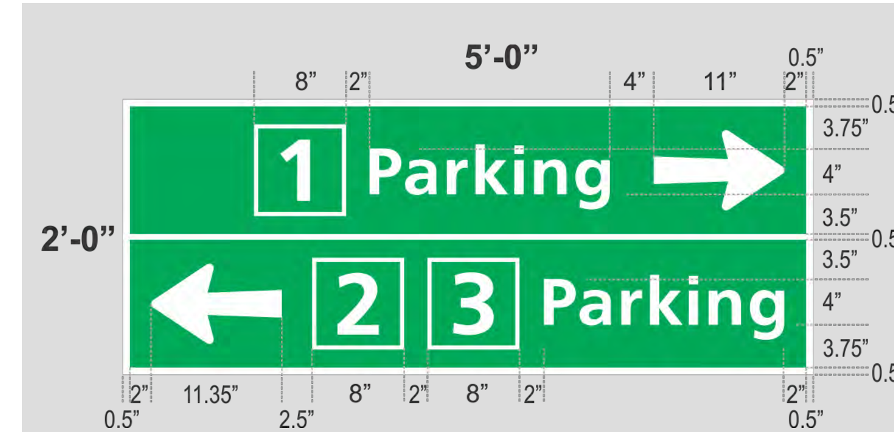


Figure 15-3

Figure 15-4

Figure 15-2

For all individual messages within the same message group or on signs with two or more message groups separated vertically, messages shall be listed according to the following message hierarchy:

1. Terminals: "A" or "1" shall be listed first, followed by other terminals in ascending order, as shown in **Figure 15-3**.
2. Parking garage levels: "1" shall be listed first, followed by other levels in ascending order, as shown in **Figure 15-4**.
3. The "Exit" message, as shown in **Figure 15-4**.
4. Other messages that do not belong to the above categories:
   a. This includes specific types of traffic, such as:
      - Stretch Limos (may include terminal logos and level numbers)
      - *MUTCD* accessibility symbol (D9-6) overlay
      - Passenger Drop Off (may include terminal logos and level numbers)
      - Motorcycle Parking

   b. Use the *MUTCD* arrow hierarchy defined in *Section 3C – Arrow Hierarchy*. Messages associated with the up arrow shall be listed first, followed by messages associated with the left, right, and down arrows. Messages associated with a directional message shall be listed last.

On signs with two or more message groups separated horizontally, the message group associated with the left arrow shall be on the left of the sign and the message group associated with the right arrow shall be on the right of the sign, as shown in **Figures 15-2** and **15-5**.

On ground mounted signs, each message associated with the same arrow orientation or directional message shall be displayed on separate lines. On non-ground mounted signs, different messages in the same message group may be displayed on the same line if required by space constraints, separated as described in *Section 15A.3 – Terminology*.

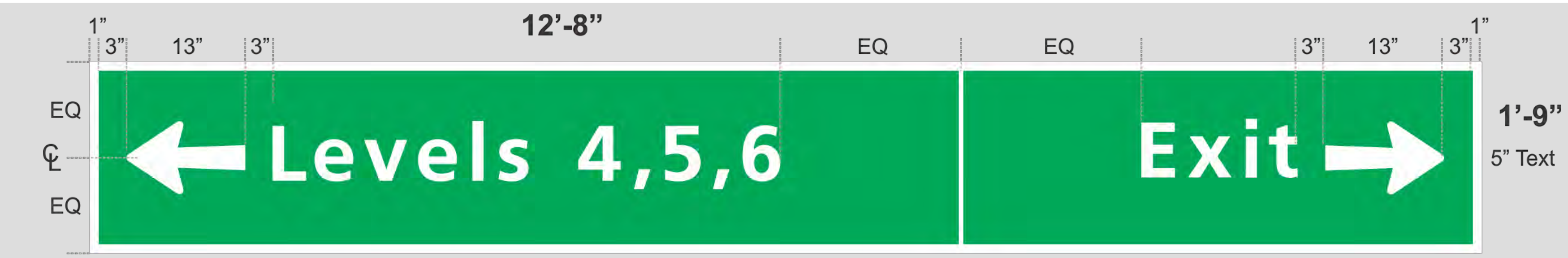


Figure 15-5

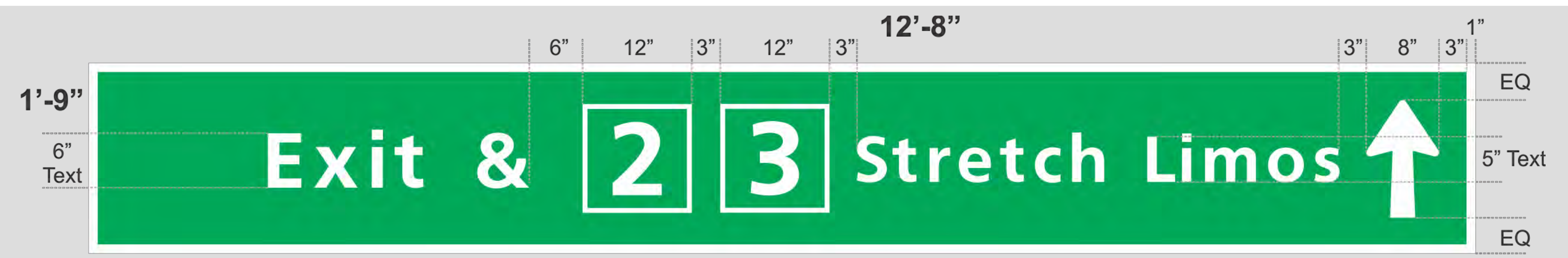


Figure 15-6

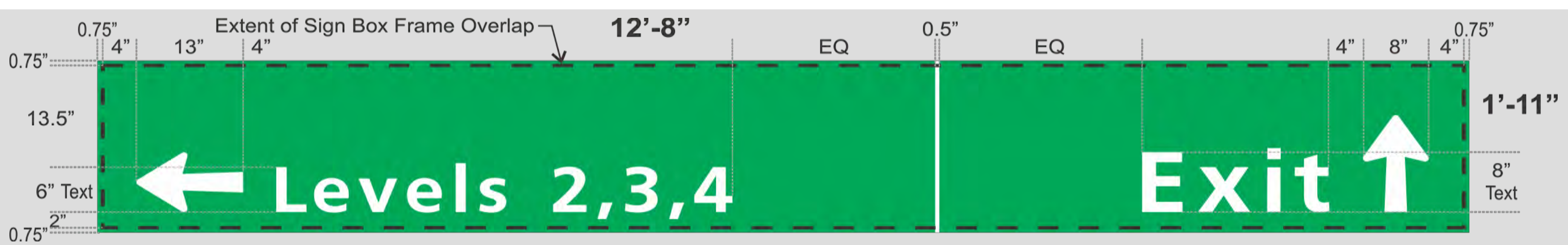


Figure 15-7

15A.3 Terminology

Sign messages shall be selected from the approved list in *Appendix B – Sign Terminology*. Signing should avoid using abbreviations whenever possible, even on non-ground mounted signs with limited height and width. If it is necessary to include abbreviations after all other options have been considered, only those abbreviations listed in the approved terminology shall be used. Parking facility terminology includes the following:

- The term "Level" shall be used to refer to multiple levels of a parking garage. Levels are always designated by numbers, not letters. The word "Parking" shall not be used before the word "Level."
- Parking facility exits shall always be signed using the term "Exit."
- "Aisle" and "Row" shall be used to refer to parking areas as described in *Section 15C – Aisle and Row Markers*.
- The word "and" or the ampersand symbol (&) shall be used to separate different messages in the same message group that are displayed on the same line, as shown in **Figures 15-3** and **15-6**.

15A.4 Text Placement

Ground mounted signs shall follow the rules and guidelines presented in *Section 4D – Text Placement*. Other signs should also follow Section 4D, but text placement may be adjusted based on the following considerations:

- The spacing between the left, right, top, or bottom of a line of text and any border or message separator line should be at least 3 inches but may be reduced to a minimum of 2 inches.
- As shown in **Figure 15-2**, the vertical spacing between two related or unrelated lines of text may be reduced to a minimum of ½ the upper case text height, with increased spacing for descenders as discussed in *Section 4D.2 – Vertical Alignment*.
- Messages on signs suspended from the ceiling should be vertically aligned toward the bottom of the sign for greater visibility, maintaining the minimum spacing defined above, as shown in **Figure 15-7**.

15A.5 Graphic Elements

Graphic elements on vehicular parking signs are limited to the following logos and symbols. The Parking symbol (letter "P" in a green or colored square) shall not be used.

- **Terminal logos:** Parking facilities that serve multiple terminals may designate parking areas for each terminal. In those facilities, terminal logos shall be used to direct traffic to those designated areas. Terminal logos shall be designed as shown in *Section 6B – Graphic Elements – Terminals* and shall be applied directly to the sign as shown in **Figures 15-3** and **15-6**. The *MUTCD* airport symbol shall not be used on vehicular signs.

- **Passenger drop off / pick up symbol:** The symbol shall be used on signs designating and directing traffic to passenger drop off and pick up areas in parking facilities. The symbol shall not be used when the "Passenger Drop Off" message is preceded by one or more terminal logos. The symbol is shown in **Figure 15-2**.
- **Motorcycle symbol:** The symbol and associated "Motorcycle Parking" text shall be used as described in *Section 6C.5 – Motorcycle Parking*. An example is shown in **Figure 15-4**.
- **MUTCD accessibility symbol:** The *MUTCD* accessibility symbol (D9-6) shall be followed by the "Parking" message in white legend on a blue overlay, as shown in **Figure 15-8**.

The following rules apply to graphic elements on parking signs:

- The recommended height of a logo or symbol is 12 inches. Logos and symbols on ground mounted signs should adhere to the recommended height. Logos and symbols on other signs should be a minimum of twice the height of the associated text.
- Logos and symbols shall always be placed before the text. All logos, symbols, and text on a single line shall be vertically centered. When logos and symbols appear before two or more associated lines of text, the logos and symbols shall be top justified to the first line of text. **Figure 15-2** shows logo and symbol placement.
- The minimum spacing between text and a logo or symbol should be 4 inches on ground mounted signs and may be reduced to ½ the upper case text height or 3 inches, whichever is smaller, on other signs. The maximum spacing between text and a logo or symbol should be equal to the upper case text height. These guidelines are shown in **Figure 15-3**.
- The minimum spacing between a logo or symbol and a sign border or message separator line should be 4 inches on ground mounted signs and may be reduced to ½ the upper case text height or 3 inches, whichever is smaller, on other signs. The minimum spacing between two logos is defined in the same manner. These guidelines are shown in **Figure 15-3**.

When the *MUTCD* accessibility symbol appears on an overlay, overlay placement should be as described in *Section 5 – Placement of Overlays on Signs* and as shown in **Figure 15-8**, incorporating the following rules and guidelines:

- The spacing may be reduced between the logo and the edge of the overlay if required by sign dimension constraints, but the spacing shall not be eliminated.
- Overlays shall be vertically centered to other elements (such as arrows) on the same line.
- Overlays should not exceed the height of logos and symbols on that sign.
- The *MUTCD* accessibility symbol may be reduced in size to a minimum of 9" square.

Figure 15-8

15A.6 Arrows

Type A and Type B arrows, as described in *Section 7 – Arrows*, are the only arrow types used on vehicular parking facility signs.

- On signs that are ground, column, or wall mounted, Type A and Type B arrows should be used as described in *Section 7C.2 – Arrows – Placement – Ground Mounted Signs*.
- On signs that are beam mounted or suspended from the ceiling, only Type A arrows should be used, and Type B arrows should only be considered when extreme height or width limitations (especially on signs suspended from the ceiling) do not allow the use of a Type A arrow. **Figure 15-9a** shows an example of a sign with limited height.
- If the height of the sign is less than 12 inches, the length of the Type B arrow may be reduced to a minimum of 8 inches (with proportional width).

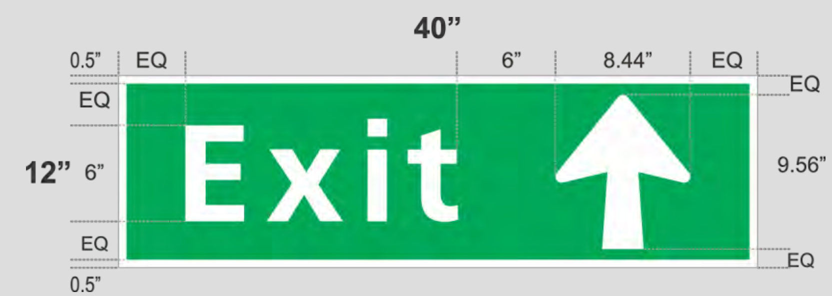


Figure 15-9a

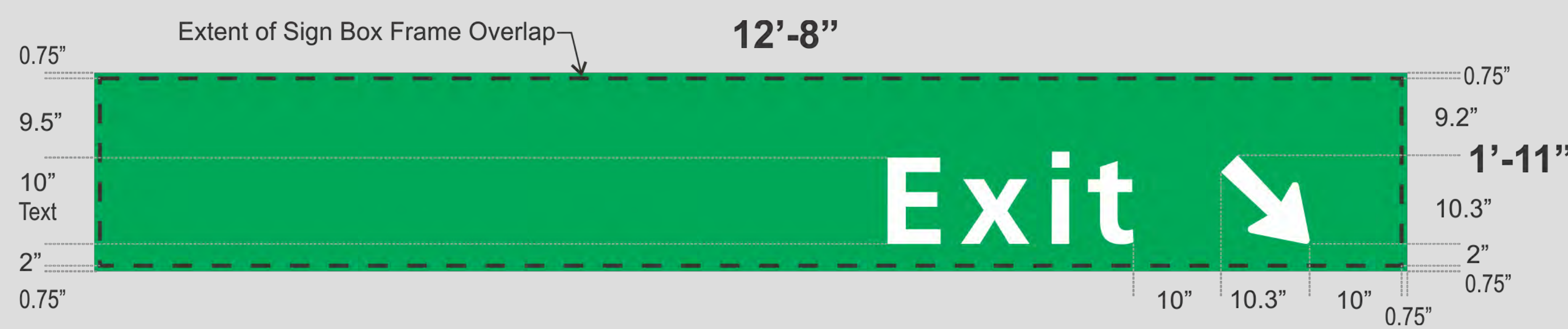


Figure 15-9b

The color of the arrow shall be white to match the sign legend. Arrow dimensions shall be as shown in **Table 15-1**. For the purpose of sign layout only, the dimensions given in **Table 15-1** may be rounded to the nearest ½ inch.

Table 15-1 - Arrow Sizes

Sign Type	*Type A Arrow (Width x Length)*	*Type B Arrow (Width x Length)*
Ground Mounted	11.25" x 18.25" 15.125" x 24.25"	8.44" x 9.56" 12.25" x 14" 14.25" x 17.25"
Non-Ground Mounted	7.25" x 11" 8" x 13"	7" x 8" 8.44" x 9.56"

The appropriate arrow should be selected based on design considerations including text height, sign location, and sign dimensions.

- In general, the arrow size should correspond to a width across the arrowhead that is approximately 1.75 times the upper case text height of the major messages on the sign, subject to aesthetic considerations and engineering judgment.
- The same size arrow shall be used for all messages on one sign.

Arrows shall be pointed at the appropriate angle to clearly convey the direction to be taken.

- Arrows should point left, right, straight up, or at an upward angle.
- Arrows should only point straight down or at a downward angle if a movement is accomplished by descending a ramp in that direction, as shown in **Figure 15-9b**.
- Arrows are typically rotated in increments of 45 degrees, but may be rotated at other angles depending on considerations such as roadway geometry and sign location.
- Up arrows and down arrows shall not both be used on the same sign.

On ground mounted signs, arrows may be located on the left, right, or bottom of all messages on the sign. On other signs, arrows may be located on the left or right of the associated message or group of messages.

- Left arrows and right arrows shall be placed at the side of the sign that will reinforce the movement of traffic.
- Straight up or down arrows should be placed on the side of the sign closest to the driver or the center of the lane.
- Arrows, especially when pointing up or down, should not be located over an opposing lane of traffic or other invalid path of travel.

The minimum spacing between an arrow and text, logo, symbol, sign border, or message separator line should be 4 inches on ground mounted signs. On non-ground mounted signs, the minimum spacing may be reduced to 3 inches or ½ the upper case text height, whichever is smaller. These guidelines are shown in **Figures 15-3** and **15-8**.

15A.7 Panel Design

The following rules and guidelines apply to vehicular signs, as shown in **Figure 15-1** (ground mounted) and **Figure 15-2** (suspended from the ceiling).

- **Panel Dimensions:** Panels for ground mounted signs should be sized in 6-inch increments. The overall dimensions of panels for sign boxes shall be determined by the dimensions of the sign box. The extent of material beyond the visible sign face, overlapping the sign box frame, shall be verified to fit the dimensions of the sign box and should be a minimum of ½ inch. All other parking signs shall be sized in 1-inch increments. Unless a non-ground mounted sign is fit to a sign box or the back of another sign, the messages on the sign shall determine the overall sign dimensions.
- **Borders:** Signs mounted within sign boxes shall have no border, and sign material beyond the visible sign face shall be the color of the sign background. Other signs shall have a border of ½ inch if sign area is less than 20 square feet and shall have a border of 1 inch otherwise. Border widths shall be maintained around both rounded and square corners.
- **Corner Radii:** Ground mounted signs shall have rounded corners and all other parking facility signs shall have square corners. All corner radii shall be rounded to the nearest 3 inch interval and shall be no greater than 12 inches, as shown in Section 8, **Table 8-2**.
- **Message Separator Lines:** Message separator lines shall be ½ inch wide as shown in **Figure 15-2** and shall be white to match the border. Message separator lines shall extend to the border or another separator line, or to the edge of the sign if there is no border.

15A.8 Exit Signs

The layouts shown in **Figure 15-10a** shall be used for exit signs in parking lots and should be used for exit signs in parking garages. The layouts shown in **Figure 15-10b** are typically used for exit signs mounted on light poles on the roof level of parking garages, and may be used at other parking garage locations where sign dimension constraints preclude use of the layouts shown in **Figure 15-10a**.

Where the signs shown in **Figure 15-10** cannot feasibly be installed in a parking garage or would not be sufficiently visible to traffic, the exit message may be included on a sign suspended from the ceiling, designed according to Sections 15A.1 through 15A.6. This typically occurs in parking garages below the roof level. The exit message should be the only message on the sign, as shown in **Figure 15-9**, but the exit message may be included on the same sign as other messages if necessary, as shown in other figures in *Section 15A – Vehicular Signing*.

15A.9 Regulatory and Warning Signs

Regulatory and warning signs in parking facilities shall follow *Section 12 – Regulatory and Warning Signs*. The only exceptions are parking garage locations, especially below the roof level, where it is not feasible to install a standard sign or where a standard sign would not be appropriately visible to traffic. In these locations, regulatory and warning signs may be suspended from the ceiling so that the sign covers the full width of the lane. All regulatory and warning signs shall implement the typefaces specified in the *MUTCD*.

When a regulatory or warning sign is suspended from the ceiling, as shown in **Figure 15-11**:

- The sign panel and sign panel text shall be the same colors as the associated regulatory or warning sign.
- Regulatory or warning signs with a recognizable shape, such as “Do Not Enter” and “Stop,” shall be the largest possible size that will fit within the visible sign panel. Other signs, such as “Clearance,” may be replaced with the associated text.
- Regulatory or warning signs that are reduced in size shall maintain the same proportions, colors, and shapes as the full-size sign. Text may be eliminated from inside the regulatory or warning sign if it is too small to be legible at the reduced scale.
- The regulatory or warning sign shall be to the left of its associated text. If space permits, the sign should be repeated to the right of the text as well. Regulatory and warning signs shall only appear with the associated text when located on sign panels suspended from the ceiling.
- For the purpose of sign layout, the horizontal and vertical spacing of regulatory and warning signs shall be the same as for logos and symbols as described in *Section 15A.5 – Graphic Elements*.
- Signs mounted within a sign box shall not have borders or insets.
- When a sign is not mounted within a sign box and has a white, yellow, or orange background, the border shall be inset from the edge of the sign, and the space between the border and the edge of the sign shall be the same color as the sign background. The border width and inset dimensions shall be determined based on the sign dimensions.

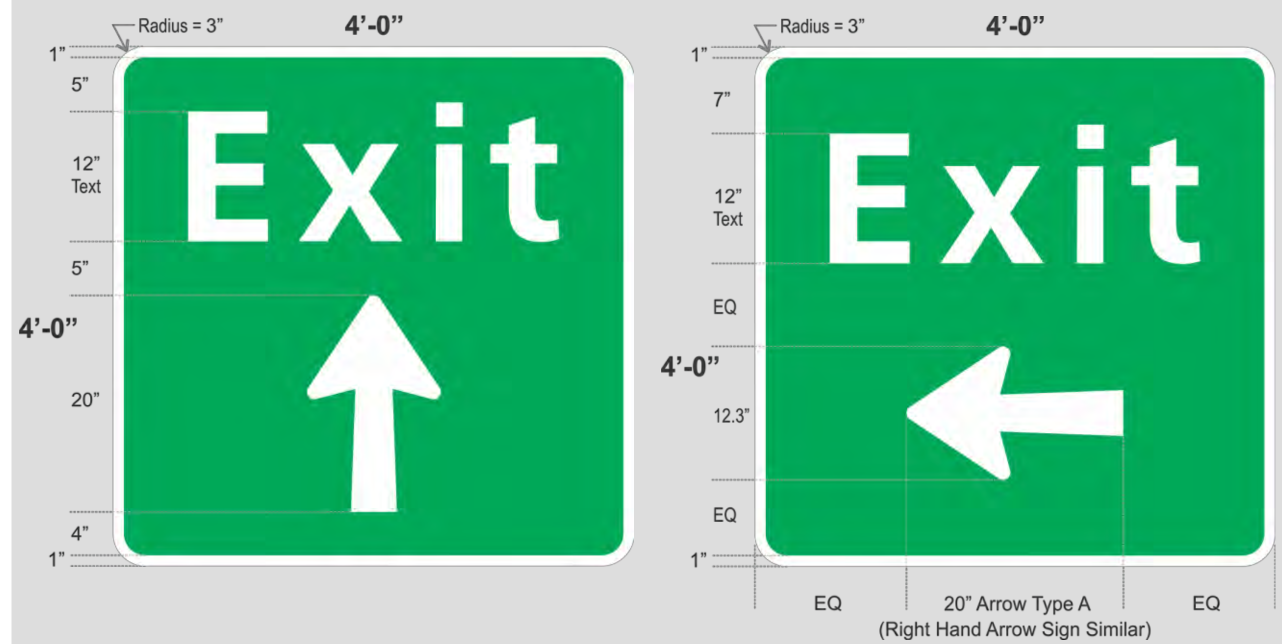


Figure 15-10a

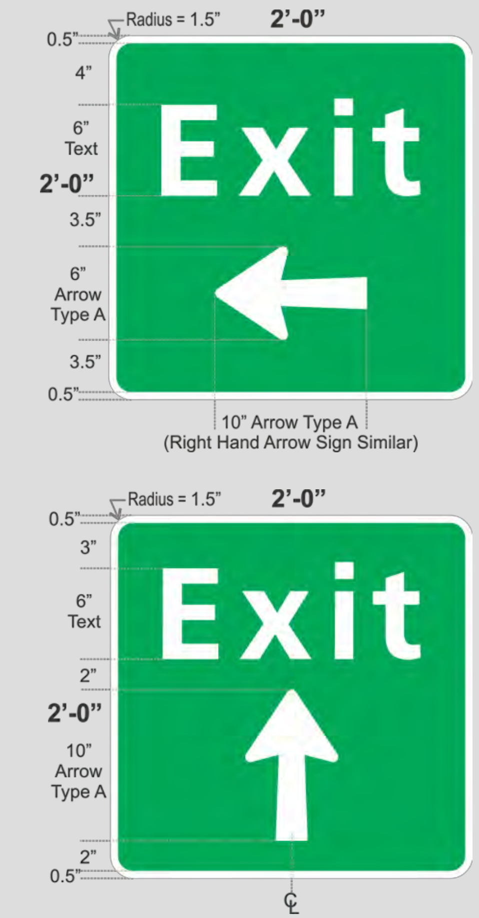


Figure 15-10b

Figure 15-11a

Figure 15-11b

15B. Pedestrian Signing

Pedestrian signs in parking facilities are designed to guide pedestrians from their vehicle to the terminal or other destination, and back to their vehicle upon their return to the parking facility.

- Pedestrian signs shall conform to the *Manual for Pedestrian Signing & Wayfinding*.
- Signs related to services (baggage cart and help phone) and occupancy or egress codes (such as fire extinguisher signs) shall be coordinated with the Port Authority Architecture Department.
- Service or code-related signs that include lighting or other electrical elements, such as "EXIT" signs, shall be coordinated with Port Authority Electrical Engineering.

Pedestrians do not need advance signing, but messages should be repeated on consecutive signs for reassurance along pedestrian routes. Especially in garages or at night, dim ambient light conditions may reduce the visibility of a sign face compared to locations with controlled lighting. In addition, pedestrians may need to read signs from a longer distance in parking facilities to reach their destinations. For these reasons, pedestrian signs in parking facilities should be larger than the minimum dimensions given in the *Manual for Pedestrian Signing & Wayfinding* and consideration should be given to use of illumination for non-ground mounted signs as described in *Section 15D – Illumination*.

15B.1 General Rules and Guidelines

The following rules and guidelines apply to pedestrian signs, as shown in **Figure 15-12**.

- **Color Coding System:** As described in the *Manual for Pedestrian Signing & Wayfinding*, pedestrian signs within parking facilities shall adhere to the color scheme described in **Table 15-2**.

Table 15-2 - Pedestrian Signing Color Schemes

Legend Color	*Background Color*	*Application*
Black	Yellow	Get to the terminal or other destination directly or via ground transportation, and related vertical circulation messages
White	Green	Find one's vehicle within the parking facility and related vertical circulation messages
Yellow	Black	Vertical circulation (only when not part of another message) and non-emergency services
Black	Light gray	Instructions or information such as rules, policies, and "AirTrain to:" message
White	Dark gray	Directory messages
White	Red	Emergency services and occupancy or egress codes
White	Blue	Signs for ADA accessibility

- **Message Hierarchy:** The message hierarchy shall be as described in the *Manual for Pedestrian Signing & Wayfinding*.
- **Typeface:** Frutiger 65, which is equivalent to "Frutiger Bold" specified in the *Manual for Pedestrian Signing & Wayfinding*, shall be used as described in *Section 4B – Typeface*, except an inter-letter spacing of +0% shall be applied. If message width is limited, reductions in inter-letter and inter-word spacing require the approval of the Port Authority.
- **Text Height:** The minimum text height shall be 3 inches as described in the *Manual for Pedestrian Signing & Wayfinding*. The designer should make every effort to provide text height greater than the minimum.
- **Terminology:** Sign messages shall be selected from the approved Airport Nomenclature list in the *Manual for Pedestrian Signing & Wayfinding*. The term "Level" shall be used to refer to multiple levels of a parking garage. "Aisle" and "Row" shall be used to refer to parking areas as described in *Section 15C – Aisle and Row Markers*.

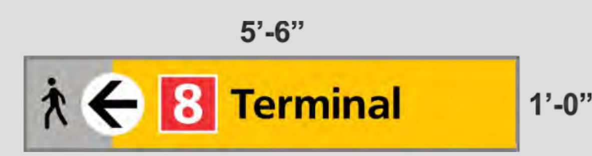


Figure 15-12a

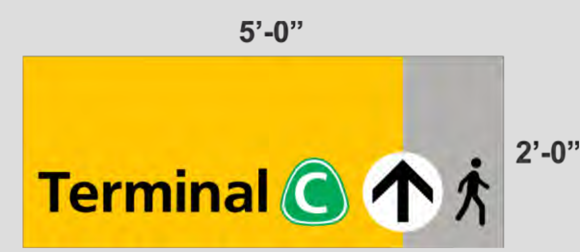


Figure 15-12b

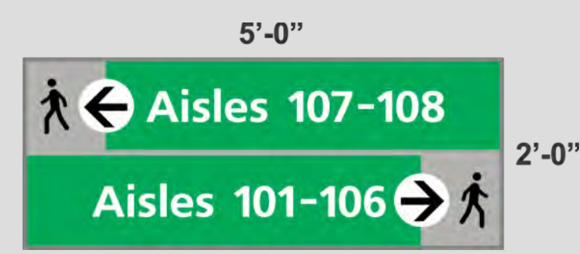


Figure 15-12c

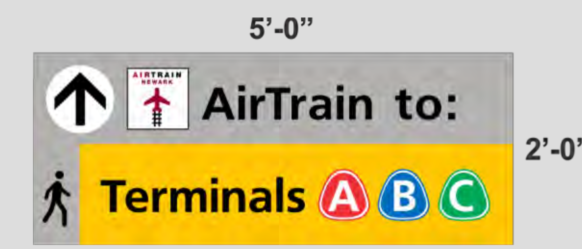


Figure 15-12d

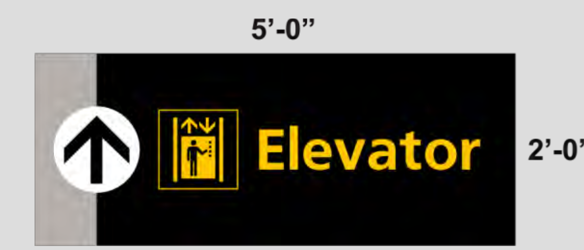


Figure 15-12e

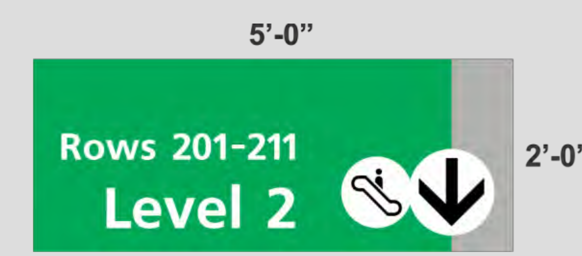


Figure 15-12f

- **Text Placement:** Text shall be placed as described in the *Manual for Pedestrian Signing & Wayfinding*, except messages on signs suspended from the ceiling should be vertically aligned toward the bottom of the sign for greater visibility.
- **Arrows:** The pedestrian directional arrow shall be colored black and centered on a white circular background. No other arrow shall be used on pedestrian signs. Refer to the *Manual for Pedestrian Signing & Wayfinding* for additional discussion.
- **Panel Design:** Sign panels shall be designed as described in the *Manual for Pedestrian Signing & Wayfinding*. All signs shall be sized in increments of 1 inch. Pedestrian signing incorporates a light gray neutral area, also known as the arrow field, that overlaps half of the arrow or half of the logo when there is no arrow. The dimensions and placement of the neutral area shall be as described in the *Manual for Pedestrian Signing & Wayfinding*.
- **Borders:** Signs mounted within sign boxes shall have no border. Sign material beyond the visible sign face shall be the color of the sign background. Other signs shall have a dark gray border of ½ inch.
- **Corner Radii:** All signs shall have square corners with no rounding.
- **Message Separator Lines:** Message separator lines shall be as described in the *Manual for Pedestrian Signing & Wayfinding*.

Pedestrian signs should be manufactured with reflective sheeting as specified in *Appendix F – Color and Material Specifications*. Internally illuminated signs shall follow the translucent color specifications and non-reflective sheeting shall follow the opaque color specifications in the *Manual for Pedestrian Signing & Wayfinding*.

Pedestrian signs located above roadways shall preserve the same minimum vertical clearance as vehicular signs. Other pedestrian signs shall be placed as described in the *Manual for Pedestrian Signing & Wayfinding*.

15B.2 Graphic Elements

Logos and symbols shall be designed and located as described in the *Manual for Pedestrian Signing & Wayfinding*. Graphic elements on pedestrian parking signs are limited to the following logos and symbols:

- Terminal logos
- Transportation logos (bus, shuttle, JFK AirTrain, Newark AirTrain)
- International pedestrian symbol
- Vertical circulation symbols (escalator, elevator, stairs)
- Passenger drop off / pick up symbol

When a sign may be visible to both pedestrians and motorists, the international pedestrian symbol should be added as described in the *Manual for Pedestrian Signing & Wayfinding* and as shown in **Figures 15-12a** to **15-12d**. The symbol should be the same height as other logos and symbols and shall not be larger.

Vertical circulation symbols may be standalone symbols with square borders or may be located next to the arrow in a smaller, overlapping circle, as shown in **Figures 15-12e** and **15-12f**. When located in an overlapping circle, vertical circulation symbols shall be shown with black legend on a white background.

15B.3 Specific Parking Facility Signs

This Section describes specific types of pedestrian signs found near vertical circulation elements (elevators, escalators, and stairs) in parking facilities.

Parking garage level identifiers should follow the layouts shown in **Figure 15-13** and presented in more detail in the *Manual for Pedestrian Signing & Wayfinding*. The legend and background colors of the level number shall match the legend and background color of the corresponding terminal. If there is no corresponding terminal, the level number shall have a green legend on a white background.

Vertical circulation directories should follow the layouts shown in **Figure 15-14** based on the sign dimension constraints at each location. This figure provides additional detail to what is shown in the *Manual for Pedestrian Signing & Wayfinding*.

- If additional rows need to be added to the directory or rows need to be made wider to accommodate the required information, maintain the row height and spacing as shown in **Figure 15-14** for each new or widened row of text.
- When space is limited, signs should be scaled proportionally and the minimum spacing and size criteria of parking facility sign design elements shall be adhered to.

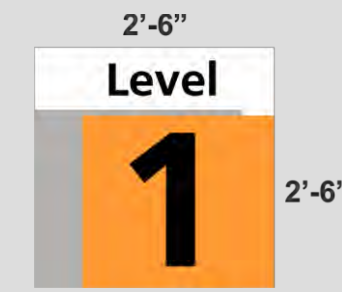


Figure 15-13a

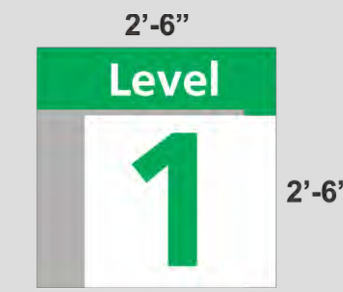


Figure 15-13b

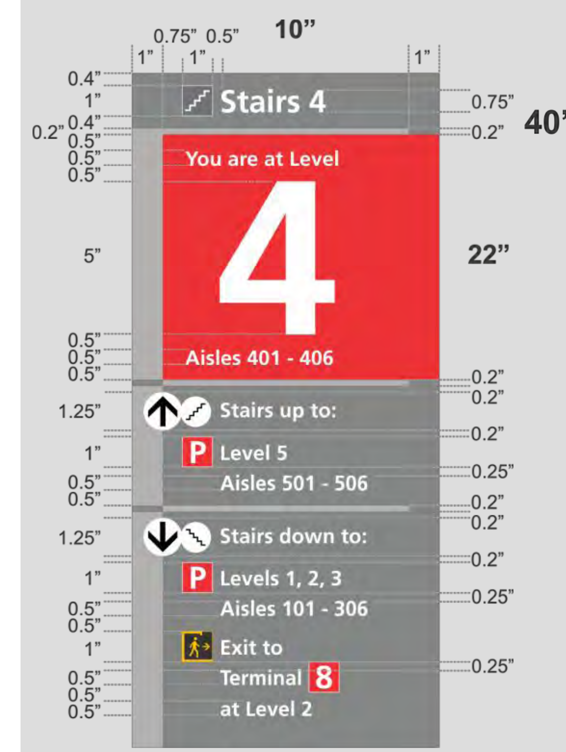


Figure 15-14a

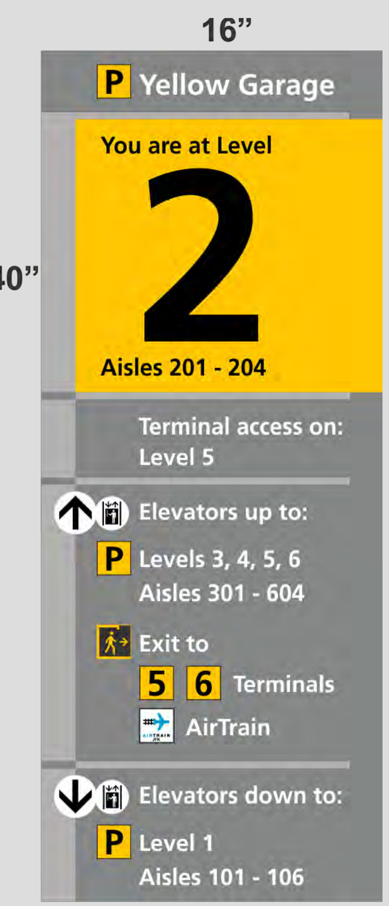


Figure 15-14b

15C. Aisle and Row Markers

Aisle and row markers are unique signs that apply to both vehicular and pedestrian traffic. They serve to reaffirm the location of motorists and help pedestrians identify where their vehicle is parked. To design aisle and row markers:

- Detailed dimensions are provided in *Appendix D – Aisle and Row Markers*.
- Electronic design files for aisle and row markers are available from Port Authority Traffic Engineering.
- Sign color specifications shall be as described in the *Manual for Pedestrian Signing & Wayfinding*.

An "aisle" is defined as the parking spaces accessible from a single parking roadway. A "row" is defined as the parking spaces between two adjacent parking roadways or between a parking roadway and wall. **Figure 15-15** shows a comparison of the definitions of an aisle and a row. Aisle markers are used at JFK and LaGuardia Airports, and row markers are used at Newark and Stewart Airports.

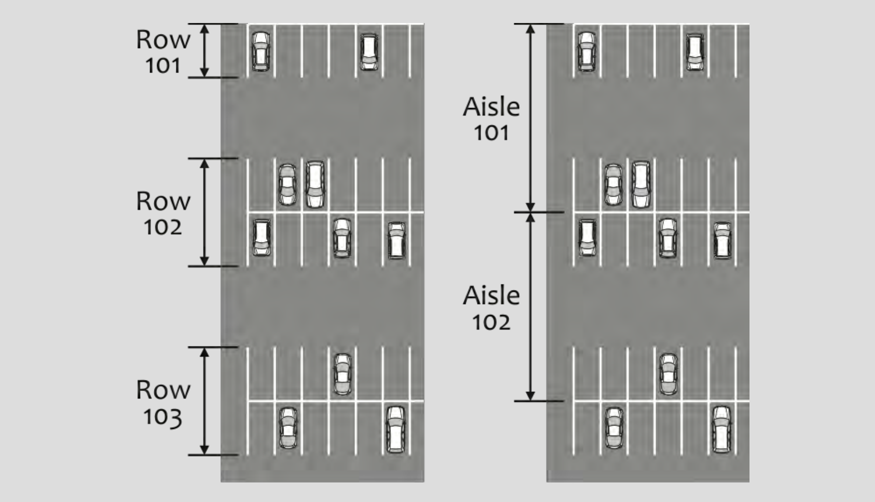


Figure 15-15

Aisle markers are typically mounted next to each other in pairs, with the gray neutral area on each sign located toward the center of the pair of signs as shown in **Figure 15-16**. Row markers are typically either pole mounted on the four sides of a cube or individually mounted (such as on columns or walls), and the gray neutral area is always located on the left of the sign as shown in **Figure 15-17**.

Large parking lots such as JFK Airport Long Term Parking and Newark Airport Lot P6 (Economy Parking) are divided into "areas." Areas are designated with letters to distinguish them from numbered aisles and rows, and are included on aisle and row markers in those parking lots.

At JFK Airport:

- **Figure 15-16a** shows the layout of Short Term Parking lot aisle markers.
- **Figure 15-16b** shows the layout of Short Term Parking garage aisle markers, which shall always include the level number.
- **Figure 15-16c** shows the layout of Long Term Parking lot aisle markers.
- In Short Term Parking facilities, the aisle marker legend and background colors shall match the colors of the zone.
- In Long Term Parking, aisle markers shall have white legend on a green background and the headers shall have green legend on a white background for contrast with Short Term Green Parking.
- The layout and colors of Employee Parking lot aisle markers are shown in *Appendix D – Aisle and Row Markers.*

At Newark Airport:

- **Figure 15-17a** shows the layouts of Short Term Parking lot row markers.
- **Figure 15-17b** shows the layout of Short Term Parking garage row markers except for roof-level markers mounted on light poles.
- **Figure 15-17c** shows the layout of Short Term Parking garage roof-level row markers mounted on light poles.
- **Figure 15-18a** shows the layouts of Daily Parking lot row markers.
- **Figure 15-18b** shows the layout of Daily Parking garage row markers except for roof-level markers mounted on light poles.
- **Figure 15-18c** shows the layout of Daily Parking garage roof-level row markers mounted on light poles.
- **Figure 15-18d** shows the layout of Economy Parking lot row markers.
- In Short Term Parking facilities, the row marker legend and background colors shall match the colors of the associated terminal as shown in *Appendix C – Logos and Symbols*.
- In Daily and Economy Parking facilities, row markers shall have green legend on a white background for contrast with the Terminal C Garage.
- The layout and colors of Employee Parking lot row markers are shown in *Appendix D – Aisle and Row Markers*.

Figure 15-16a

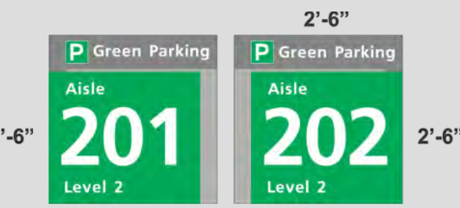


Figure 15-16b

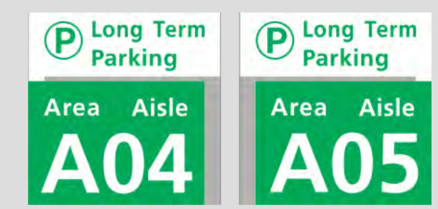


Figure 15-16c

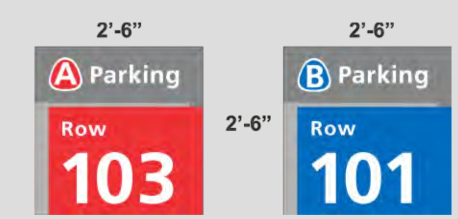


Figure 15-17a

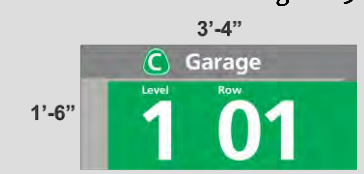


Figure 15-17b

Figure 15-17c

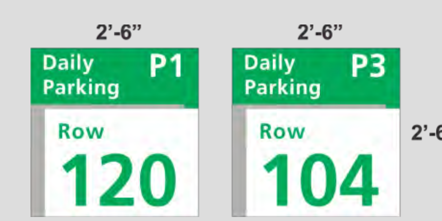
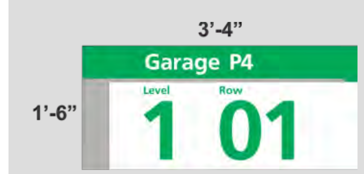


Figure 15-18a



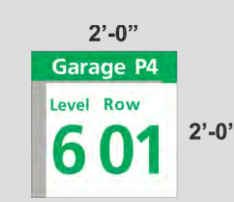


Figure 15-18b

Figure 15-18c

Figure 15-18d

At LaGuardia Airport:

- **Figure 15-19a** shows the layout of Short Term Parking lot aisle markers.
- **Figure 15-19b** shows the layout of Short Term Parking garage aisle markers, which shall always include the level number.
- **Figure 15-19c** shows the layout of Long Term Parking lot aisle markers.

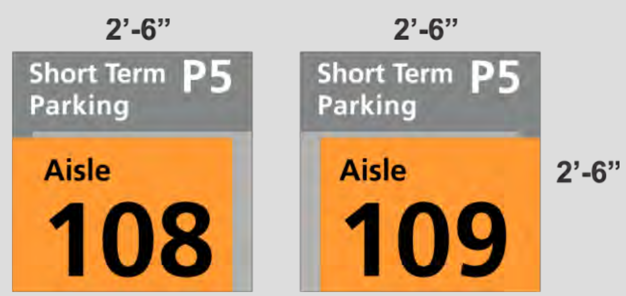


Figure 15-19a

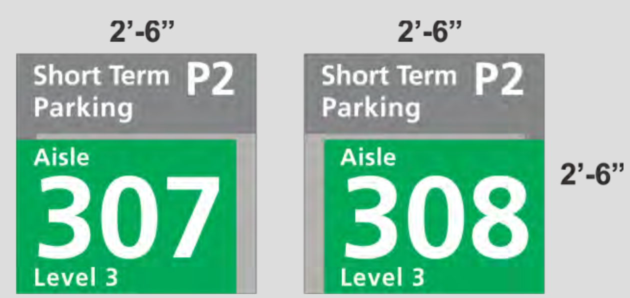


Figure 15-19b

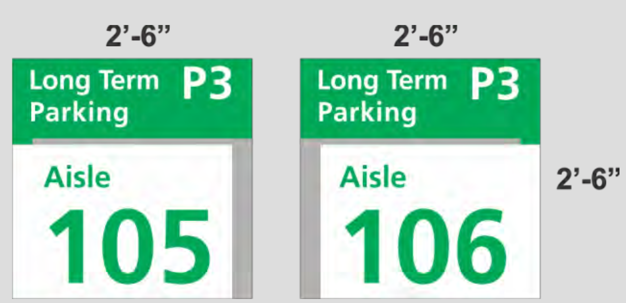


Figure 15-19c

- In Short Term Parking facilities, the aisle marker legend and background colors shall match the colors of the associated terminal as shown in *Appendix C – Logos and Symbols*.
- In Long Term Parking Lot P3, aisle markers shall have green legend on a white background for contrast with Short Term Parking Lots P1 and P2.
- The layout and colors of Employee Parking lot aisle markers are shown in *Appendix D – Aisle and Row Markers.*

At Stewart Airport, **Figure 15-20** shows the layouts of parking lot row markers. Row markers shall have white legend on a green background to emphasize the row number.

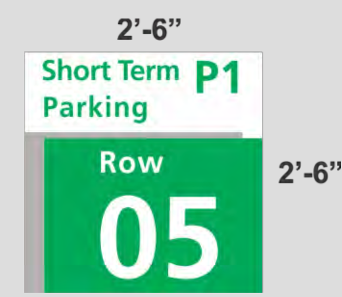


Figure 15-20a

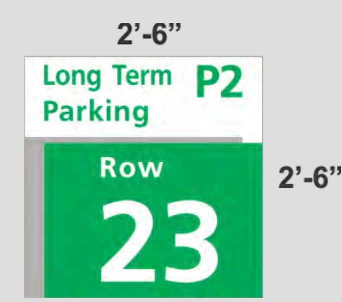


Figure 15-20b

15D. Illumination

Within parking garages, signs mounted within sign boxes may be internally illuminated for greater visibility. Signs are illuminated in garages due to adverse lighting conditions, complex maneuvers required within a short distance, and shorter sight distances than outside the garage. Illumination is warranted for both vehicular and pedestrian signs that are located at key decision points. Sign illumination shall be coordinated with Port Authority Electrical Engineering.

Signs that are internally illuminated shall be made of translucent material. The color specifications shall be as described in the *Manual for Pedestrian Signing & Wayfinding*.

15E. Variable and Changeable Message Signs (VMS and CMS)

Variable Message Signs (VMS) and Changeable Message Signs (CMS) are used in parking facilities to indicate the parking availability within a particular lot, garage, or garage level and can direct motorists to other facilities or levels. VMS and CMS are controlled centrally at each airport and may also be controlled locally at each parking facility or at each individual sign.

VMS and CMS within parking facilities are generally standalone signs. They may be ground mounted or suspended from the ceiling. The characteristics of VMS and CMS are described in *Section 13 – Variable and Changeable Message Signs*.

Parking availability indicators are combinations of a fixed sign panel with VMS or CMS elements. They are located at parking facility entry plazas and are described in *Section 16A – Parking Plaza Signs*.

16. Parking Entry and Exit Plazas

This section addresses signs at and approaching parking lot entry and exit plazas. Signs within parking lots and garages are discussed in *Section 15 – Parking Facilities*.

Parking plaza signs at JFK, Newark, and LaGuardia Airports are typically installed within frames. Sign dimensions given in this section are based on the dimensions of existing frames. Note that if new frames with different dimensions are installed, the specified dimensions of signs in this section shall be updated to match. Signs installed in frames or signs mounted on columns or walls shall be designed with square corners, and all other signs shall be designed with rounded corners. The borders on all signs shall have rounded corners.

Figure 16-1a

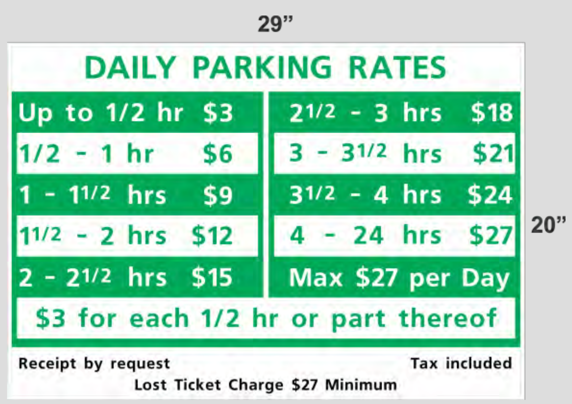


Figure 16-1b

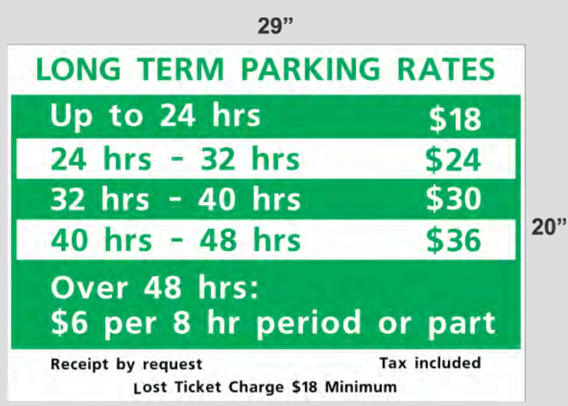


Figure 16-1c

16A. Parking Plaza Signs

Parking toll rate signs are found at and approaching entry and exit plazas. Examples of toll rate signs are shown in **Figure 16-1**. Detailed dimensions and specifications are shown in *Appendix E – Parking Toll Rate Signs*, reflecting the rate structures of each type of parking facility at each airport. As shown in Appendix E, some parking toll rate signs at LaGuardia Airport are installed in vertically oriented frames due to space restrictions, and parking toll rate decals are installed directly on toll plaza structures at some JFK Airport locations.

Note that the Aviation Department may change rates and rate structures at each airport. Consult Port Authority Traffic Engineering for the current rates prior to designing the toll rate sign.

Other signs found at parking entry and exit plazas include the following:

- "Stop – Take Ticket," shown in **Figure 16-2a**, is found at entry plazas only.
- "Stop – Insert Ticket," shown in **Figure 16-2b**, is essentially the same as **Figure 16-2a** and is found at exit plazas only.
- "Stop – Wait Here," shown in **Figure 16-2c**, is found at exit plazas but only where a license plate recognition (LPR) system is present. Depending on location, one of the two arrows shown may be omitted.
- "Lane Closed," shown in **Figure 16-2d**, is found on barriers at both entry and exit plazas, and is only visible when the barrier is deployed.

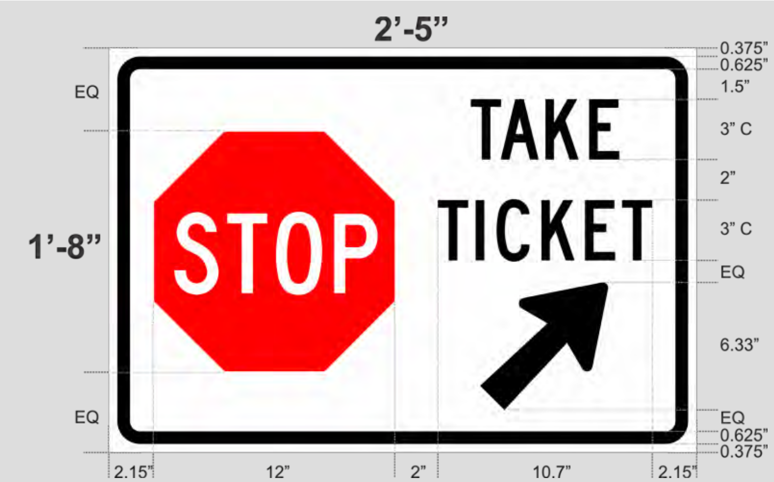


Figure 16-2a

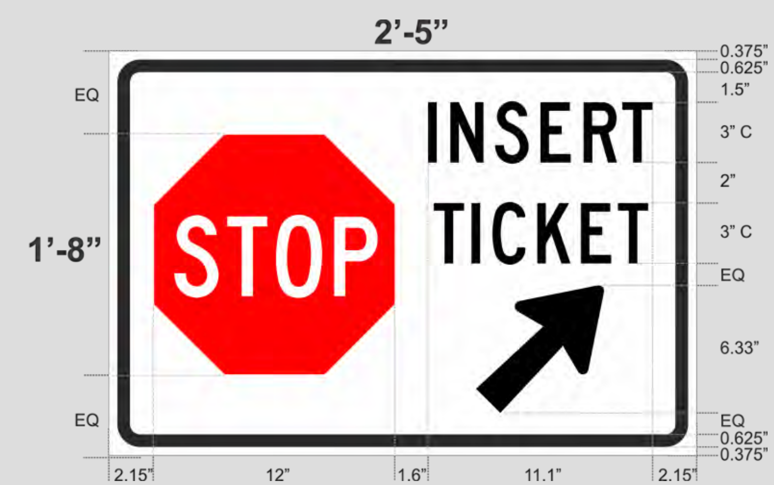


Figure 16-2b

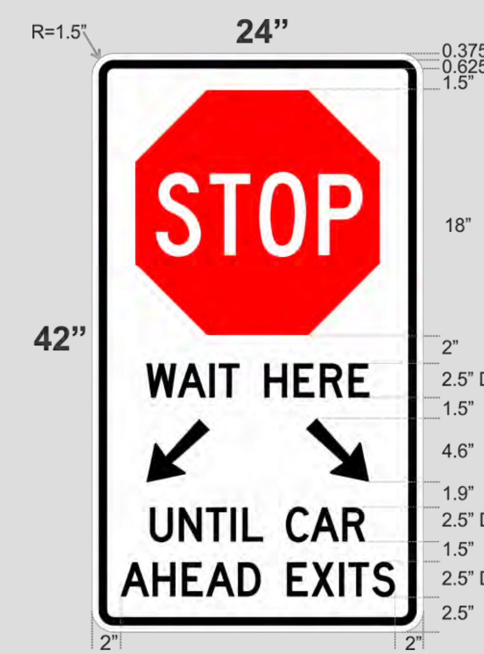


Figure 16-2c

Figure 16-2d

At entry and exit plazas where traffic spikes are employed, signs include the "Severe Tire Damage" message:

- "Do Not Back Up," shown in **Figure 16-3a**.
- "Wrong Way," shown in **Figure 16-3b**, facing the opposing (incorrect) direction of traffic.

At entry and exit plazas without traffic spikes, signs omit the "Severe Tire Damage" message:

- "Do Not Back Up," shown in **Figure 16-3c**.
- "Wrong Way," shown in **Figure 16-3d**, facing the opposing (incorrect) direction of traffic.

The sign shown in **Figure 16-4** is installed just before entering entry plazas at parking facilities that provide a grace period for motorists, allowing them to proceed through the parking lot and exit without being charged.

Figure 16-3a

Figure 16-3c

Figure 16-4

Figure 16-3b

Figure 16-3d

At garage entry plazas, a level status sign may be provided indicating which levels of the parking garage are open or full. An example is shown in **Figure 16-5**. The changeable message sign (CMS) elements shall be designed according to *Section 13 – Variable and Changeable Message Signs*.

In advance of the exit plaza, a sign will indicate whether electronic tolling is accepted in all lanes, as shown in **Figure 16-6a**, or in designated lanes only, as shown in **Figure 16-6b**. If electronic tolling is only accepted in designated lanes, signs as shown in **Figure 16-7** will be mounted on the exit plaza canopy. The first four signs shown are CMS, with two rotating drums that show the accepted payment methods for each lane.

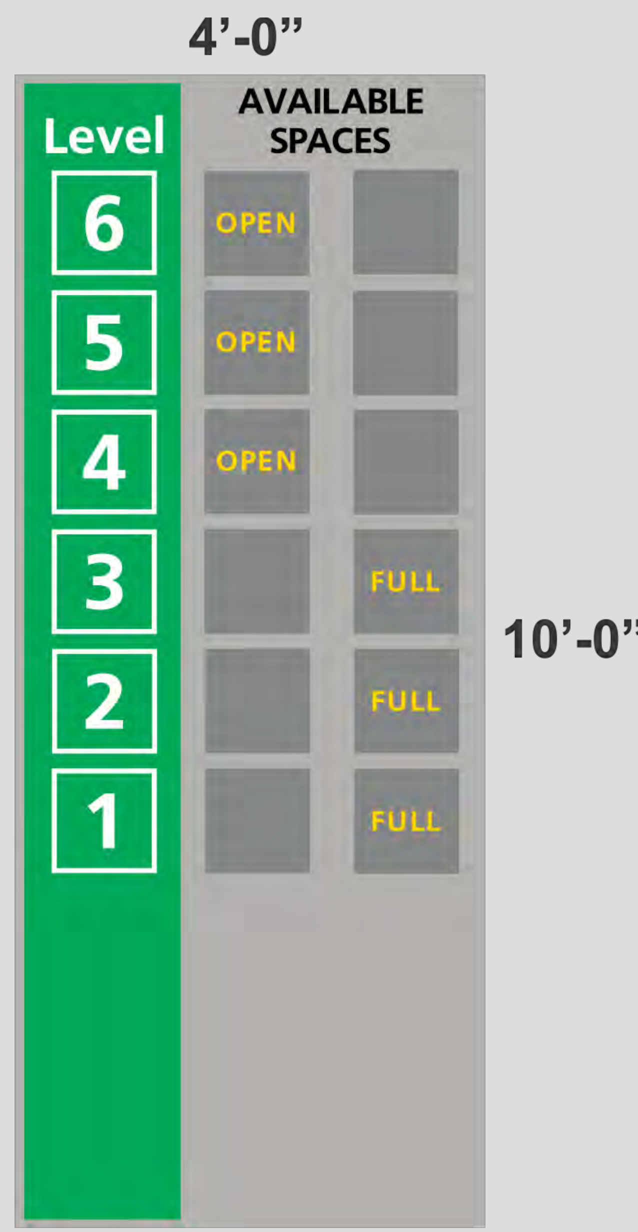


Figure 16-5

Figure 16-6a

Figure 16-6b

Figure 16-7

17. Airside

This section describes signing entering or within the AOA (Air Operations Area).

17A. Guard Posts

Guard posts are the access points from landside roadways to airside roadways. They are designated by letters and numbers at JFK, Newark, and LaGuardia Airports.

A guard post identification sign is typically posted at the guard post, in advance, or both. As shown in **Figure 17-1**, the sign consists of:

- Post designation (if applicable) in yellow text on black background
- "Restricted Area" in white text on red background
- "Authorized Vehicles Only" and related messages in black text on white background

Many guard posts are equipped with a barrier system to prevent unauthorized access. The following three signs are found on an approach to a guard post with a barrier system:

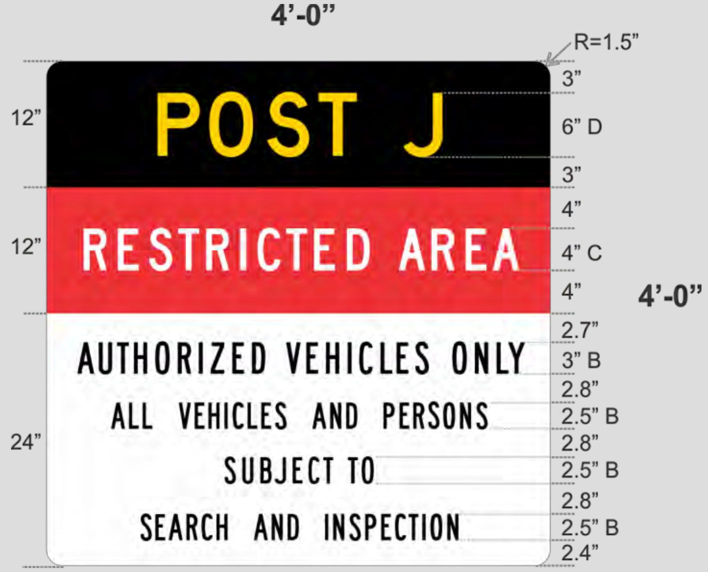


Figure 17-1

- "Barrier Ahead" warning sign with "5 MPH" auxiliary sign, as shown in **Figure 17-2a**, referencing *MUTCD* designations.
- "Stop – Wait here until car ahead exits" regulatory sign, as shown in Section 16, **Figure 16-2c**. This sign is omitted at guard post locations where there is insufficient room for one or more cars to queue behind the vehicle stopped at the guard post.
- "Stop here on red" regulatory sign, as shown in **Figure 17-2b**.

Figure 17-2a

Figure 17-2b

Other signs may be located at specific guard posts with messages or designs particular to that location or facility. These signs may indicate specific restrictions or rules to be observed within the AOA, give instructions to be followed at a specific guard post, or designate lanes for different types of traffic. Examples of these signs are shown in **Figure 17-3**.

Figure 17-3a

Figure 17-3b

17B. Restricted Service Roads

A limited set of signs are used on airside roads, called restricted service roads because they are not open to the public. As per Federal Aviation Administration (FAA) Advisory Circular *AC 150/5340-18*, latest edition or superseding circular, paragraph 11:

- "STOP" signs shall be installed wherever a restricted service road intersects an aircraft roadway (apron, taxiway, or runway). Signs shall be installed at these locations directing drivers to obtain clearance from Traffic Control before proceeding. The only exception is that at crossings in jet blast areas, such as at aprons, it may not be possible to provide mounted signs, so signs may be painted on the pavement as per paragraph 16 of *AC 150/5340-18*.
- Regulatory and warning signs shall adhere to the *MUTCD*.
- Signs shall be mounted at an appropriate height and sized appropriately so as not to interfere with any aircraft using the apron, taxiway, or runway that is intersected. All signs on restricted service roads pertaining to vehicular traffic shall be mounted such that the top of the sign is no higher than 5 feet from the ground.

The Port Authority uses some signs on restricted service roads that are not described in the *MUTCD*. They are shown and dimensioned in **Figure 17-4**.

17C. Aprons, Taxiways, and Runways

Aircraft guide signs are signs on aprons, taxiways, and runways that are intended to be viewed by pilots. These signs are neither designed nor maintained by Port Authority Traffic Engineering. Aircraft guide signs are subject to the FAA, and guidelines and requirements are contained in the FAA's Advisory Circulars:

- The latest edition of *AC 150/5345-44* (or superseding circular) contains the specifications for designing, manufacturing, and testing aircraft guide signs.
- The latest edition of *AC 150/5340-18* (or superseding circular) contains the standards for locating and installing aircraft guide signs.
- The latest edition of *AC 150/5360-12* (or superseding circular) contains guidance on airport sign design, including aircraft guide signs.

All aircraft guide signs shall meet the requirements and should meet the guidelines established by the FAA.

Figure 17-4a

Figure 17-4b

Figure 17-4c

Figure 17-4d

APPENDIX C

PA LOW CLEARANCE SIGNING GUIDELINES

DRAFT

Low Clearance Signing Guidelines

April 15, 2022

Prepared by: Traffic Engineering, Design Division, Engineering Department

For External Use

THE PORT AUTHORITY OF NY & NJ

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1.0 Introduction

Low clearance signs are used to advise road users of the locations on roadways with restricted vertical clearances. The purpose of this policy is to provide a guideline for posting low vertical clearance for structures such as bridges, overpasses and tunnels under Port Authority's jurisdiction. Use of this policy along with sound engineering judgment in the design of a Low Clearance Signing System for a facility will produce a uniform and efficient design for all road users and sufficiently guide overheight vehicles to an appropriate route.

2.0 Policy and Procedures

The Port Authority has established these guidelines to reflect a consistent approach to low clearance signing at its facilities wholly contained in the states of New York and New Jersey and for its bridges and tunnels connecting the two states.

2.1 Facilities within a state

A uniform low clearance signing policy shall be used for facilities within New York or New Jersey following the general rules set forth by the respective states' Departments of Transportation. **Figure 1** illustrates examples of low clearance signing for these facilities.

2.1.a State of New York facilities

For Port Authority facilities entirely contained within the state of New York, all structures with a measured clearance of less than 14' – 0" shall be signed for low clearance, and the clearance indicated on the signs shall be the measured clearance minus 12 inches rounded down to the whole inch, as specified in *New York State Supplement to the Manual on Uniform Traffic Control Devices (MUTCD)*, dated March 16, 2010.

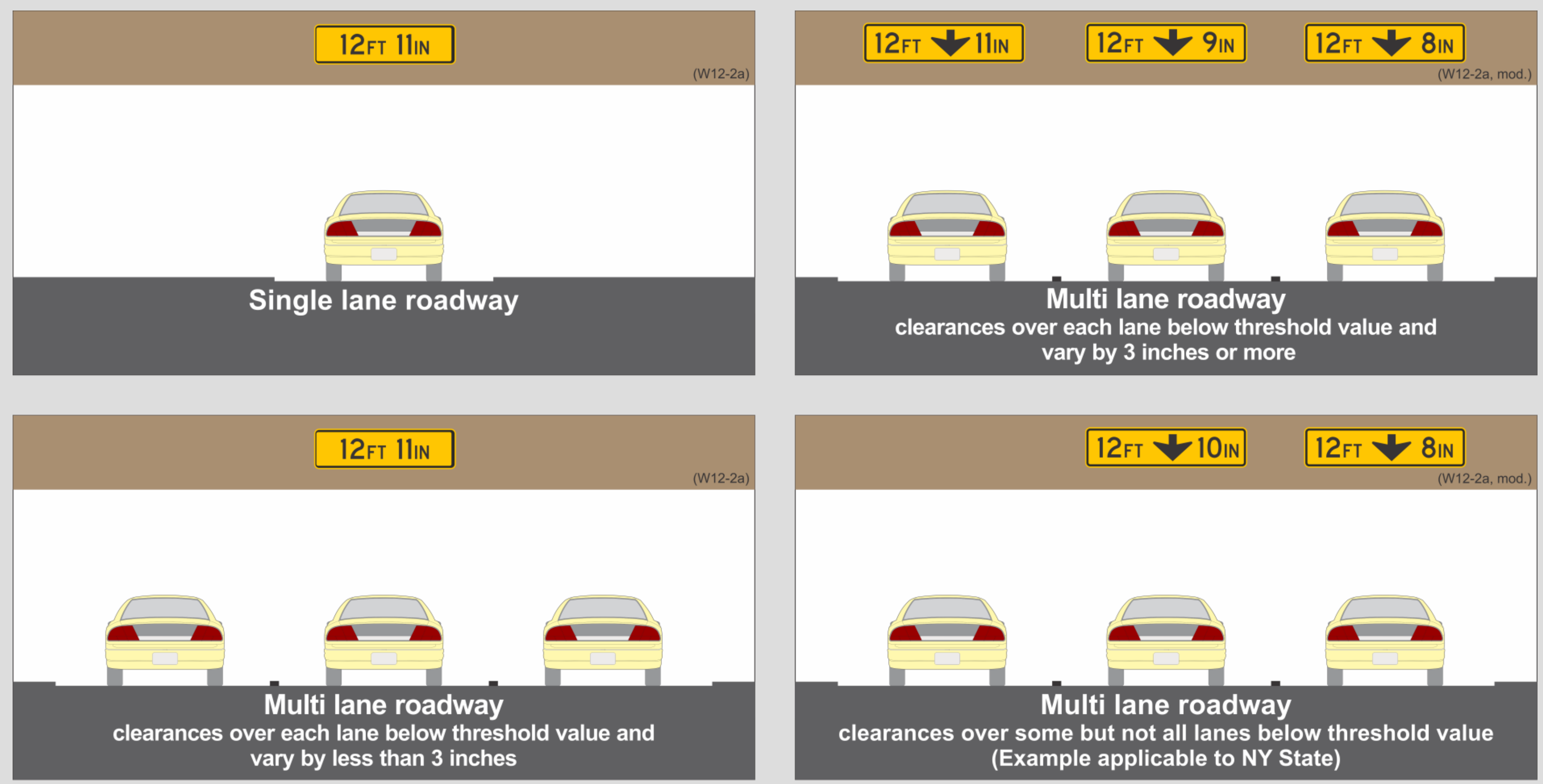
Based on this requirement, a structure having a measured clearance of 13' – 11" (rounded down to the whole inch) would be the starting highest value requiring a clearance posting on Port Authority roadways in the State of New York and the starting clearance posting for this condition would be 12' – 11".

2.1.b State of New Jersey facilities

For Port Authority facilities entirely contained within the state of New Jersey, all structures with a measured clearance of less than 14' – 9" shall be signed for low clearance, as specified in *New Jersey Department of Transportation's Memorandum dated July 22, 2008, "Vertical Clearance Posting of Bridges (For Bridges over State owned roadways)."* The clearance indicated on the signs shall be the measured clearance minus 3 inches rounded down to the whole inch.

Based on this requirement, a structure having a measured clearance of 14' – 8" would be the starting highest value requiring a clearance posting on Port Authority roadways in the State of New Jersey and the starting clearance posting for this condition would be 14' – 5".

Figure 1: Low Clearance Signing for Facilities in New York & New Jersey



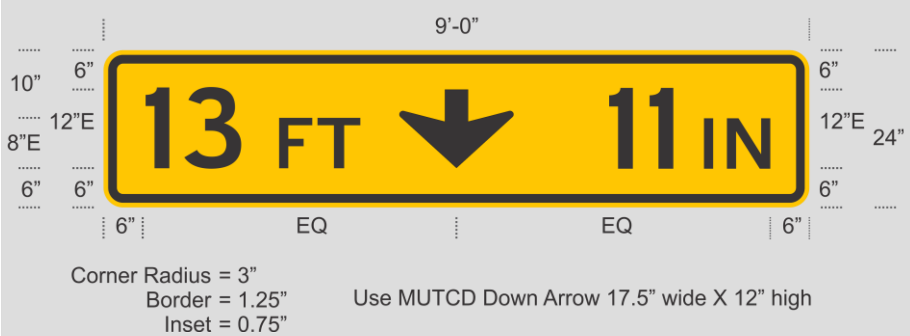
Notes: 1. Use low clearance posting threshold values and buffers specified by NYSDOT and NJDOT for respective facilities.
2. Advance warning sign shall always be W12-2.

2.1.c Signing Guidance

Only Signs W12-2 and W12-2a, as specified in the 2009 edition of MUTCD; and the Sign W12-2a (mod), a modified version of the MUTCD Sign W12-2a, shall be used to warn drivers of low clearances. Signs W12-2a or W12-2a (mod) shall be installed on the structure with the low clearance roadway underneath it. Sign W12-2 shall only be used in advance of the structure.

Refer to Tables 2C-2 and 2C-4 in the 2009 edition of the MUTCD for choosing sign sizes according to roadway type and for choosing location of advance warning signs respectively. Refer to Figure 2 for design details of Sign W12-2a (mod).

Figure 2: Sign W12-2a (modified)



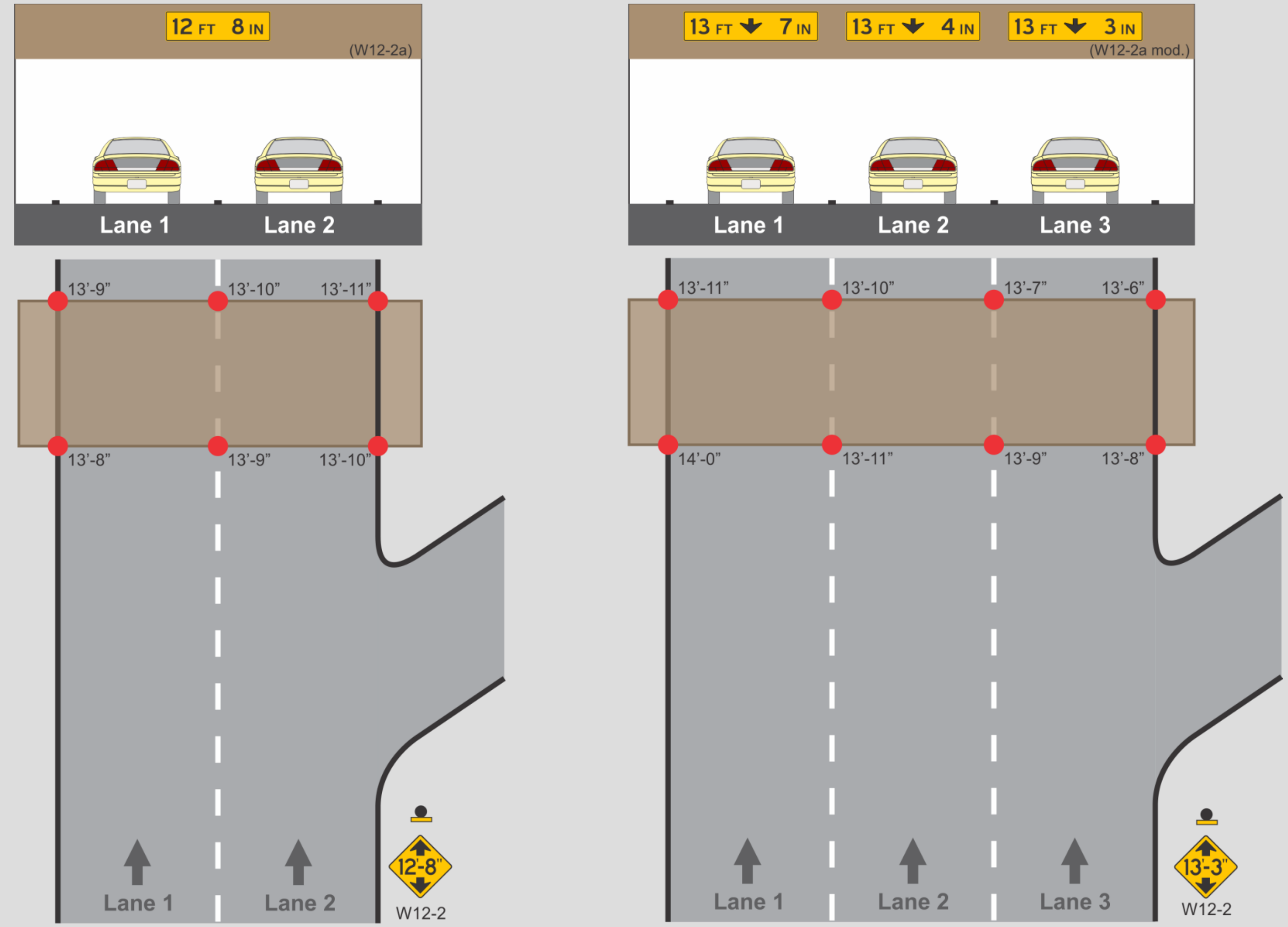
Where the posted clearance is less than the legal maximum vehicle height of 13'-6" (see *Appendix A, Section A.1*), an advance warning sign with a supplemental distance plaque should be placed at the nearest intersecting road or wide point in the road at which a vehicle can detour or turn around.

Low clearance information may be included on a guide sign as a supplementary message, but it does not replace the requirement of installing an advance low clearance warning sign.

Consideration should be given to install signs over shoulders more than 8 feet wide and with low clearance. There may be a need to shift traffic onto the shoulder as a traffic control measure during construction or in response to a crash.

The illustration in Figure 3 shows how typical vertical clearance measurements taken in the field are interpreted and low clearance message is signed on a 2 lane roadway.

Figure 3 - Interpretation of Field Data and Signing on



- Lowest measured vertical clearance on roadway = 13'-8". Advance warning sign shall display posted clearance of 12'-8" (12" buffer in NY).
- Since lowest measured clearances on individual lanes do not vary by more than 3", lanes should not be individually signed.

Lane	Lowest measured vertical clearance	Posted vertical clearance
1	13'-8"	12'-8"
2	13'-9"	12'-8"

Two Lane Roadway
with varying vertical clearances
(in the State of NY)

- Lowest measured vertical clearance on roadway = 13'-6". Advance warning sign shall display posted clearance of 13'-3" (3" buffer in NJ).
- Since lowest measured clearances on individual lanes vary by more than 3", lanes should be individually signed.

Lane	Lowest measured vertical clearance	Posted vertical clearance
1	13'-10"	13'-7"
2	13'-7"	13'-4"
3	13'-6"	13'-3"

Multi Lane Roadway
with varying vertical clearances
(in the State of NJ)

2.1.c.i Warning Signs for Structures over Multilane Roadways

Refer to Figures 1 and 3 for signing details on multilane roadways. If the clearance over each lane is below the threshold value for that jurisdiction and the difference in minimum clearances over individual lanes is less than three inches, then a single low clearance warning sign W12-2a shall be installed on the structure and in the center of the roadway to cover all travel lanes. The minimum clearance of the entire structure shall govern the posted low clearance.

If the clearance over each lane is below the threshold value for that jurisdiction and the difference in minimum clearances between any two lanes equals or exceeds three inches, then separate W12-2a (mod) signs shall be installed over each travel lane displaying the clearance pertinent to that lane. The clearance displayed on the advance warning sign, if used, shall be the lowest of the values posted.

If the clearance over some but not all lanes is below the threshold value for that jurisdiction, then separate W12-2a (mod) signs shall be installed only over the travel lanes requiring the low clearance posting. An advance warning sign is not required in this case as the vehicles should be able to use travel lanes that have clearance above the threshold value.

2.2 Bridges connecting New York & New Jersey

As specified in the *PANYNJ Traffic Rules and Regulations (Green Book)*, the height restrictions at the upper and lower levels of George Washington Bridge are 14' – 0" and 13' – 6" respectively. The maximum vehicle height for all of the Staten Island Bridges is 14' – 0". Vehicles over these heights may cross Port Authority bridges with police escort but require a permit. As part of the permitting process, Port Authority strictly controls the movement of overheight vehicles across its bridges and therefore posting of the maximum permitted height regulations is not required.

Due to the existing procedures at the bridges, signs directing vehicles to a hold area for escort shall be installed prior to the hold area. Within the hold area, signs with instructions for overheight vehicles may be installed. Other applicable restrictions such as HAZMAT and width constraints should be evaluated and incorporated, if possible, while developing the hold area signing.

2.3 Holland and Lincoln Tunnels

The maximum vehicle height restriction is 12' – 6" for the Holland Tunnel and 13' – 0" for the Lincoln Tunnel. Since the maximum vehicle height regulations for the tunnels are lower than the legal statutory maximum vehicle height of 13'– 6", regulatory signs shall be posted defining maximum vehicle height.

A sign shall be installed at the exit that overheight vehicles must take to avoid an overheight crash at the facility. At least one advance sign shall be installed before such an exit. Regulatory signs shall also be posted near the tunnel entrance portal. Signs shall not be installed on the portal itself so that the maximum vehicle height regulation will not be confused with the actual vertical clearance of the structure.

Regulatory signing shall be designed in accordance with the signing principles outlined in the most current *MUTCD*.

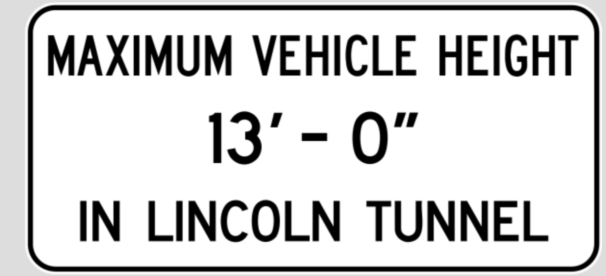
Additional advance signing may be used on approach roadways to direct overheight vehicles to an alternate route without low clearance limitations.

Other applicable restrictions such as HAZMAT and width constraints should be evaluated and incorporated if possible while developing the low clearance signing implementation plan. Variable message signs (VMS) may be used for supplementary signing only.

Figure 4 illustrates a typical regulatory signing sequence on an approach to a Port Authority tunnel.

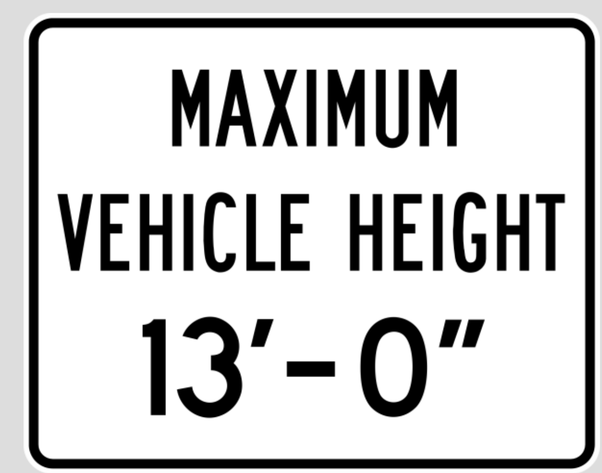
Figure 4: Sample Regulatory Signing Sequence for PANYNJ Tunnels

Sign 1 – Typical Advance Sign



Sign 2 – Typical Sign at the last exit for Overheight Vehicles

Sign 3 – Typical Sign at Facility Entrance



APPENDIX A - Low Clearance Signing Laws and Standards

A.1 Statutory Vehicle Height

Each state has adopted statutes to legally establish the maximum legal height of a vehicle that can operate on its highways without the need for special permitting and routing. The states of New York and New Jersey have adopted thirteen and one-half feet (13' – 6") as the legal maximum vehicle height, so traffic entering into Port Authority facilities in New York and New Jersey has the same legal maximum height requirements. The following statutes define the legal height of vehicle in each jurisdiction.

New York State, Vehicle and Traffic Law, Title 3, Article 10, Section 385- …The height of a vehicle from under side of tire to top of vehicle, inclusive of load, shall be not more than thirteen and one-half feet. Any damage to highways, bridges or highway structures resulting from the use of a vehicle exceeding thirteen feet in height where such excess height is the proximate cause of the accident shall be compensated for by the owner and operator of such vehicle.

New York City, Traffic Rules, Chapter 4, Title 34, Section 4-15 LIMITATIONS UPON DIMENSIONS AND WEIGHTS OF VEHICLES …(b)..(2) Height of vehicle. The height of a vehicle from underside of tire to top of vehicle, including its load, shall not be more than 13 1/2 feet; provided, however, that air cargo carried in containers and pallets loaded onto flatbed trucks that thereby exceed such height may travel between any airport under the jurisdiction of the Port of New York Authority and off-airport facilities involved in the handling of air cargo located within one mile of such airport on local routes to be designated by the commissioner. Any such vehicle on such route shall not be required to obtain a permit for such travel.

The New Jersey Statutes - Title 39 Motor Vehicles and Traffic Regulation - 39:3-84 Vehicles, dimensional, weight limitations; routes, certain; prohibited. … the maximum height of any vehicle or combination of vehicles, including load or contents of any part or portion thereof, except as otherwise provided by this subsection, shall not exceed 13 feet, 6 inches.

A.2 Existing Low Clearance Standards

A.2.a Manual of Uniform Traffic Control Devices (MUTCD) 2009

Signing is the most widely used mitigation strategy for substandard vertical clearances. Whenever substandard vertical clearances are identified, warning signs should be installed in advance of the nearest intersecting road or point where an overheight vehicle can detour or turn around.

The MUTCD criteria for low clearance signing are based on legal maximum height. The standard, guidance and option are defined below:

Section 2C.27 Low Clearance Signs (W12-2 and W12-2a)

Standard:
The Low Clearance (W12-2) sign….shall be used to warn road users of clearances less than 12 inches above the statutory maximum vehicle height.

Guidance:
The actual clearance should be displayed on the Low Clearance sign to the nearest 1-inch not exceeding the actual clearance. However, in areas that experience changes in temperature causing frost action, a reduction, not exceeding 3 inches, should be used for this condition.

Where the clearance is less than the legal maximum vehicle height, the W12-2 sign with a supplemental distance plaque should be placed at the nearest intersecting road or wide point in the road at which a vehicle can detour or turn around.

In the case of an arch or other structure under which the clearance varies greatly, two or more signs should be used as necessary on the structure itself to give information as to the clearances over the entire roadway.

Clearances should be evaluated periodically, particularly when resurfacing operations have occurred.

Option:
The Low Clearance sign may be installed on or in advance of the structure. If a sign is placed on the structure, it may be a rectangular shape (W12-2a) with the appropriate legend.

A.2.b New York State Policy/New York City Policy

The New York State Vehicle and Traffic Law, Section 1621 (c) states the following:

"…..Such department of transportation shall cause signs to be erected to inform persons of the legal overhead clearance for all bridges and elevated structures on highways under its jurisdiction. The legal clearance shall be one foot less than the measured clearance. The measured clearance shall be the minimum height to the bridge or structure measured vertically from the traveled portion of the roadway. On bridges or structures having fourteen feet or more of measured clearance, no such signs shall be required".

New York City has adopted the New York State Policy.

A.2.b.i New York State MUTCD Supplement

New York State's latest MUTCD Supplement, dated March 16, 2010 addresses the changes in the 2009 MUTCD. The following section contains revisions identified in the Supplement.

Section 2B.108 Regulatory Clearance Signs (NYR5-6, NYR5-7)

NYR5-6

NYR5-7

Standard:
Regulatory Clearance (NYR5-6 and NYR5-7) signs … shall be used to indicate legal overhead clearances at bridges and elevated structures when measured overhead clearance is less than 14 feet. Such legal overhead clearance shall be one foot less than the measured clearance (the vertical distance between the traveled portion of the roadway and the overhead structure).

Support:
Sections 1621(c), 1640(d), 1650(c), and 1660(c) of the New York State Vehicle and Traffic Law require posting of signs informing persons of the legal overhead clearances of bridges and elevated structures when the measured clearance is less than 14 feet; legal clearance is one foot less than measured clearance.

Standard:
The NYR5-6 sign shall be used where there is only one approach lane. It shall also be used where there is more than one approach lane if a single clearance applicable to all approach lanes is to be indicated. Where used, the NYR5-6 sign shall be placed on, or immediately in advance of, the bridge or elevated structure.

The NYR5-7 sign shall be used where there is more than one approach lane, and there is a significant difference in clearance between any two of the lanes. Where used, the NYR5-7 sign shall be mounted over each lane having a measured clearance less than 14 feet, and shall be placed on, or immediately in advance of, the bridge or elevated structure. It shall be mounted over the lane to which it applies.

The clearance stated on the NYR5-6 or NYR5-7 sign shall be the legal clearance in feet and inches, to the nearest whole inch. The clearance stated on the NYR5-6 sign shall be the minimum legal clearance over the entire approach roadway. The clearance stated on the NYR5-7 sign shall be the minimum legal clearance over the lane to which it applies.

Option:
The NYR5-6 sign may be mounted either over the roadway or at the side of the roadway.

Support:
Overhead mounting of the NYR5-6 sign is desirable on multilane approaches".

Section 2C.27 Low Clearance Signs (W12-2 and W12-2a)

Standard:
The W12-2a sign shall not be used in New York.

Option:
The Low Clearance (W12-2) sign may be used to warn of overhead bridges and elevated structures, which are posted with Regulatory Clearance (NYR5-6 and NYR5-7) signs …

Guidance:
The Low Clearance sign (W12-2) should be used on the immediate approach to the bridge or elevated structure.

Option:
Additional Low Clearance signs (W12-2) may be used, as necessary, along the highway on which the low clearance is located.

Guidance:
Where additional Low Clearance signs are used, they should be placed at locations where affected traffic can detour or conveniently turn around. They should also be placed immediately beyond intersections where affected vehicles might enter the highway on which the low clearance is located. Low Clearance signs more than 1000 feet from the low clearance structure should be supplemented with Distance plaques … stating the distance to the structure.

The Low Clearance sign (W12-2) should not be used on highways intersecting the highway on which the low clearance is located.

Standard:
The clearance displayed on the Low Clearance sign shall be the same as that on the Regulatory Clearance sign (or signs) to which it pertains. Where separate low clearances are posted for individual lanes with NYR5-7 signs, the clearance displayed on the Low Clearance sign shall be the lowest of the values posted.

Option:
If separate Low Clearance signs are placed over each lane, each may display the low clearance pertaining to that lane".

A.2.c New Jersey State Policy

The New Jersey State policy is delineated in NJDOT Design Manual for Bridges and Structures as follows:

"…State Laws, N.J.S.A. 27:5G-1 through 27:5G-4, require that every bridge or overpass carrying municipal, county, or state roads, including railroads, with a vertical clearance of less than 14' - 6" from the roadway beneath shall have a minimum clearance marked or posted thereon in accordance with the current standards prescribed by the Manual of Uniform Traffic Control Devices for Streets and Highways.

Signs warning persons operating motor vehicles that they are approaching a bridge or overpass with less than 14' - 6" clearance shall be placed at the last safe exit or detour preceding the bridge or overpass. The minimum clearance of the bridge or overpass shall be indicated on these signs. The signs required by this section shall be maintained by the appropriate government entity, which has jurisdiction over the roadway underneath the bridge or overpass. The above provisions do not apply to toll road authorities."

NJDOT, being on the conservative side, starts posting low clearance signs on structures with clearance less than 14' – 9".

APPENDIX B –New York State DOT Research Project

B.1 Bridge Vehicle Impact Assessment

NYSDOT has funded a research project, Project # C-07-10- "Bridge Vehicle Impact Assessment" that is being conducted by The City College of New York, with Principal Investigators, A.K. Agrawal and C. Chen from the Department of Civil Engineering; April 1, 2008 to December 31, 2010. The objectives of this research are to review contributing factors to bridge impacts, provide recommendations to NYSDOT on means of reducing the likelihood of future bridge hits for frequently hit bridges, provide long term, feasible, and economical suggestions to reduce likelihood of bridge hits for the complete population of bridges in New York State and review and comment on the NYSDOT Collision Vulnerability Assessment Procedure and provide recommended improvements. Currently, the project has published three task reports, "Task 1- Problem Background Investigation, Task 2- Determine Current Practices and Task 3- Collect NYSDOT Expertise on Bridge Hits".

Review of these task reports indicates that these are the most thorough research on the subject of low bridge crashes related to low vertical clearance for the area affecting Port Authority facilities. The reports include results of a national survey regarding under-reporting of bridge underclearance postings. Of the 29 responding states, only New York State under-reported by 12 inches. The state of Montana uses 6 inches and all others states use between 0 and 3 inches. Since this study is not yet complete, specific recommendations regarding low clearance policies for New York State are not available and therefore not included in this guideline.

APPENDIX C – Overheight Vehicle Warning System

C.1 General

An overheight vehicle warning system should be considered at a location when there has been a history of overheight vehicle crashes.

C.2 Warrants

An engineering study should be conducted to determine the need for an overheight vehicle warning system. An overheight vehicle warning system should be considered when one or more of the following conditions occur:

a. When all other standard protective measures that have been implemented at the site have proven to be ineffective as countermeasures for overheight vehicle crashes.

b. The structure clearance over the roadway is less than 13' – 6".

c. The cost of repair to the structure and impacts to traffic are considered significant.

d. The impacts of a structure collision are considered extensive to the surrounding roadway network.

e. The installation of an overheight vehicle warning system will provide long term economic benefit. Specifically, the cost of installing, maintaining, and operating the Overheight Vehicle Warning System is less than the projected cost of repairs and road user impacts due to projected collisions with overheight vehicles.

The satisfaction of one or a combination of warrants for an Overheight Vehicle Warning System shall not in itself require the installation of a system. The decision to install an overheight vehicle warning system shall be based on the results of an engineering study and sound engineering judgment.

APPENDIX D – References

A Policy on Geometric Design of Highways and Streets – 5th Edition
American Association of State Highway Transportation Officials (AASHTO)

Manual on Uniform Traffic Control Devices (MUTCD) – 2009 Edition
Federal Highway Administration (FHWA)

Highway Design Manual
MUTCD Supplement, March 16, 2011
New York State Department of Transportation (NYSDOT)

Design Manual for Bridges and Structures – 5th Edition
New Jersey Department of Transportation (NJDOT)

APPENDIX D

PA TRAFFIC PAVEMENT MARKINGS DESIGN AND DRAWING PREPARATION GUIDELINES

Traffic Pavement Markings Design and Drawing Preparation Guidelines

THE PORT AUTHORITY OF NY & NJ

April 15, 2022

Prepared by: Traffic Engineering, Design Division, Engineering Department

For External Use

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General Procedures

The following information is presented as a guideline for the design of typical traffic pavement marking designs and is not intended to define all potential conditions that may be encountered. Pavement markings on all PANYNJ facilities must be in strict conformance to these guidelines, and the latest edition of the FHWA *Manual on Uniform Traffic Control Devices* (MUTCD).

Design Procedures

A. Stage 1 – Concept Design

If pavement markings are proposed, concept drawings shall be developed including the following:

1. Pavement marking layout
2. Lane width dimensions

B. Stage 2 – Preliminary Design

Stage 2 design shall include the following:

1. Pavement marking layout
2. Pavement marking callouts (type, color)
3. Critical Dimensions

C. Stage 3 – Final Design

Pavement marking drawings shall only include pavement marking details, and exclude all other items (e.g. signs, barriers, etc.). All other items (e.g. signs, barrier) shall not be combined on one drawing, unless otherwise directed by PA Traffic. Pavement Marking Contract Drawings shall be designated “T”.

1. The Traffic General Notes, Abbreviation and Legend Drawing shall include all information related to pavement markings. See Standard Details (TD.010).
2. Pavement Marking Removal Plan – see sample plan in Appendix A
   a. All existing markings that will be in conflict with proposed markings shall be shown on a removal plan unless otherwise removed by milling and/or pavement replacement.
   b. Use of blackout paint or other coating material on any finished wearing surface is prohibited.
3. Pavement Marking Installation Plan – see sample plan in Appendix A
   a. All items shown in Stage 1 and 2. Including: Pavement marking layout, pavement marking callouts, and critical dimensions.
   b. Constructability dimensions
      i. Lane width
      ii. Crosswalk width
      iii. Location & Offsets
4. Pavement Marking Detail Sheet - See Standard Details (TD.050).

D. Stage 4 – Construction Services

During Stage 4, the following shall be performed:

1. The designer may be asked by the RE to inspect the pavement marking installation to ensure that it is in accordance with the approved contract drawings.
2. The designer is responsible for coordinating the commissioning of the pavement marking assets, in accordance with the Roadway Device Management System (RDMS) process.
   a. Upon final installation of the pavement markings, the engineer of record is required to provide the Traffic Asset Manager with final contract drawings showing final as-built conditions. The approved product submittals and/or specifications should also be provided so that the Roadway Devices Management System (RDMS) can be updated to reflect the work.

Design Criteria

A. Longitudinal Markings

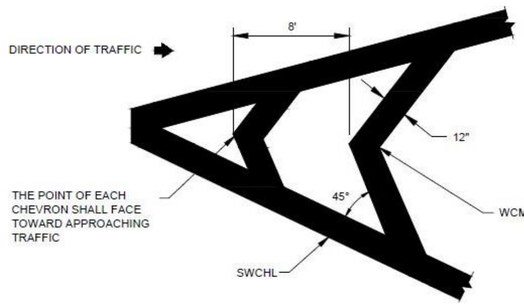
Longitudinal markings shall be designed in accordance with the MUTCD and the PANYNJ Traffic Standard Detail TD50.01. Specific design considerations shall be made for the following:

1. Lane Line Widths
    a. As shown on Standard Detail TD50.01, the designer must choose between normal width solid/dotted lane lines (6") or "wide" solid/dotted lanes (12"). The wide solid/dotted lane lines shall be used whenever the lane delineates an exclusive turning movement and/or engineering judgement dictates its use.
2. Yellow vs. White Lines
    a. Whenever determining the color of longitudinal markings, the designer shall strictly adhere to MUTCD Section 3A.05.
3. High Contrast
4. Through Lane Markings at Airport Frontages

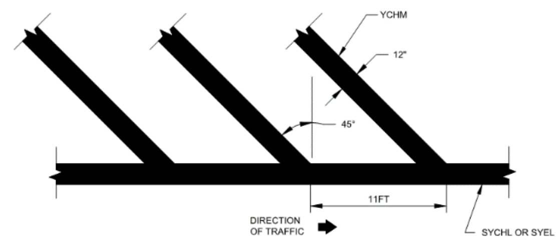
B. Transverse Markings

Transverse markings shall be designed in accordance with the MUTCD and the PANYNJ Traffic Standard Details. Design drawings must be prepared showing specific dimensions and striping layout for all markings. Specific design considerations shall be made for the following:

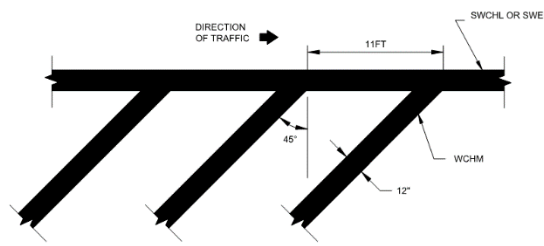
1. Stop Lines (see TD50.02)
    a. Stop line width is 24" on all PANYNJ facilities. In the event that the stop bar is in NYCDOT jurisdiction, the width may be reduced to 18" in accordance with their guidelines.
    b. Stop lines should be placed 4 feet in advance of the nearest crosswalk line at controlled intersections. This can be increased to accommodate vehicle turning movements. The 4 foot dimension is measured from the outside edge of the line markings (not center-to-center).
    c. In the absence of a marked crosswalk, the stop line should be placed at the desired stopping point but should not be placed more than 30 feet or less than 4 feet from the nearest edge of the traveled way. The minimum desirable distance from the edge of the travel way should be 10'.
    d. If more than 30' is needed to account for vehicle turning movements, it must be approved by the Chief Traffic Engineer.
2. Yield Lines (see TD50.02)
    a. Yield line width is typically 24". The designer may use 12" yield line if engineering judgement dictates.
    b. Yield lines should be placed a minimum of 4 feet in advance of the nearest crosswalk line at controlled intersections. The 4 foot dimension is measured from the outside edge of the line markings (not center-to-center).
    c. In the absence of a marked crosswalk, the yield line should be placed at the desired stopping point, but should not be placed more than 30 feet or less than 4 feet from the nearest edge of the traveled way.
3. Crosswalks (see TD50.02)
    a. High visibility crosswalks should be used in high traffic pedestrian areas and/or in circumstances that require a higher level of visibility.
    b. The selection of crosswalk locations shall be in accordance with the latest PANYNJ *Signalized Intersection Crossing Guidelines*.
    c. Crosswalks consist of two parallel 12" white lines. Crosswalk lines should extend across the full width of pavement. This crosswalk type shall be used in areas with basic pedestrian traffic loads.
    d. Crosswalk width (gap between the lines) shall be determined by the designer and shown on the contract drawings, but should not be less than 6 feet. In areas of high pedestrian volume, such as Airport Terminal Frontages, this width should be increased to accommodate multiple pedestrians crossing at the same time.
4. Channelizing Lines
    a. A channelizing line shall be a 12" white line.
    b. Solid white channelizing lines (SWCHL) should be used to form islands where traffic in the same direction of travel is permitted on both sides of the island.
    c. Exit ramps and entrance ramps with parallel acceleration lanes shall have channelizing lines placed on both sides of the neutral area.
    d. Entrance ramps with tapered acceleration lanes shall have channelizing lines placed along both sides of the neutral are to a point at least one-half of the distance to the theoretical gore.
    e. Cross hatch markings should be used in-between channelizing lines when the buffer area is wider than 4 feet (See figure).
5. Cross Hatch Markings (see TD50.03)
    a. White chevron markings (WCM) should be placed in the neutral area of exit ramp and entrance ramp gores for special emphasis.
    b. Yellow cross hatch markings (YCHM) should be placed in the flush median area between the two sets of no-passing zone markings.
    c. The cross hatch markings are placed at a 45º angle to the direction of travel, such that the cross hatch lines provide the appearance of a barrier to traffic (See figure).



WHITE CHEVRON MARKING
(WCM)



YELLOW CROSS HATCH MARKING
(YCHM)
N.T.S.

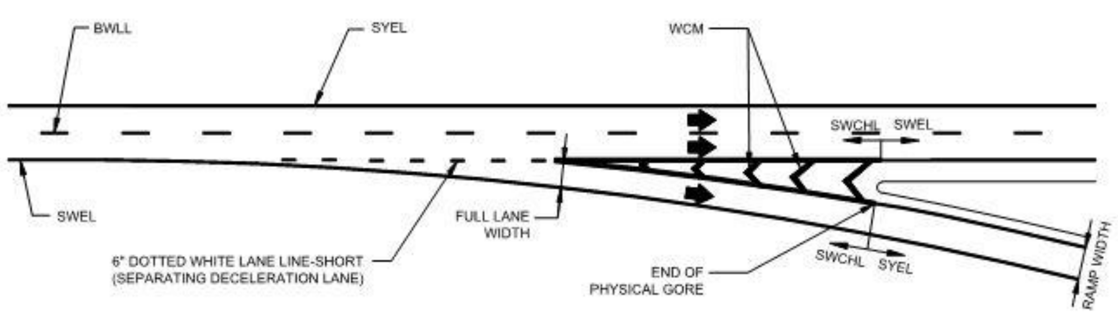


WHITE CROSS HATCH MARKING
(WCHM)
N.T.S.

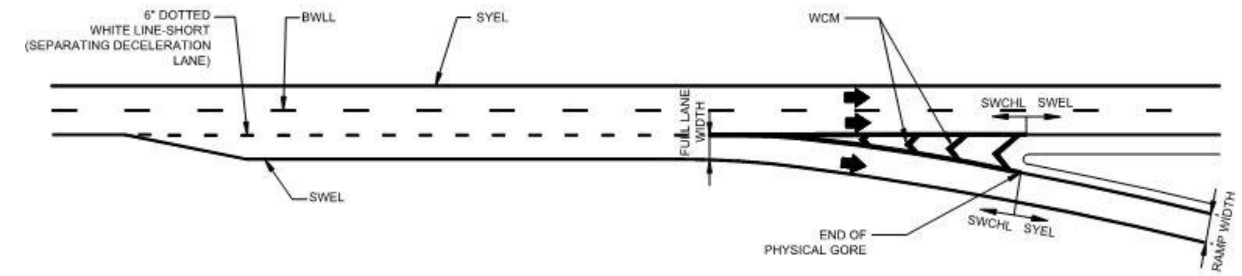
C. Exit and Entrance Ramps

There are two types of exit ramps: taper type and parallel type. Design drawings must be prepared showing specific dimensions and striping layout for all ramps. The design shall be based on the following figures.

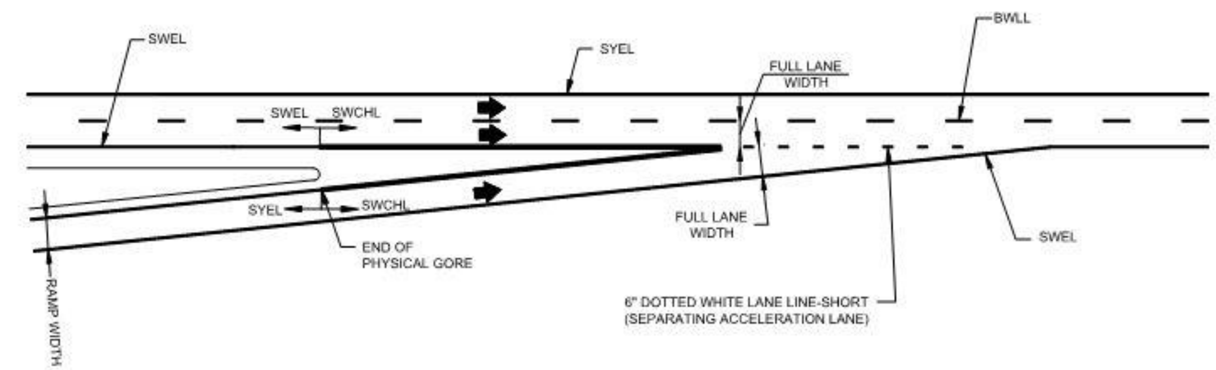
1. At the exit or entrance to a ramp, the 12” solid white channelizing line (SWCHL) shall separate the mainline traffic from the ramp traffic. At the point where the physical gore starts (separation between the ramp and mainline), the channelizing line will end and a 6” solid white edge line (SWEL) will begin (See figures).



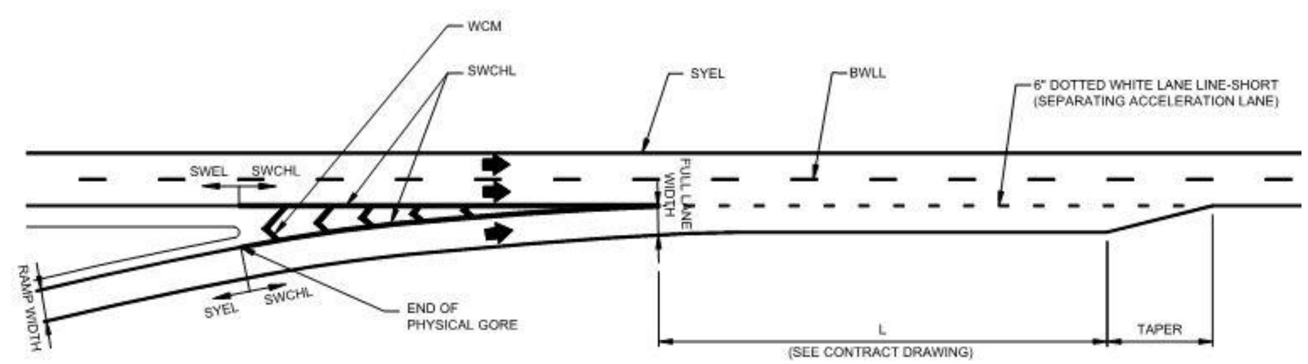
EXIT RAMP - TAPER TYPE



EXIT RAMP - PARALLEL TYPE



ENTRANCE RAMP - TAPER TYPE



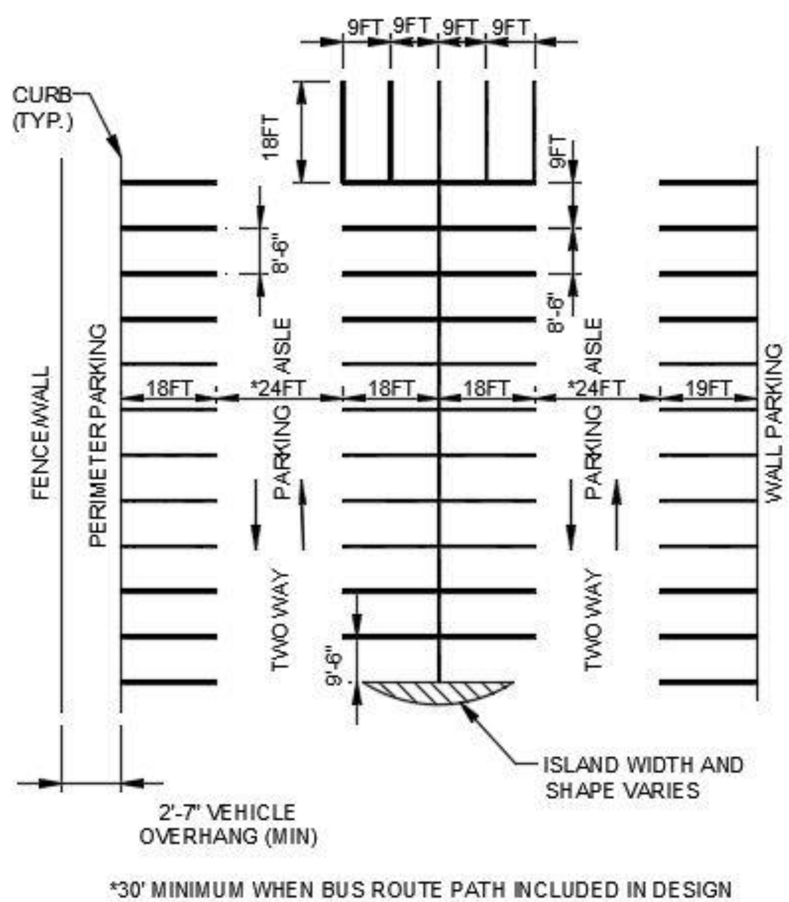
ENTRANCE RAMP - PARALLEL TYPE

D. Parking Lot Markings

Design drawings must be prepared showing specific dimensions and striping layout for all parking layouts. The design shall be based on the following figures. The selection of parking lot layout angle and aisle characteristics shall be based on the geometry of the parking area. Columns and light poles may protrude into the parking stalls a combined maximum of 2 feet as long as they do not affect more than 25% of the stalls in that bay. All pavement markings are white. Drive aisles (no parking on either side) should contain Full Yellow Barrier Lines (FYBL), stop lines, and all appropriate signing. FYBL and stop lines are not necessary in parking aisles and should be used at the discretion of the designer.

1. Typical Parking Bay Layout

   a. 90º Parking



90° PARKING

(i) Parking stalls shall be 9' x 18'.

(ii) May be used when there is 2-way traffic through the parking aisles.

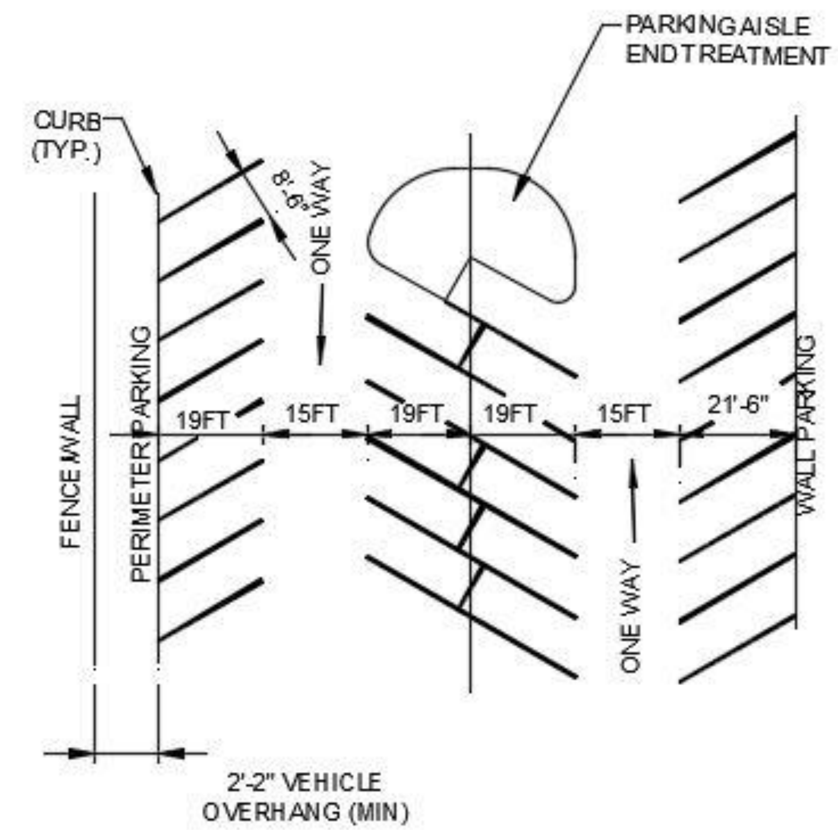
(iii) Aisle is typically 24 feet wide. If a bus route utilizes the aisle, it shall be a minimum of 30 feet.

(iv) Size and shape of islands at the end of parking rows shall be determined by the designer and shown on the contract drawings.

(v) If parking stalls terminate at a wall/vertical obstruction, the depth of the parking stall shall be increased by 1 foot. If parking is along the perimeter, there shall be a minimum of 2'-7" vehicle overhang provided.

(vi) Parking stalls may be reduced a maximum of 2' in length to accommodate structural columns or light poles and should be labeled as a compact car space.

   b. 60º Parking



60° PARKING

(i) Can only accommodate one-way traffic through the parking aisles.

(ii) Aisle width shall be a minimum of 15 feet.

(iii) Parking aisle end treatments shall be designed in accordance with Section D.1.f. below.

(iv) If parking stalls terminate at a wall/vertical obstruction, the depth of the parking stall, measured perpendicular to the wall/vertical obstruction, shall be increased by 2'-6". If parking is along the perimeter, there shall be a minimum of 2'-2" vehicle overhang provided.

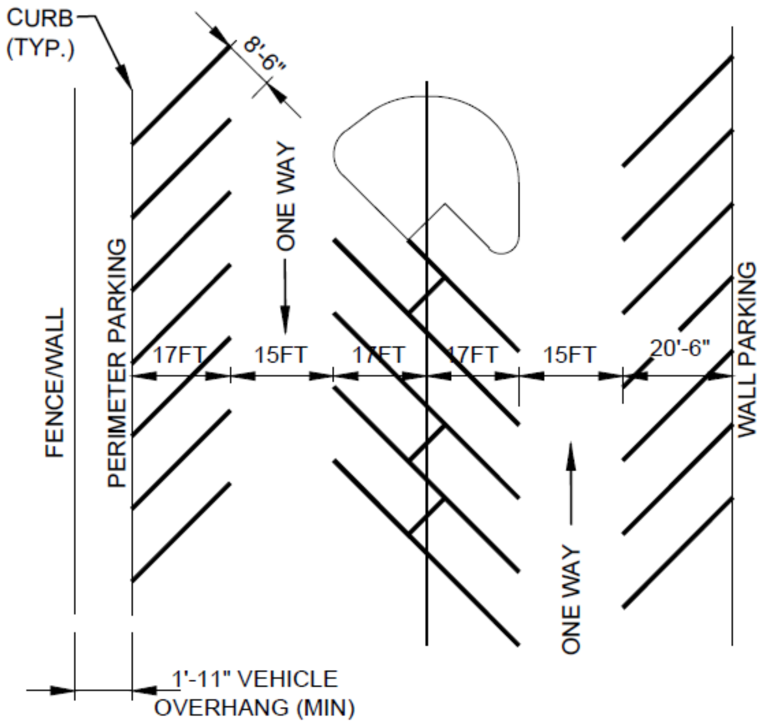
c. 45º Parking

(i) Can only accommodate one-way traffic through the parking aisles.

(ii) Aisle width shall be a minimum of 15 feet.

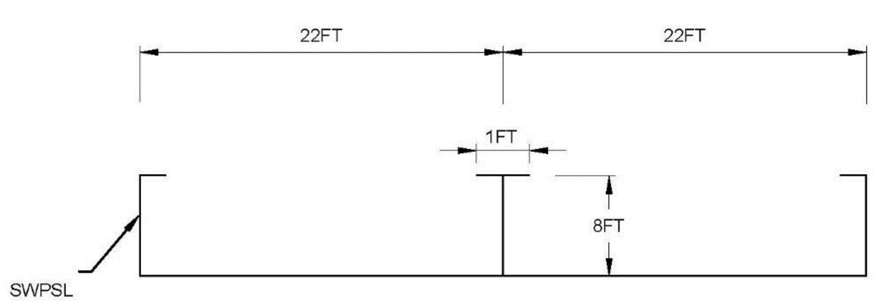
(iii) Parking aisle end treatments shall be designed in accordance with Section D.1.f. below.

(iv) If parking stalls terminate at a wall/vertical obstruction, the depth of the parking stall, measured perpendicular to the wall/vertical obstruction, shall be increased by 3’-6”. If parking is along the perimeter, there shall be a minimum of 1’-11” vehicle overhang provided.



45° PARKING

d. Parallel Parking

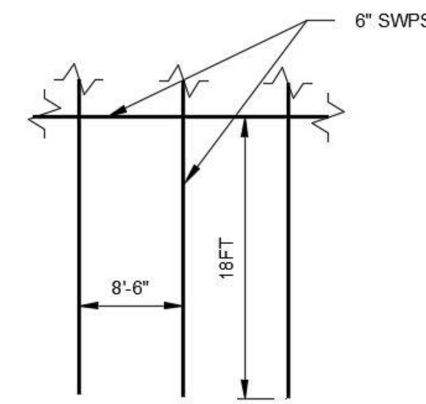


PARALLEL PARKING

e. Stall Layout

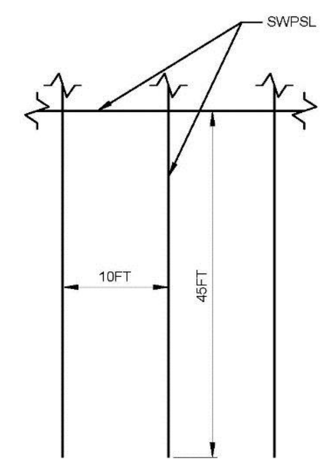
(i) Stall layout shall be provided on the contract drawings and should be designed in accordance with the figure below. Coordination with facility staff is required to determine number and type of stalls.

(ii) Car Stalls

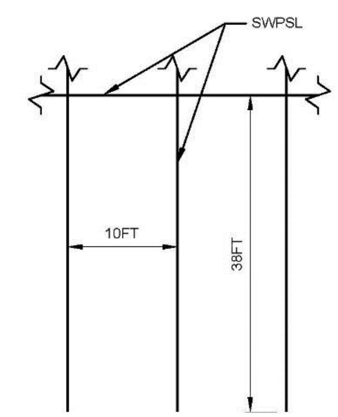


CAR STALL

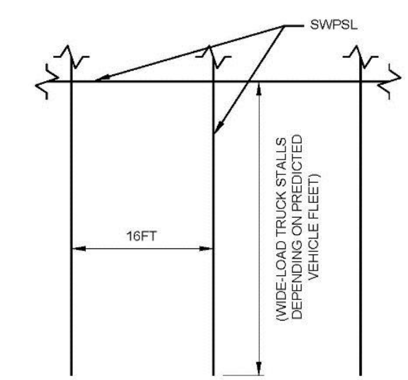
(iii) Bus, Limo and Wide-Load Truck Stalls



BUS STALL



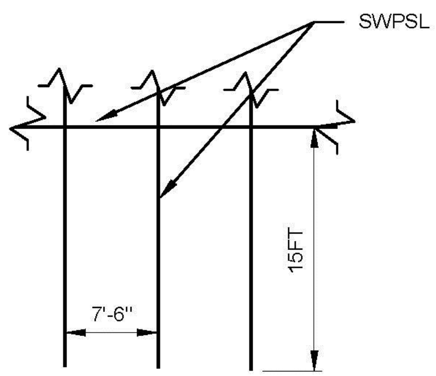
LIMO STALL



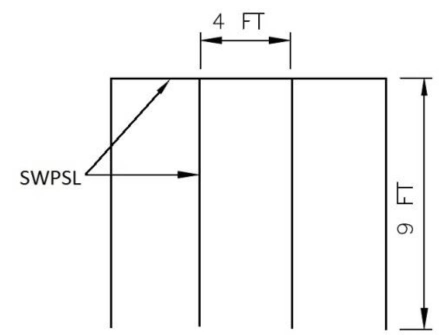
WIDE-LOAD TRUCK STALL

(iv) Compact car only stalls (7’-6” wide by 15’-0” long) should only be used at constrained locations or in remnants of space. The number of these stalls should not exceed 15% of the total capacity.

(v) If required, motorcycle stalls shall be 4’ wide by 9’ long.



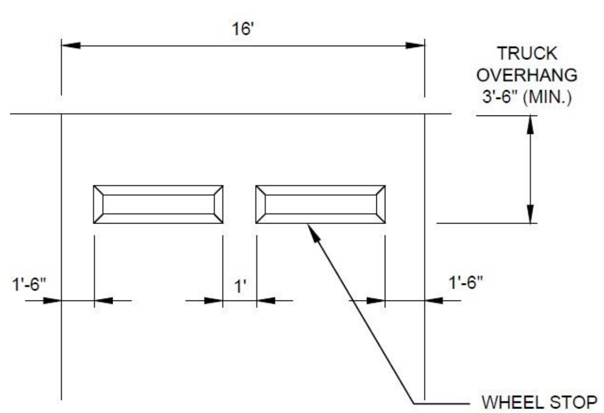
COMPACT CAR STALL



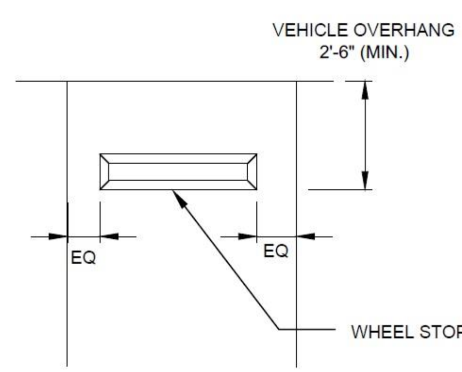
MOTORCYCLE STALL

(vi) Wheel Stops – The use of wheel stops should be avoided if possible. At the request of the facility, wheel stops may be used to contain the vehicle within the parking stall, primarily to prevent encroachment into a pedestrian walkway. Precast wheel stops are to be provided where shown on the contract drawings and shall be in accordance with detail TD50.10.

(a) One wheel stop shall be placed in the center of each parking stall, with an equal spacing on each side to the stall stripe. For wide load stalls, two wheel stops shall be placed 1’ apart and centered in the lane with 1’-6” spacing on each side to the stall stripe.



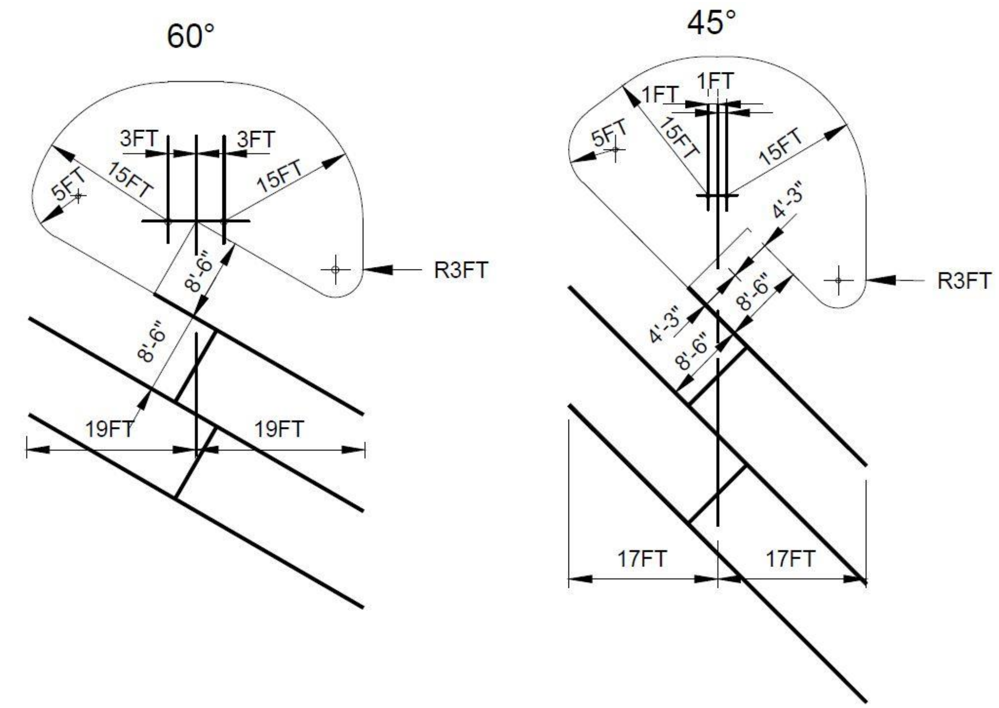
WIDE-LOAD TRUCK
WHEEL STOP PLACEMENT



WHEEL STOP
PLACEMENT

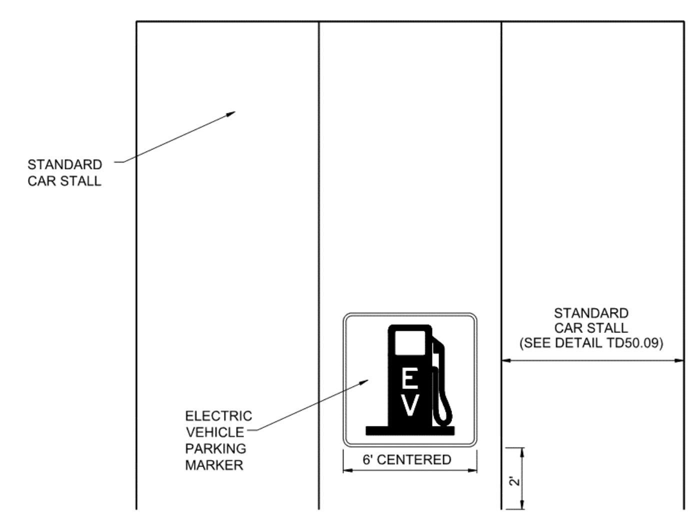
f. End Treatments

(i) Size and shape of end treatments at the termination of parking rows shall be determined by the designer and shown on the contract drawings. Below are samples.



END TREATMENT

g. Electric Vehicle Parking Symbol



ELECTRIC VEHICLE PARKING SYMBOL LAYOUT

E. Accessible Parking

The number, location and design criteria for accessible parking spaces shall be in compliance with the Americans with Disabilities Act Accessibility Guidelines (ADAAG). Design drawings must be prepared showing specific dimensions and striping layout for all accessible parking.

1. Number of Spaces

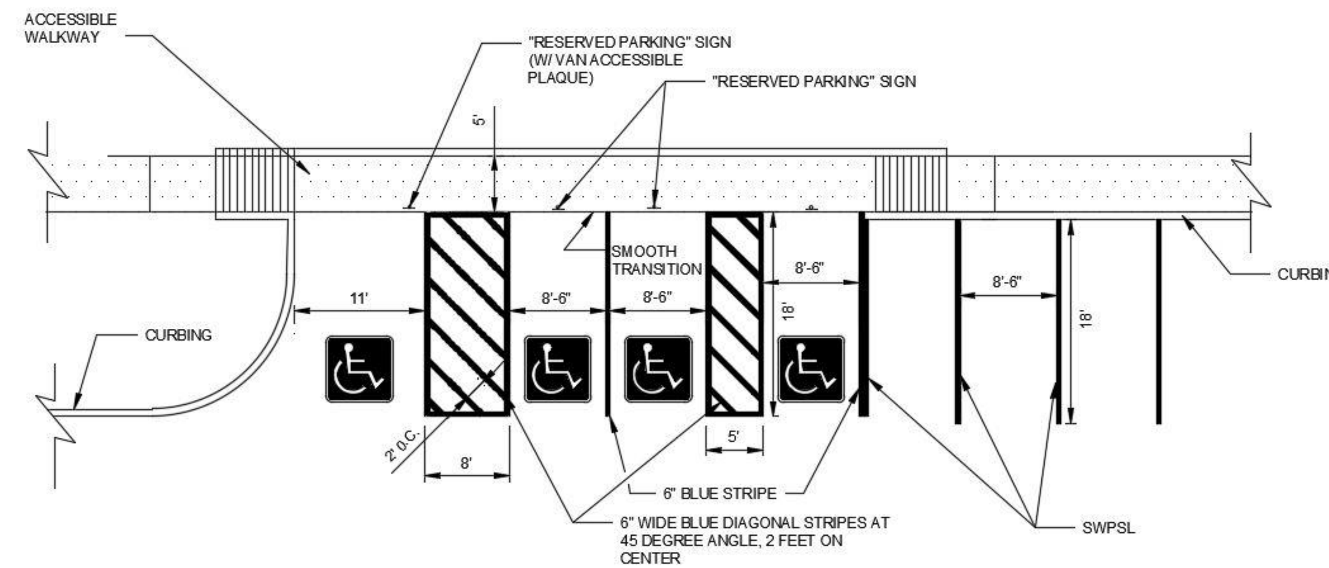
TOTAL SPACES IN LOT	MINIMUM NUMBER OF ACCESSIBLE SPACES	VAN ACCESSIBLE*
1 TO 25	1	1
26 TO 50	2	1
51 TO 75	3	1
76 TO 100	4	1
101 TO 150	5	1
151 TO 200	6	1
201 TO 300	7	2
301 TO 400	8	2
401 TO 500	9	2
501 TO 1000	2% OF TOTAL	4
1001 AND OVER	20 PLUS 1 FOR EACH 100 OVER 1000	TBD

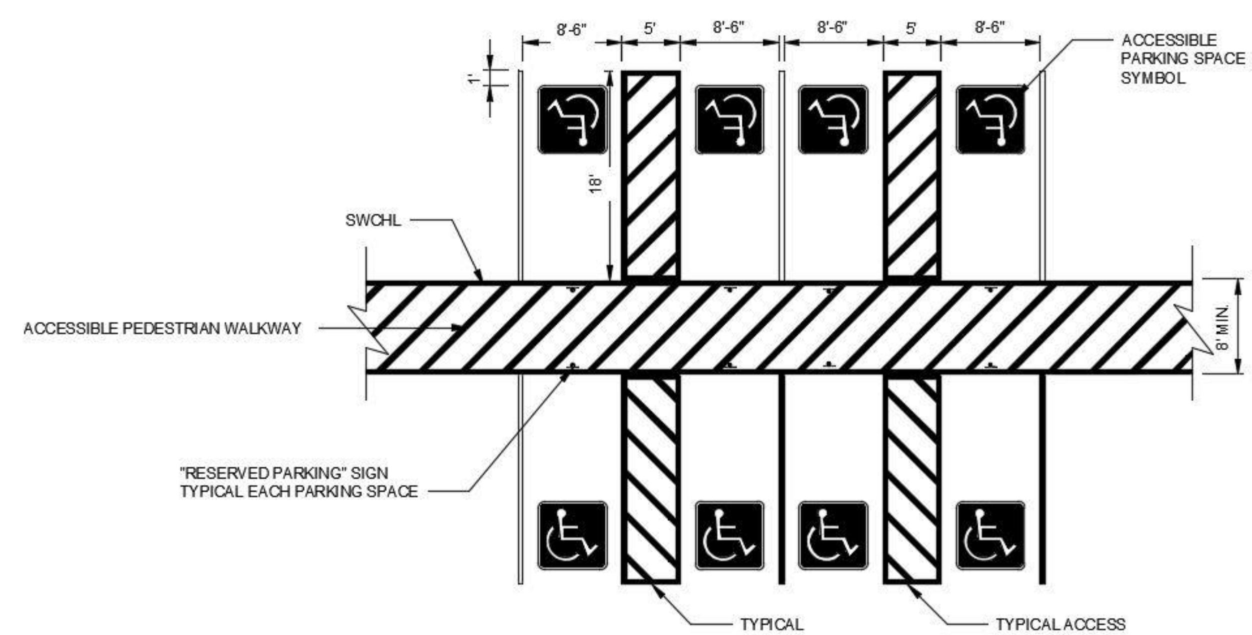
*VAN ACCESSIBLE SPACES ARE NOT IN ADDITION TO THE MINIMUM NUMBER OF ACCESSIBLE PACES.

2. Location
   a. Parking spaces for use by person with disabilities shall be the spaces closest to the nearest accessible building or facility entrance on an accessible route.
3. Stall Dimensions
   a. The typical width of accessible parking stalls is 8'-6".
   b. For van accessibility, the width of the accessible spots adjacent to a curb is increased to 11'. Van accessible spaces must be signed with van accessible plaque below the reserved parking sign.
4. Access Aisles
   a. Each accessible parking space requires an access aisle.
   b. Two accessible parking spaces may share a common access aisle.
   c. Width of access aisle is typically 5'.
   d. For van accessible spaces, the access aisle is increased to 8'.

   PROWAG requires all spaces to be van accessible. Section R309.3 Perpendicular or Angled Parking Spaces states: "Where perpendicular or angled parking is provided, an access aisle 2.4 m (8.0 ft) wide minimum shall be provided at street level the full length of the parking space and shall connect to a pedestrian access route. The access aisle shall comply with R302.7 and shall be marked so as to discourage parking in the access aisle. Two parking spaces are permitted to share a common access aisle." *(R302.7 applies to surfaces)*

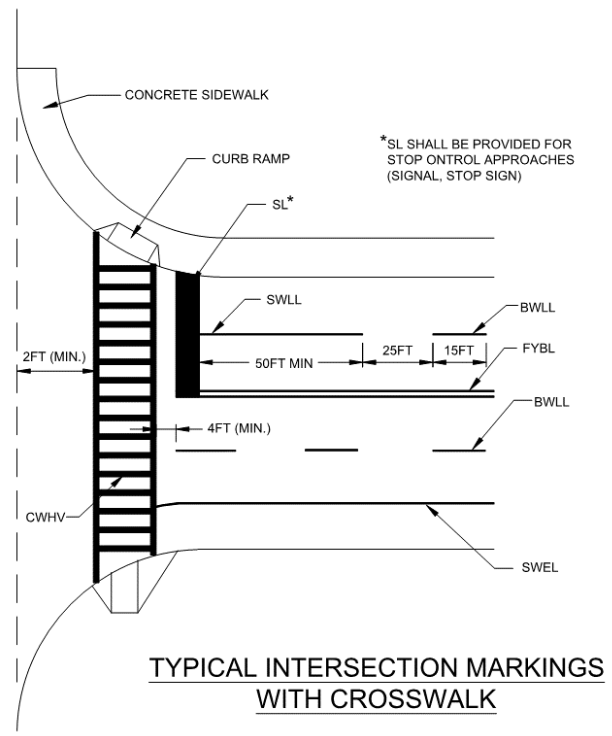
5. Overhead Clearance
   a. Vehicle access routes to and from accessible parking spaces, including in garages and open parking structures, shall have a minimum vertical clearance of 9'-6".





F. Intersection Markings

1. Typical Intersection Markings with Crosswalk
   a. The following figure shows the typical layout of pavement markings at an intersection with a crosswalk.
   b. Crosswalk shall not be less than 2 feet from the extended curb or edge line of the parallel road.

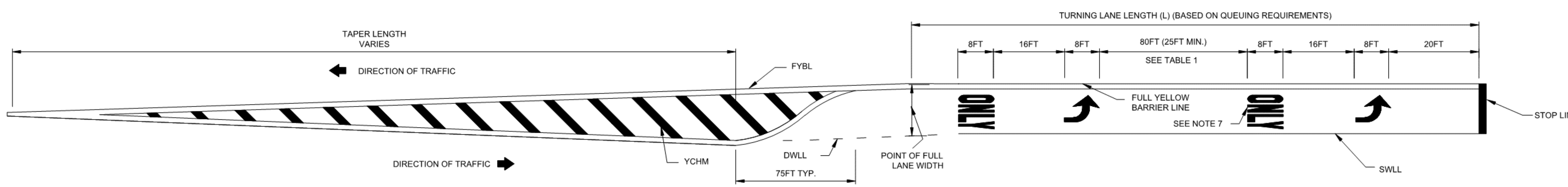


TYPICAL INTERSECTION MARKINGS WITH CROSSWALK

2. Channelizing Island and Left Turn Lane Markings
   a. Channelizing islands used to guide through vehicles around a left turn lane shall be designed and shown on the contract drawings in accordance with the following (right turn lanes are similar):
   b. Stop line shall not be provided for uncontrolled approaches (no signal, stop or yield sign).
   c. Arrow and only markings shall be centered horizontally in the lane.

TABLE 1
LEFT TURN LANE LAYOUT AND SPACING

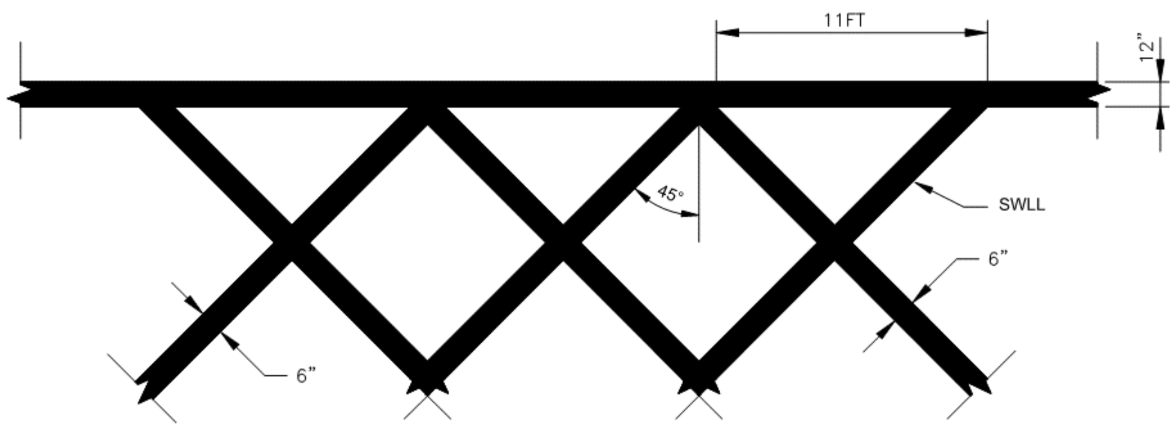
TURNING LANE LENGTH (L)	NO. OF ARROW/ONLY MARKINGS	SPACING
LESS THAN 90 FEET	1 SET	20 FEET FROM STOP LINE
90 FEET TO 135 FEET	2 SETS	AS SHOWN, 80 FOOT SPACING BETWEEN SETS OF MARKINGS MAY BE REDUCED TO 25 FEET
135 FEET TO 250 FEET	2 SETS	AS SHOWN
250 FEET TO 500 FEET	3 SETS	FIRST TWO SETS AS SHOWN, THIRD SET 35 FEET FROM END OF BAY
GREATER THAN 500 FEET	PROVIDE ADDITIONAL SETS AS APPROPRIATE	AS APPROPRIATE



CHANNELIZED ISLAND DETAIL AND
LEFT TURN LANE MARKING
(RIGHT TURN LANE SIMILAR)

3. Don't Block the Box Marking

   a. Where it is determined that additional striping is required to discourage vehicles from stopping in the inside of the intersection and block opposing traffic, "Don't Block the Box" markings shall be installed in accordance with the following. Markings shall be accompanied by the appropriate signing.

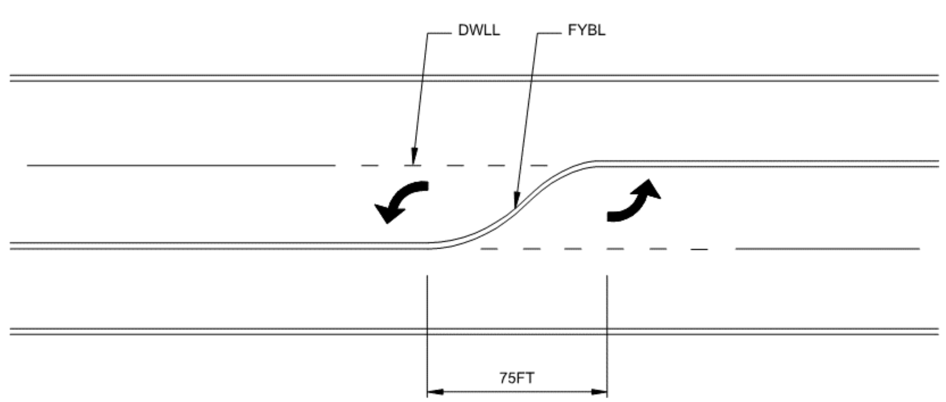


DON'T BLOCK THE BOX MARKING

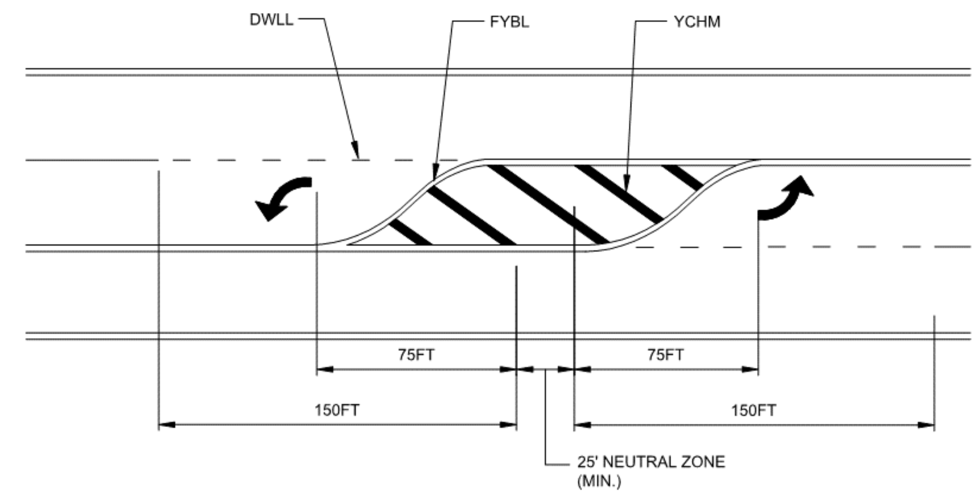
(WHITE)

4. Median Left Turn Lane

   a. Pavement markings for back to back left turn lanes shall be designed in accordance with one of the following methods. Typically, Method 2 is utilized unless Method 1 is needed based upon the left turn lane storage length needs.



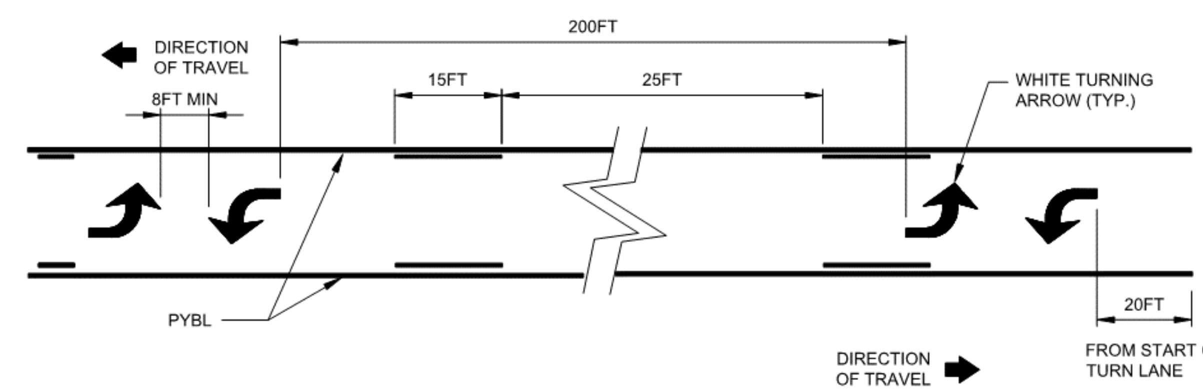
METHOD 1



METHOD 2

5. Two-way Left Turn Lanes

   a. The lane line pavement markings on each side of the two-way left-turn lane shall consist of a normal broken yellow line and a normal solid yellow line to delineate the edges of a lane that can be used by traffic in either direction as part of a left-turn maneuver. These markings shall be placed with the broken line inside the two-way left-turn lane and the solid line toward the adjacent traffic lane as shown below.

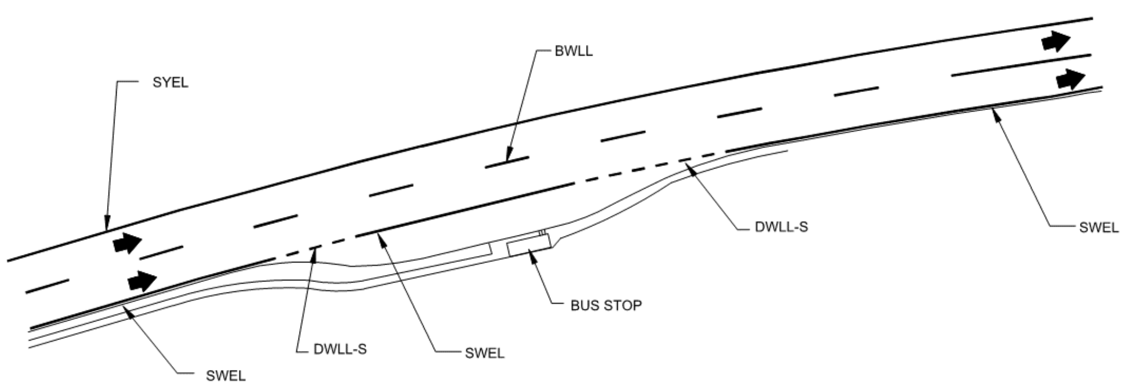


TWO-WAY LEFT TURN LANE DETAIL

G. Miscellaneous Markings

1. Typical Bus Stop Marking

   a. For design of Bus Stop markings, designer shall adhere to AASHTO Guidelines for the Location and Design of Bus Stops.

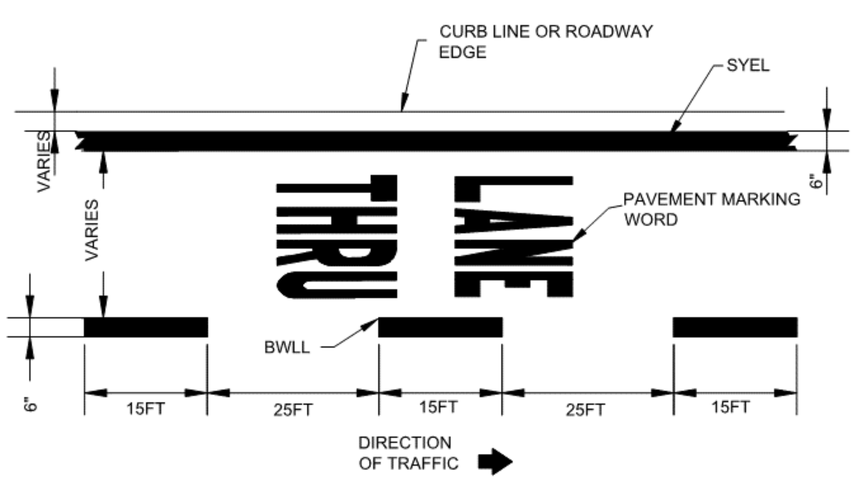


TYPICAL BUS STOP MARKING
N.T.S.

2. Thru Lane Pavement Marking

   a. The offset distance to the curb shall be in accordance with facility shoulder width requirements. May be used at Aviation facilities on terminal frontages.

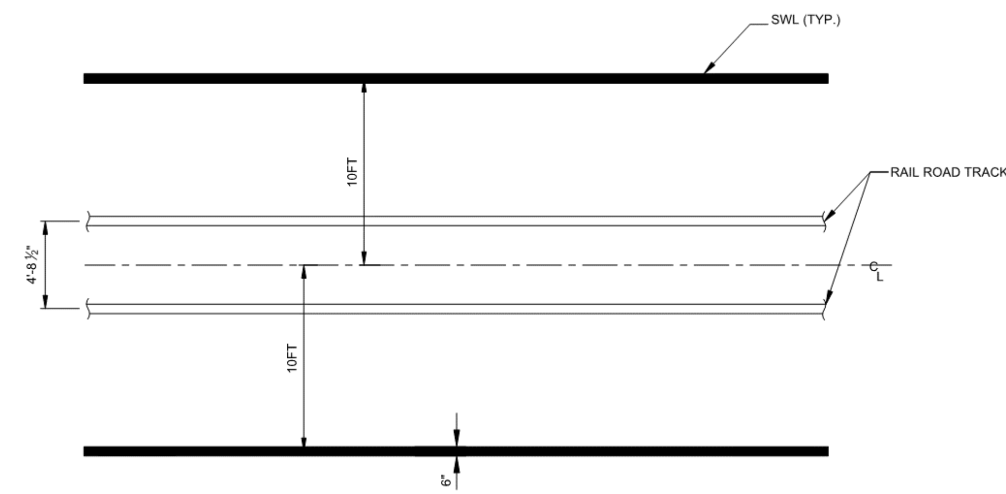
   b. For spacing of Pavement Marking Word Symbols, designer shall adhere to MUTCD section 3B.20.



THRU LANE PAVEMENT MARKING
N.T.S.

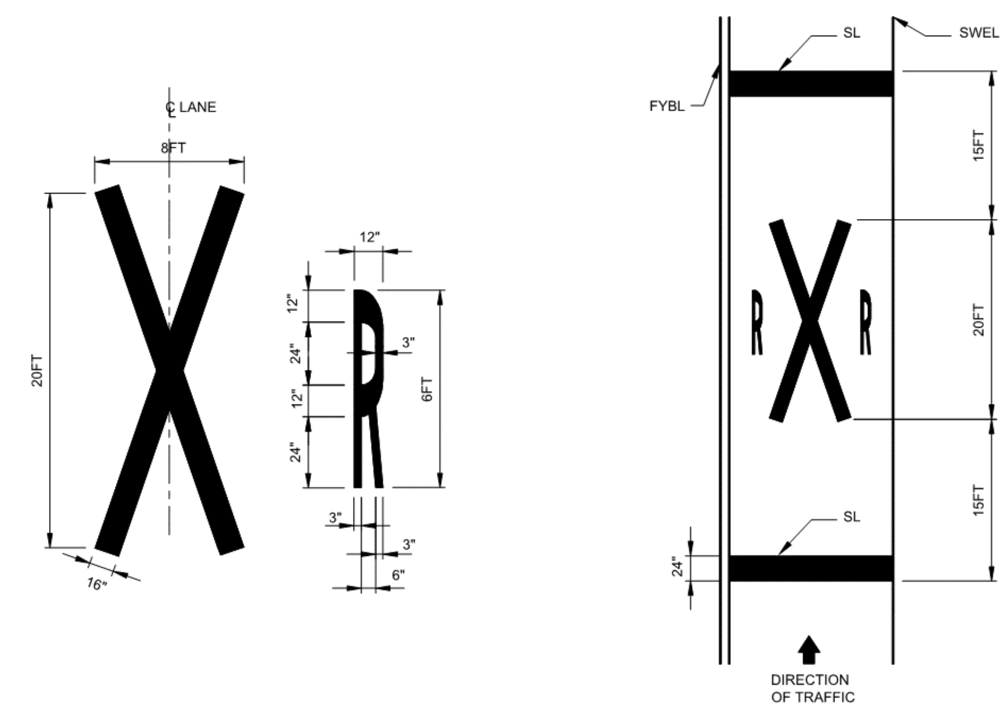
3. Railroad Markings

   a. Dynamic Envelope Marking



DYNAMIC ENVELOPE MARKING
(WHITE)

   b. Railroad Grade Crossing Marking

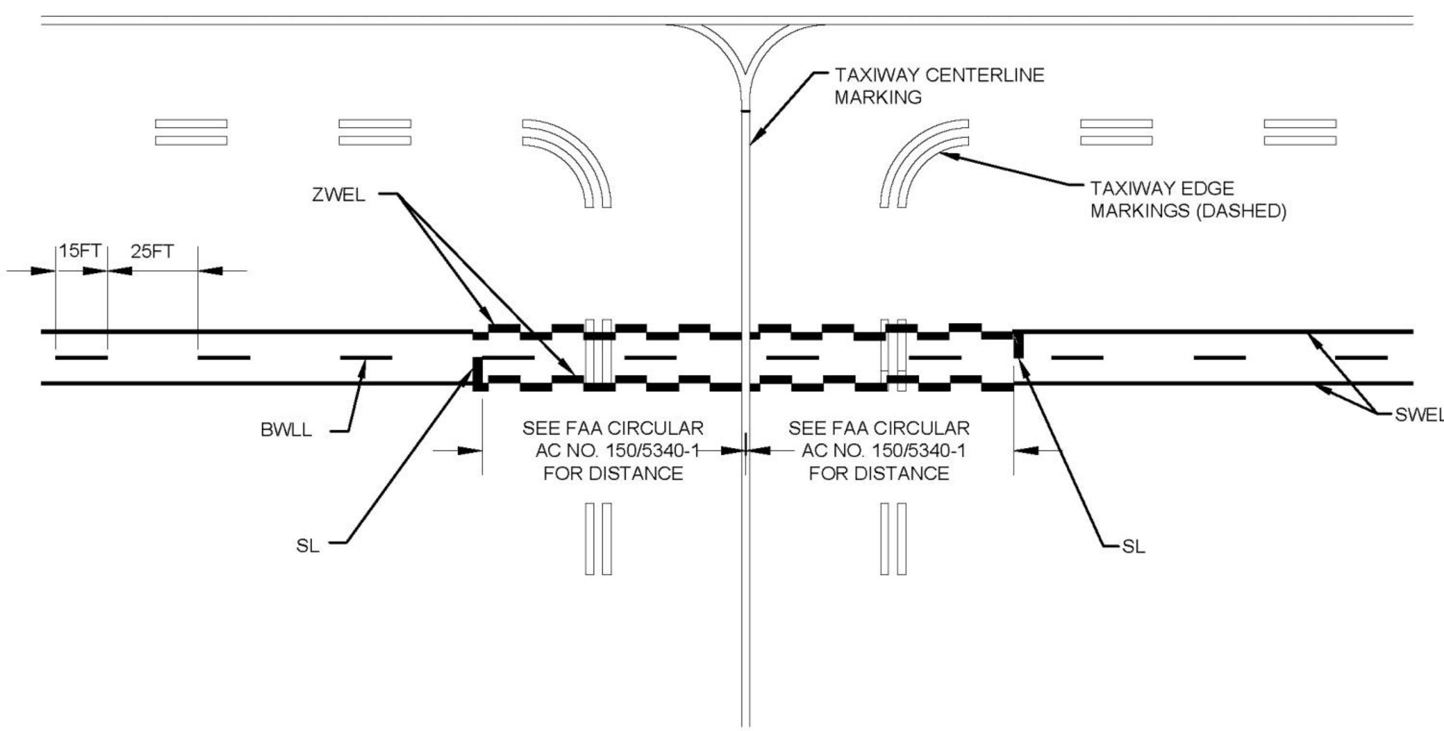


RAILROAD GRADE CROSSING MARKINGS
(RGCM)

H. Airside Markings

Airside markings shall be in accordance with the latest Federal Aviation Administration (FAA) Advisory Circular AC No. 150/5340-1, Section 4. Design drawings must be prepared showing specific dimensions and layout for airside markings.

1. Roadway pavement markings on airside vehicle roadways shall be white only.
2. A minimum spacing of 2 feet must be maintained between the roadway edge marking and the non-movement area boundary marking for vehicle roadway delineation on airside.
3. Vehicle roadway marking consists of a solid line to delineate each edge of the roadway and a dashed line to separate lanes within the edges of the roadway. The edge lines and lane lines are both 6 inches wide and the dashes for the lane lines are 15 feet in length with spacing of 25 feet between dashes.
4. In lieu of the solid lines, zipper markings may be used to delineate the edges of the vehicle roadway wherever the airport operator determines that the roadway edges need enhanced delineation. The zipper marking consists of two dashed lines side by side with alternating dashes that are 12 inches wide and 4 feet in length, along each edge of the roadway.
5. Where a roadway crosses a taxiway, a 24 inch stop bar is provided across the approach lane at distances specified in FAA Circular AC No. 150/5340-1 to assure adequate clearance from the taxiing aircraft.



TYPICAL ROADWAY-TAXIWAY DESIGN

(SEE NOTE 5)

Specifications

Based on the Master PA Specification List, the designer shall select all appropriate specifications for each project, which will include all striping items for all disciplines (i.e. specifications for traffic, civil, structural, and electrical). If required for non-standard items, a custom "C Spec." must be prepared.

PANYNJ Pavement Marking Material Guidelines

Application	Recommended Marking Material	
	Asphalt	Concrete
Longitudinal Lines (Lane lines, edge lines, toll plazas, etc.)	**Preferred: WR Thermoplastic-** *Specification 321724* **Alternate: WR Preformed Tape-** *Specification 321729*	**Preferred: Epoxy Resin-** *Specification 321730* **Alternate: WR Preformed Tape-** *Specification 321729*
Transverse Markings (Intersection markings, crosswalks, etc.)	**Preferred: WR Thermoplastic-** *Specification 321724* **Alternate: WR Preformed Tape-** *Specification 321729*	**Preferred: Epoxy Resin-** *Specification 321730* **Alternate: WR Preformed Tape-** *Specification 321729*
Symbols, Letters and Numbers	**Preferred: WR Preformed Tape-** *Specification 321729* **Alternate: WR Thermoplastic-** *Specification 321724*	**Preferred: Epoxy Resin-** *Specification 321730* **Alternate: WR Preformed Tape-** *Specification 321729*
Airside RVSR (Restricted Vehicle Service Road)	**Preferred: WR Thermoplastic-** *Specification 321724* **Alternate: Traffic Paint Pavement Markings – WR High Build Paint-** *Specification 321727*	**Preferred: Epoxy Resin-** *Specification 321730* **Alternate: Traffic Paint Pavement Markings – WR High Build Paint-** *Specification 321727*
Temporary Markings (To be used on temporary surfaces that will be overlaid with new pavement)	**Preferred: Traffic Paint Pavement Markings – WR High Build Paint-** *Specification 321727* **Alternate: WR Preformed Removable Tape-** *Specification 321728*	**Preferred: Traffic Paint Pavement Markings – WR High Build Paint-** *Specification 321727* **Alternate: WR Preformed Removable Tape-** *Specification 321728*
Temporary Markings (To be used on final pavement courses)	**Preferred: WR Preformed Removable Tape-** *Specification 321728* **Alternate: Discussion required with PA Traffic**	**Preferred: WR Preformed Removable Tape-***Specification 321728* **Alternate: Discussion required with PA Traffic**
Parking Lots and Garages – Stall Lines – Stop Lines – Symbols	**Preferred: Thermoplastic Reflectorized Pavement Markings** *–Specification 321723* **Alternate: Traffic Paint Pavement Markings – Standard Paint** *-Specification 321725*	**Preferred: Traffic Paint Pavement Markings-Standard Paint** *-Specification 321725* **Alternate: Traffic Paint Pavement Markings – WR High Build Paint-** *Specification 321727*

WR – Wet Reflective
High contrast Markings should be considered for long line applications on light colored concrete surfaces

Marking Product	Characteristics
Thermoplastic Reflectorized Pavement Markings *– Specification 321723*	***Not Wet Reflective*** – Includes reflective beads in base material (use for parking facilities)
WR Thermoplastic- *Specification 321724*	***Wet Reflective –*** Includes 3M elements in base material Reflective beads and 3M elements dropped on surface during installation
Standard Paint- *Specification 321725*	***Not Wet Reflective*** – Use for parking facilities
WR High Build Paint- *Specification 321727*	***Wet Reflective*** – High Build Paint, reflective beads and 3M elements dropped on surface
WR Preformed Removable Tape- *Specification 321728*	***Wet Reflective*** – Includes 3M elements in base material (use for temporary markings)
WR Preformed Tape- *Specification 321729*	***Wet Reflective*** – Includes 3M elements in base material

APPENDIX E

PA ROADSIDE AND MEDIAN BARRIER DESIGN GUIDE

THE PORT AUTHORITY OF NY & NJ

Engineering Department

ROADSIDE AND MEDIAN BARRIER DESIGN GUIDE

April 15, 2022
For External Use

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I. Introduction

These guidelines are based on the *Roadside Design Guide, AASHTO, 4th Edition, 2011*. This Design Guide will govern where it differs from the *Roadside Design Guide*.

The information in **Section II** is intended to serve as guidelines that will assist the designer in determining conditions that warrant the installation of roadside barriers and the dimensional characteristics of the installations. **Section III** contains information to serve as guidelines to assist the designer in determining conditions that warrant the installation of a median barrier. Test Level Matrices for longitudinal barriers in **Appendix A** provide hardware test parameters based on vehicle class and speed**.**

There are circumstances where site conditions do not permit standard installation details to be used and a reasonable balance between competing safety considerations is needed. For example, roadways in the vicinity of bus terminals and parking garages, along urban street facilities, and other locations may incorporate unique conditions where these guidelines might not be deemed applicable. It is important that application of this Design Guide be made in conjunction with engineering judgment to arrive at a reasonable solution.

The design standards in this Guide are primarily developed for TL-2 and TL-3 design speeds. TL-1 design speeds of 30 MPH or less (posted 25 MPH or less) are often found in urban settings and recommendations in this Guide may not be compatible with low-speed roadside features. Engineering judgement should be used in conjunction with this Guide to determine if the installation of safety hardware is appropriate at low-speed locations. Roadside barriers should be considered for low-speed roadways where practical.

In some cases, another type of traffic barrier may be more effective than a roadside barrier. For example, obstructions in gores can often be more effectively shielded with an impact attenuator. The designer should consider such alternatives and choose the most suitable solution based on safety requirements, economic limitations, maintenance, and aesthetic considerations.

These guidelines are applicable to new installations on roadways within the jurisdiction of The Port Authority of New York & New Jersey (hereafter referred to as “Port Authority”). Where repairs to existing guide rail include upgrading to current standards, the entire run of guide rail should be upgraded where practical. The design of roadside barrier and median barriers outside the jurisdiction of the Port Authority shall be in accordance with the standards and guidelines of the agency having jurisdiction.

II. Roadside Barriers

A. Roadside Barrier Warrants

The primary functions of guide rail and concrete barrier are to prevent penetration and to safely redirect an errant vehicle away from an obstruction on either side of the traveled way. An obstruction's physical characteristics and its location within the clear zone are the basic factors to be considered in determining if a roadside barrier is warranted. Although some wide ranges of roadside conditions are covered in this Design Guide, special cases will arise for which there is no clear choice about whether a roadside barrier is warranted. Such cases should be evaluated on an individual basis using engineering judgment.

1. Clear Zone

Clear zone is defined as the unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes. The width of the clear zone varies with the design speed, roadside slope and horizontal roadway alignment. If the design speed is known, then it should be used to determine the clear zone. Otherwise, the speed used for design purposes should be 5 MPH above the posted speed. On ramps and connectors that do not have a posted speed, the design speed may be estimated using engineering judgment based on geometry and/or nearby traffic control devices such as signing (regulatory or warning signs) or traffic signals.

Table 1 contains the suggested range of clear zone distances on tangent sections of roadway based on selected traffic volumes, speed and roadside slopes. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway section if previous experience with similar projects or designs indicates satisfactory performance. According to the *Roadside Design Guide, AASHTO, 4th Edition, 2011*, the designer may provide clear zone distances greater than 30 feet as indicated in **Table 1**, where such occurrences are indicated by crash history.

Figure 1 contains an example of determining clear zone distance on a foreslope. This figure depicts a clear zone distance reaching a non-recoverable parallel foreslope and the subsequent clear runout area that may be provided at the toe of the non-recoverable slope to provide a suggested adjusted clear zone distance. More examples and further explanation are contained in the *Roadside Design Guide, AASHTO, 4th Edition, 2011*.

Table 1 Clear Zone Distances From Edge of Traveled Way (feet)							
		Foreslopes (Fill)			Backslopes (Cut)		
Design Speed	Design ADT	6H:1V or flatter	5H:1V to 4H:1V	3H:1V	3H:1V	5H:1V to 4H:1V	6H:1V or flatter
40 mph or less	Under 750	7 – 10	7 – 10	**	7 – 10	7 – 10	7 – 10
	750 – 1,500	10 – 12	12 – 14	**	10 – 12	10 – 12	10 – 12
	1,500 – 6,000	12 – 14	14 – 16	**	12 – 14	12 – 14	12 – 14
	over 6,000	14 – 16	16 – 18	**	14 – 16	14 – 16	14 – 16
45 – 50 mph	Under 750	10 – 12	12 – 14	**	8 – 10	8 – 10	10 – 12
	750 – 1,500	14 – 16	16 – 20	**	10 – 12	12 – 14	14 – 16
	1,500 – 6,000	16 – 18	20 – 26	**	12 – 14	14 – 16	16 – 18
	over 6,000	20 – 22	24 – 28	**	14 – 16	18 – 20	20 – 22
55 mph	Under 750	12 – 14	14 – 18	**	8 – 10	10 – 12	10 – 12
	750 – 1,500	16 – 18	20 – 24	**	10 – 12	14 – 16	16 – 18
	1,500 – 6,000	20 – 22	24 – 30	**	14 – 16	16 – 18	20 – 22
	over 6,000	22 – 24	26 – 32*	**	16 – 18	20 – 22	22 – 24
60 mph	Under 750	16 – 18	20 – 24	**	10 – 12	12 – 14	14 – 16
	750 – 1,500	20 – 24	26 – 32*	**	12 – 14	16 – 18	20 – 22
	1,500 – 6,000	26 – 30	32 – 40*	**	14 – 18	18 – 22	24 – 26
	over 6,000	30 – 32*	36 – 44*	**	20 – 22	24 – 26	26 – 28
65 – 70 mph	Under 750	18 – 20	20 – 26	**	10 – 12	14 – 16	14 – 16
	750 – 1,500	24 – 26	28 – 36*	**	12 – 16	18 – 20	20 – 22
	1,500 – 6,000	28 – 32*	34 – 42*	**	16 – 20	22 – 24	26 – 28
	over 6,000	30 – 34*	38 – 46*	**	22 – 24	26 – 30	28 – 30

* When a site specific investigation indicates a high probability of continuing crashes, or when such occurrences are indicated by crash history, the designer may provide clear zone distances greater than the clear zone shown in **Table 1**. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway template if previous experience with similar projects or design indicates satisfactory performance.

** Because recovery is less likely on the unshielded, traversable 3H:1V slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery areas at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 3H:1V slope should influence the recovery area provided at the toe of slope. While the application may be limited to several factors, the foreslope parameters that may enter into determining a maximum desirable recovery area are illustrated in **Figure 1**.

SOURCE: Chapter 3, "Roadside Topography and Drainage Features", *Roadside Design Guide, AASHTO, 4th Edition, 2011*

Horizontal alignment can affect the clear zone width. Clear zone widths on the outside of horizontal curves should be adjusted by multiplying the clear zone values in **Table 1** by the Curve Correction Factor shown in **Table 2**. The Curve Correction Factor applies to the outside of the curve only. Adjustment is not required for radii flatter than 2,950 feet or for design speeds less than 40 MPH.

Table 2 Curve Correction Factor for Horizontal Curves						
Radius (feet)	Design Speed (mph)					
	40	45	50	55	65	70
2,950	1.1	1.1	1.1	1.2	1.2	1.2
2,300	1.1	1.1	1.2	1.2	1.2	1.3
1,970	1.1	1.2	1.2	1.2	1.3	1.4
1,640	1.1	1.2	1.2	1.3	1.3	1.4
1,475	1.2	1.2	1.3	1.3	1.4	1.5
1,315	1.2	1.2	1.3	1.3	1.4	--
1,150	1.2	1.2	1.3	1.4	1.5	--
985	1.2	1.3	1.4	1.5	1.5	--
820	1.3	1.3	1.4	1.5	--	--
660	1.3	1.4	1.5	--	--	--
495	1.4	1.5	--	--	--	--
330	1.5	--	--	--	--	--

SOURCE: Chapter 3, "Roadside Topography and Drainage Features", *Roadside Design Guide, AASHTO, 4th Edition, 2011*

2. Warranting Obstructions

A warranting obstruction is defined as a non-traversable roadside or a fixed object located within the clear zone and whose physical characteristics are such that injuries resulting from an impact with the obstruction would probably be more severe than injuries resulting from an impact with a roadside barrier.

a. Non-traversable Roadside

Examples of a non-traversable roadside that may warrant a roadside barrier are: rough rock cuts, large boulders, streams or permanent bodies of water more than 2 feet in depth, roadside channels with slopes steeper than 1H:1V and depths greater than 2 feet, embankment slopes and slopes in cut sections as described in the following:

i. Foreslopes (Fill)

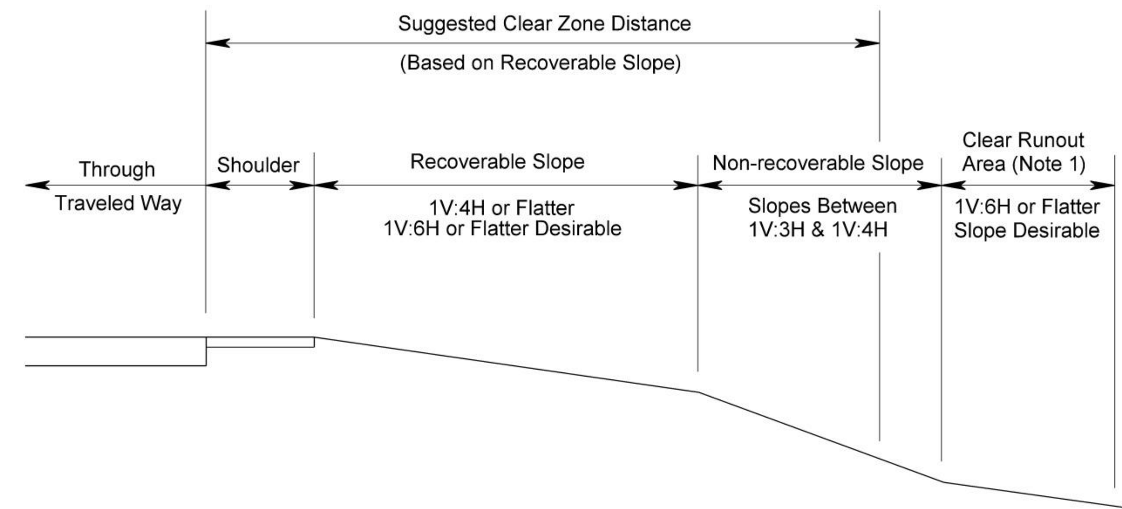
A critical slope is one in which a vehicle is likely to overturn. Foreslopes steeper than 3H:1V generally fall into this category. If a slope steeper than 3H:1V begins closer to the traveled way than the suggested clear zone distance, a roadside barrier might be warranted if it is not practical to flatten the slope. Roadside barrier warrants for critical slopes are shown in **Table 3**.

Table 3
Critical Slope Warrants

Critical Foreslopes (Fill)	Maximum Height without a Roadside Barrier (feet)
1½H:1V	3
2H:1V	6
2½H:1V	9

A non-recoverable foreslope is defined as one that is traversable, but the vehicle can be expected to travel to the bottom of the slope before steering recovery can be obtained. Foreslopes from 3H:1V to steeper than 4H:1V generally fall into this category. Fixed objects should not be constructed or located along such slopes that begin closer to the traveled way than the suggested clear zone distance. A clear runout area at the base of these slopes is desirable as shown in **Figure 1**. A minimum of 10 feet of runout area should be provided where practical. The designer should evaluate each site before providing 3H:1V slopes without a roadside barrier.

When flattening existing foreslopes to remove a roadside barrier, the proposed foreslopes should be recoverable (4H:1V or flatter). Where foreslopes are being constructed, the designer should investigate the feasibility of providing a recoverable foreslope instead of a critical foreslope with a roadside barrier.



Note 1 The Clear Runout Area is additional clear zone space that is needed because a portion of the suggested clear zone falls on a non-recoverable slope. The width of the Clear Runout Area is equal to that portion of the Clear Zone Distance that is located on the non-recoverable slope.

SOURCE: Chapter 3, "Roadside Topography and Drainage Features", *Roadside Design Guide, AASHTO, 4th Edition, 2011*

Figure 1 – Example of Clear Zone Distance on a Foreslope

ii. Backslopes (Cut)

Backslopes in cut sections should not ordinarily be shielded with a roadside barrier. However, there may be obstructions on the slope that warrant shielding, such as bridge piers, retaining walls, trees, rocks, etc., that may cause excessive vehicle snagging rather than permit relatively smooth redirection.

Backslopes in cut sections of 2H:1V or flatter may be considered traversable. As the cut slope steepens, the chance of rollover increases. Where feasible, slopes steeper than 2H:1V should be flattened. If there is a warranting obstruction on the backslope, the following apply:

- A roadside barrier should be installed if the warranting obstruction is on a backslope flatter than 0.7H:1V and is within the clear zone width specified in **Table 1** for a 3H:1V slope.
- A roadside barrier should be installed if the warranting obstruction is on a backslope of 0.7H:1V or steeper and is less than 6 feet (measured along the slope) from the base of the backslope and is within the clear zone width specified in **Table 1** for a 3H:1V slope.

- A roadside barrier is not required if the warranting obstruction is on a backslope of 0.7H:1V or steeper and is 6 feet or more (measured along the slope) from the base of the backslope.

iii. Drainage Features

Proposed channels should be designed to be traversable, and where feasible, existing channels should be reconstructed to be traversable. See Section 3.2.4 of the *Roadside Design Guide, AASHTO, 4th Edition, 2011*, for further guidance.

b. Fixed Objects

Examples of fixed objects that may warrant a roadside barrier are: non-breakaway sign supports, traffic signals and lighting poles of non-breakaway design, concrete pedestals extending more than 4 inches above the ground, bridge piers, abutments and ends of parapets and railings, wood poles or posts with a cross sectional area greater than 50 square inches (except as modified by **Section II.A.2.b.ii**, "Utility Poles"), and drainage structures.

Fixed objects should not be located less than the minimum offset from the face of the rail element shown in **Table 4**.

In no case, on new or upgraded roadside barrier installations, shall breakaway or non-breakaway sign supports, highway lighting, trees, utility poles, fire hydrants, and mailboxes remain in front of the roadside barrier.

i. Trees

Trees are considered fixed objects. However, trees are not considered a warranting obstruction for a roadside barrier since barriers are not installed solely for shielding trees. On limited access roadways, trees shall not be located within the clear zone. On lower speed access permitted roads, a clear zone free of trees is preferred. Factors such as crash experience, traffic volume, speed, clearance from the traveled way and roadway geometry should be evaluated when determining whether it is appropriate to leave trees within the clear zone.

In some cases, it may be desirable to plant trees to replace those being removed. Replacement trees should be located well outside of the clear zone or at an alternate location away from the roadway.

Sick and diseased trees that are beyond reasonable repair, along with dead trees, trees that cause sight distance problems and trees with crash history shall be removed.

Trees behind guide rail located less than the minimum offset from the face of the rail element shown in **Table 4** shall be removed regardless of size. Trees, shrubs and overhanging branches shall be removed where they block or obscure horizontal sight distance. As a minimum, branches overhanging the roadway shall be removed up to a height of 16 feet. Trees and shrubs within the roadside recovery area (**Figure 7**) shall be removed. The following areas should be checked for sight distance problems due to vegetative interference:

- Along the inside of horizontal curves (mainline, ramps and jughandles)
- Ramp and jughandle entrances and exits
- Within the sight triangle at intersections
- Sign obstructions

ii. Utility Poles

Although utility poles have a cross-sectional area greater than 50 square inches (8 inches diameter), they should not be handled the same as other warranting obstructions. Utility poles shall be located as close to the right-of-way line as practical. For the offset to the utility pole from the traveled way, the designer should refer to current utility accommodation regulations (NJAC 16:25 for New Jersey locations and NYCRR Title 17 Part 131 for New York State locations).

Desirably on projects where new right-of-way is to be purchased, sufficient right-of-way should be acquired to permit the placement of the poles beyond the clear zone.

On existing roadways, any utility pole that has been struck three times or more within three years should be considered for safety measures such as utility pole relocation and/or the improvement of the contributing roadway feature.

Utility poles should not be placed in vulnerable locations, such as in gore areas, small islands or on the outside of sharp horizontal curves. For the purpose of these guidelines, a sharp horizontal curve is one that does not meet AASHTO standards given the design speed, radius and cross slope.

In no case, shall utility poles on new or upgraded guide rail installations remain in front of the guide rail. The guide rail offset has preference to existing utility pole offsets where there is sufficient right-of-way. Therefore, where practical, do not place the guide rail closer to the road, instead, relocate the pole behind the guide rail.

Where utility poles are placed behind guide rail, the recommended minimum offsets from the face of the pole to the face of the rail element are shown in **Table 4** and **Figure 2A**, **Figure 2B** and **Figure 2C**.

Utility poles should not be located within the shaded roadside recovery area shown in **Figure 7**. Utility poles should not be located closer than 25 feet in advance of a tangent guide rail terminal.

iii. Lighting Poles

Desirably all lighting poles should be breakaway. However, where lighting poles cannot be made breakaway, they should be located as far from the traveled way as practical. Unless there is an accident history, a roadside barrier should not be installed to shield a non-breakaway lighting pole. The preferred alternate would be to convert the lighting pole to a breakaway design.

In no case, shall breakaway or non-breakaway lighting poles on new or upgraded guide rail installations remain in front of the guide rail. The placement of lighting poles behind the guide rail should conform to the minimum offsets from the face of the rail element shown in **Table 4**.

iv. Traffic Signal Poles

Traffic signal poles should be located as far from the traveled way as practical on high speed roadways. The location of all traffic signal poles shall be in accordance with the Port Authority's Traffic Signal Design and Drawing Preparation Guidelines.

Due to the signal pole's required proximity to intersections, shielding with a longitudinal barrier is not required. Where there is proposed or existing guide rail, it is desirable to locate the signal pole behind the guide rail. Where traffic signal poles are installed behind guide rail, they should conform to the minimum offsets from the face of the rail element shown in **Table 4**.

v. Sign Supports

In no case, on new or upgraded guide rail installations, shall breakaway or non-breakaway sign supports remain in front of guide rail.

Where sign supports for overhead signs and non-breakaway ground mounted sign supports are installed behind guide rail, they shall conform to the minimum offsets from the face of the rail element shown in **Table 4**.

Roadside barrier protection for obstructions beyond the clear zone for critical infrastructure such as overhead sign supports may be considered based on engineering judgment.

vi. Fire Hydrants

Since fire hydrants do not meet the current AASHTO definition for breakaway design, they fall into the category of fixed objects and should be treated similar to utility poles.

Locate the hydrants as far from the traveled way as practical. In no case shall fire hydrants be located in front of the guide rail. However, the hydrants must be located to be readily accessible at all times.

Where guide rail is required for some other reason and will be in front of a hydrant, the preferred treatment is to raise the hydrant to permit connection to be made over the guide rail. Usually, the connection may be a maximum of 3 feet above grade.

It is the responsibility of the designer to confirm with the local Fire Department that such a treatment is acceptable. A less desirable treatment is to provide a short opening in the guide rail at the hydrant. Where an opening is provided, a tangent guide rail terminal or anchorage must be provided in accordance with **Section II.D**. The location of hydrants behind guide rail should conform to the minimum offsets from the face of the rail element shown in **Table 4**.

vii. Pedestrians

A roadside barrier may be used where there is a reasonable possibility of an errant vehicle encroaching into an unprotected area used by pedestrians. The basis for assessing the needs should be the crash history of the immediate area and the specifics for the cause of the crashes. There may be times when no specific factor can be identified, and sound engineering judgment must be applied. Roadside barrier should not interfere with pedestrian crossings or pedestrian access along terminal frontage.

At locations where existing guide rail and the slope break of a steep foreslope are both located directly behind a pedestrian sidewalk area and new guide rail is installed in front of the sidewalk area, the existing guide rail should either be left in place or the existing guide rail should be removed and a fence installed in its place.

Where W-beam guide rail is placed between the roadway and the sidewalk, a rail element may be attached to the back of the guide rail post so that pedestrians are shielded from the exposed back of post. The rail element, if added, shall not be located within the length of a guide rail approach end terminal.

B. Roadside Barrier Types

Roadside barriers that have been proven acceptable for use and or specific conditions either through crash testing or in-service performance are considered crashworthy and are required on all roadways under the jurisdiction of the Port Authority. To assess the crashworthiness of roadside barriers, standards for conducting crash tests have been developed and are presented in NCHRP Report No. 350 and the Manual for Assessing Safety Hardware, 2016 (MASH). These tests evaluate occupant risk, structural integrity of the barrier and post-impact behavior of the vehicle for a variety of vehicle weights, speeds and impact angles. As of January 1, 2011, manufacturers proposing new roadside barrier designs must use MASH criteria for crash testing. The test criteria for six test levels (TL-1 through TL-6) for roadside barriers has been established and are shown in **Appendix A** for both NCHRP Report 350 and MASH. For new installations of roadside barrier, the designer should select a design test level based on the design speed and the preferred vehicle class for that particular location. Test Level 3 is commonly used for design speeds greater than 45 MPH. However, a higher test level might be selected if a large volume of trucks is anticipated. The type of obstruction may also be a determining factor. For example, if damage to the obstruction would cause loss of critical infrastructure function, a higher design test level may be warranted. Roadside barriers and terminals in this Guide are either MASH or NCHRP 350 compliant with the exception of the Controlled Release Terminal (CRT) which is NCHRP 230 compliant.

Existing W-beam guide rail with no blockouts or with steel blockouts is pre-NCHRP 350. (This does not include steel blockouts at posts welded to base plates for guide rail attachment to concrete pad). Replacement of Pre-NCHRP 350 W-beam guide rail and approach terminals within project limits should be considered.

Existing W-beam guide rail with timber or synthetic blockouts and rail splices located at posts is considered NCHRP 350 compliant. NCHRP 350 guide rail may remain in place. Replacement of existing NCHRP 350 approach end terminals with a MASH compliant terminal should be considered within project limits. A vertical transition from the MASH terminal to the existing guide rail is required as shown in the *Traffic Engineering Standard Details*.

Existing box beam guide rail is MASH compliant and may remain in place. Replacement of existing box beam tapered approach terminals within the clear zone and NCHRP 350 box beam guide rail approach terminals with the MASH compliant MBEAT terminal should be considered within project limits.

There are three types of guide rail and three types of concrete barrier that have been crash tested and approved for use by the Port Authority as roadside barriers. These barriers have been crash tested and selection often requires consideration of the test deflection and physical dimensions of the barrier. Box beam guide rail is a weak post system which results in greater horizontal deflection upon impact as compared to strong post systems. Box beam guide rail deflection may be decreased by reducing the post spacing. W-beam guide rail and modified thrie beam guide rail are strong post systems that have less horizontal deflection than box beam guide rail and may be stiffened with reduced post spacing to further reduce the horizontal deflection. Where curb or a raised berm is present, the vertical displacement of a vehicle striking the curb or berm can cause the vehicle to travel over or under a guide rail system. See **Section II.C.2** for preferred guide rail offsets for curb or raised berm in front of guide rail. Concrete barrier may be appropriate where redirection without deflection is desired.

Minimum offsets from face of the rail element of guide rail to the warranting obstruction based on impact deflection are shown in **Table 4**. In a fill section where the distance from the back of the post to the slope break is less than 1 foot and the slope is steeper than 3:1, the minimum offset from the face of rail to the obstruction shown in **Table 4** is increased by 1 foot due to increased post deflection.

Table 4
Minimum Offset from the Face of the Guide Rail Element to the Obstruction

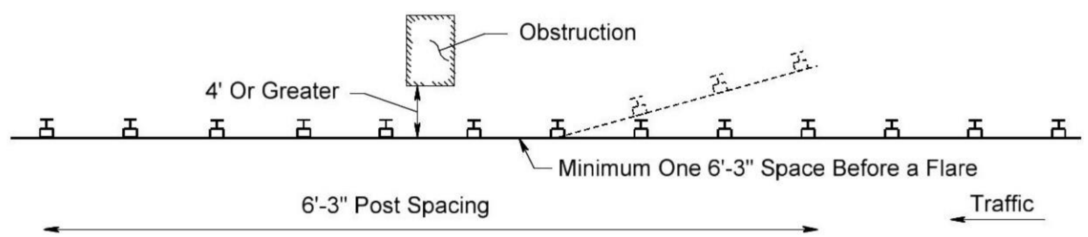
Guide Rail Type	Post Spacing	Minimum Offset
W-Beam Guide Rail	6'-3"	4'
	3'-1½"	2.5'
	1'-6¾"	1.5'
Modified Thrie Beam Guide Rail	6'-3"	3'
	3'-1½"	2'
Box Beam Guide Rail	6'-0"	5'
	3'-0"	4'

W-beam guide rail reduced post spacing details are shown in **Figure 2A**. The minimum offset of 1.5 feet with 1'-6¾" post spacing applies to narrow obstructions that are located between posts.

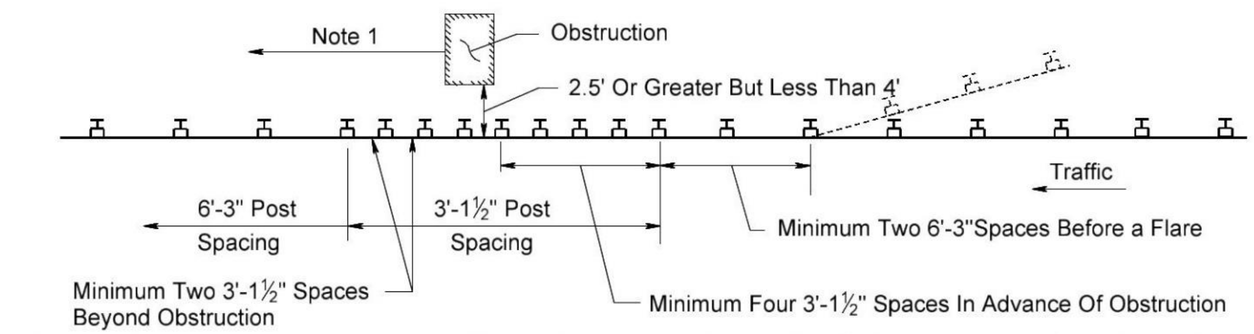
Modified thrie beam guide rail reduced post spacing details are shown in **Figure 2B**. For modified thrie beam guide rail, the minimum offset of 1.5 feet with 3'-1½" post spacing applies to narrow obstructions that are located between posts.

Box beam guide rail reduced post spacing details are shown in **Figure 2C**.

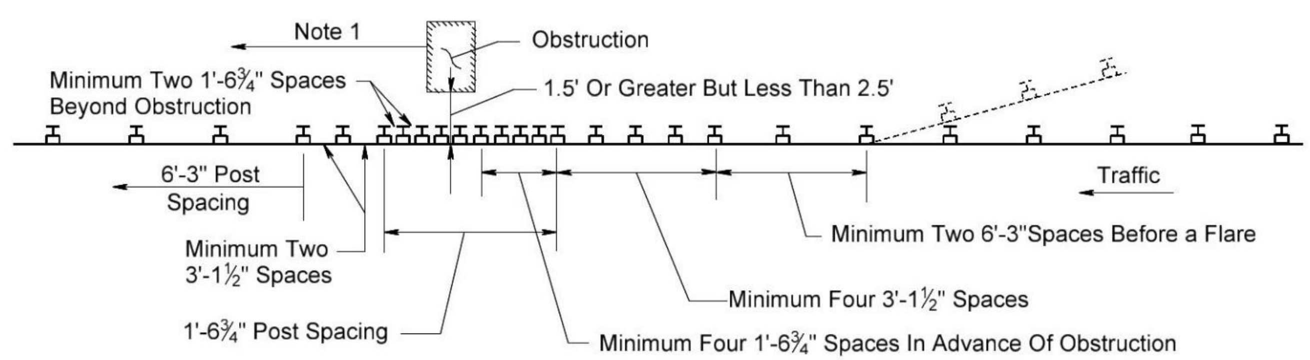
Where guide rail is modified with reduced post spacing, no portion of the modified guide rail shall be within the length of a guide rail end terminal.



Where Offset from W-Beam Face of Rail Element to Obstruction is 4' or Greater



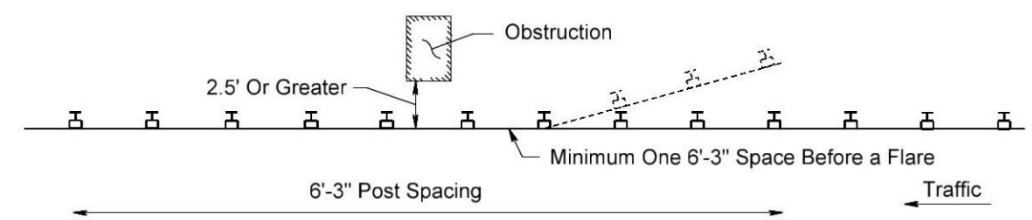
Where Offset from W-Beam Face of Rail Element to Obstruction is 2.5' or Greater But Less Than 4'



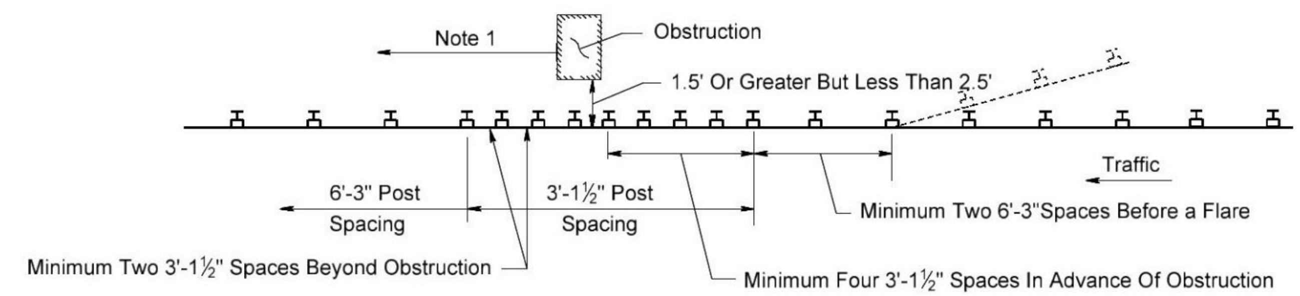
Where Offset from W-Beam Face of Rail Element to Obstruction is 1.5' or Greater But Less Than 2.5'

Note 1 Where the obstruction is within the clear zone of opposing traffic, the post spacing requirements shall be the same as the approach end.

Figure 2A – W-Beam Minimum Offset from Face of Rail to Obstruction



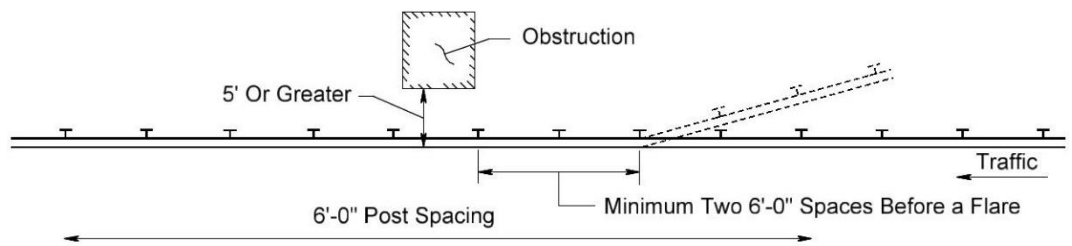
Where Offset from Modified Thrie Beam Face of Rail Element to Obstruction is 2.5' or Greater



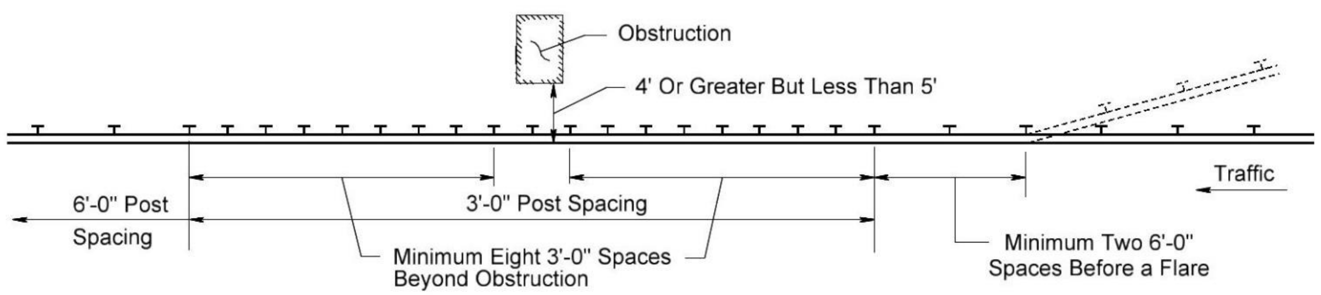
Where Offset from Modified Thrie Beam Face of Rail Element to Obstruction is 1.5' or Greater But Less Than 2.5'

Note 1 Where the obstruction is within the clear zone of opposing traffic, the post spacing requirements shall be the same as the approach end.

Figure 2B – Modified Thrie Beam Minimum Offset from Face of Rail to Obstruction



Where Offset from Box Beam Face of Rail Element to Obstruction is 5' or Greater



Where Offset from Box Beam Face of Rail Element to Obstruction is 4' or Greater But Less Than 5'

Figure 2C – Box Beam Minimum Offset from Face of Rail to Obstruction

1. Box Beam Guide Rail

Box beam guide rail is considered a weak post semi-rigid system and has passed MASH test criteria for TL-3. A minimum 125-foot length of box beam guide rail is necessary for the system to develop its deflection resistance. Box beam guide rail is preferred within the central terminal areas for aesthetic reasons. Minimum offsets from the face of the rail element to the obstruction are shown in **Table 4**.

2. W-Beam Guide Rail

W-beam guide rail is considered a strong post semi-rigid system and has passed MASH test criteria for TL-3. A minimum 75-foot length of W-beam guide rail is necessary for the system to develop its deflection resistance. Minimum offsets from the face of the rail element to the obstruction are shown in **Table 4**.

Where new W-beam guide rail meets existing W-beam guide rail, an end terminal or an impact attenuator mounted at a different height, a vertical transition is required. The vertical transition shall be accomplished in a minimum length of 12’-6” for each 2 inches of vertical change (see the *Traffic Engineering Standard Details)*.

3. Modified Thrie Beam Guide Rail

Modified thrie beam guide rail is considered a strong post semi-rigid system and has passed MASH test criteria for TL-3. A minimum 62.5-foot length of modified thrie beam guide rail is necessary for the system to develop its deflection resistance. Modified thrie beam guide rail may be considered when a wider rail element is desired for reduced deflection or due to a high volume of large vehicles. Thrie beam rail element is also used for transitioning W-beam guide rail to a concrete parapet attachment. Minimum offsets from the face of the rail element to the obstruction are shown in **Table 4**. A thrie beam to W-beam symmetrical transition section is used where modified thrie beam guide rail is transitioned to W-beam guide rail (see *Traffic Engineering Standard Details)*.

4. Concrete Barrier

Concrete barrier types for use by the Port Authority as roadside barriers are:

- 42” F Shape Concrete Barrier
- 42” Single Slope Concrete Barrier

Roadside concrete barriers can be half section or full section barriers. Full section 42” F Shape or 42” Single Slope concrete barrier is considered MASH TL-5 compliant and shall be used for roadside applications where space permits. Where space is limited, half section barrier with steel post backup is an alternative to full section barrier that requires 2” less width at the posts. Half section barrier requires a continuity connection plate at all joints as shown in the *Traffic Engineering Standard Details*. Details for transitioning guide rail to concrete barriers are also provided in the *Traffic Engineering Standard Details*. Curb in front of concrete barrier is not permitted.

Where 42” concrete barrier is transitioned to existing 32” concrete barrier, a vertical transition is required. This vertical transition shall be 6:1 or flatter (minimum 5 feet in length).

C. Design Criteria

1. Without Curb or Raised Berm in Front of Guide Rail

To the extent possible, guide rail should be located as far as possible from the through traveled way to provide a recovery area for errant vehicles and to provide adequate sight distance along horizontal curves and at intersections.

On roadways where there is a sidewalk or a sidewalk area used by pedestrians, the front face of the guide rail may be placed at any offset from the edge of pavement either between the roadway and the sidewalk or behind the sidewalk.

On roadways where there is no sidewalk and the border area is not used by pedestrians, the front face of the guide rail may be placed any distance from the edge of pavement, however, an offset of 4 feet or more is preferred.

2. Curb or Raised Berm in Front of Guide Rail

Curb or raised berm in front of guide rail requires additional design criteria. On projects that involve upgrading existing roadways, where there is existing curb in front of guide rail that does not meet the criteria for new installations of curb shown below, removal or modification of the curb should be considered. If a raised berm in front of the guide rail cannot be removed, it shall be re-graded at 10H:1V and the guide rail placed as noted in **Section II.C.1**.

Where W-beam or modified thrie beam guide rail is installed 1 foot or less of the curb line (9 inches or less for box beam guide rail), the mounting height is measured from the top of pavement at the curb line. For all other offsets, the mounting height of guide rail is measured from the ground directly below the face of rail in accordance with *Traffic Engineering Standard Details*.

Where guide rail is being installed or upgraded at locations where there is existing curb, replacing the curb to meet the following requirements should be considered.

For new installations of curb in front of guide rail, the following apply:

a. Roadways with a Design Speed 55 MPH or greater:

Curb shall be (mountable) or Type IV (traversable) and no greater than 4 inches in height. For design speeds of 60 MPH or higher Type IV curb shall be used. For a design speed of 55 MPH Type II or Type IV curb may be used, however, Type IV curb is preferred. Modified thrie beam guide rail shall be placed at the curb line. W-beam guide rail shall be placed at the curb line where Type II curb is used and 6 inches from the curb line where Type IV curb is used. Box beam guide rail shall not be used.

b. Roadways with a Design Speed of 50 MPH:

Type II curb (mountable) or Type IV curb (traversable) is the preferred option, however, Type I curb (non-mountable) is permitted. Curb shall be no greater than 4 inches in height and the following guide rail offset options apply:

- Where Type I curb or Type II curb is used, place W-beam guide rail or modified thrie beam guide rail at the curb line and place box beam guide rail 6 inches from the curb line.
- Where Type IV curb is used, place modified thrie beam guide rail at the curb line and place W-beam guide rail or box beam guide rail 6 inches from the curb line.
- Where Type I, Type II, or Type IV curb is used, place W-beam guide rail, modified thrie beam guide rail, or box beam guide rail 4 to 12 feet from the curb line.

c. Roadways with a Design Speed of 45 MPH or less:

Type II curb (mountable) or Type IV curb (traversable) is the preferred option, however, Type I curb (non-mountable) is permitted. A maximum curb height of 4 inches is desirable, however, a curb height of 6 inches is permitted. Due to the reduced risk of vaulting at lower speeds, any guide rail offset is acceptable. However, the following guide rail offset options are preferred:

- Where Type I curb or Type II curb is used, place W-beam guide rail or modified thrie beam guide rail at the curb line and place box beam guide rail 6 inches from the curb line.
- Where Type IV curb is used, place modified thrie beam guide rail at the curb line, place W-beam guide rail 6 inches from the curb line and place box beam guide rail 9 inches from the curb line.
- Where Type I, Type II, or Type IV curb is used, place W-beam guide rail, modified thrie beam guide rail or box beam guide rail 4 to 12 feet from the curb line.

3. Concept of Shy Line

A highly desirable characteristic of any roadway is a uniform clearance from the outside edge of the outermost travel lane to the roadside barrier. Wherever possible, it is desirable to place the roadside barrier at a distance beyond which it will not be perceived as a threat by the driver. This distance from the edge of traveled way to the face of the roadside barrier is the shy line offset which varies with design speed as shown in **Table 5**. Shy-line offset distance is seldom a controlling criterion for barrier placement. If the barrier is located beyond the perceived shoulder of a roadway, it will have minimum impact on driver speed or lane position. For more information see Section 5.6.3 of the Roadside Design Guide, AASHTO, 4th Edition, 2011, for further guidance.

Table 5
Shy Line Offset

Design Speed (mph)	Shy Line Offset (feet)
60	8.0
55	7.0
50	6.5
45	6.0
40	5.0
30	4.0

SOURCE: Chapter 5, “Roadside Barriers”, *Roadside Design Guide, AASHTO, 4th Edition, 2011*

4. At Fixed Objects

Where guide rail is used to shield an isolated obstruction, guide rail should be located as far from the traveled way as possible to minimize the probability of impact. The distance from the face of the rail element of guide rail to the obstruction should comply with the criteria in **Table 4**.

5. On Bridges

Safety walks range in width from 1.5 feet to less than 4 feet. On existing structures with safety walks, where it is not feasible to remove the safety walk and provide a crash tested bridge rail, guide rail shall be carried across the structure along the edge of pavement. However, on ramps where the design speed is 40 mph or less and the safety walk is 2.5 feet or less in width, it is not necessary to carry guide rail across the structure since vaulting is not likely to occur. In this case, guide rail should only be provided across the structure if the parapet does not meet NCHRP 350 or MASH crash test criteria.

Attachment of W-beam, thrie beam, or box beam guide rail to bridges or concrete barrier shall be in accordance with the Port Authority's *Traffic Engineering Standard Details*.

For W-beam guide rail, the designer shall specify at each location on the contract drawings whether the attachment is Type A or Type B and which of the *Traffic Engineering Standard Details* is applicable. Attachments Type A and Type B should also be used where W-beam guide rail is transitioned to roadside concrete barrier. A Type A attachment is used on the approach end of all bridge parapets and on the trailing end of bridge parapets that are within the clear zone of opposing traffic. The Type B attachment is used on the trailing end of parapets that are outside the clear zone, and where the trailing end is separated from the opposing traffic by a non-traversable median. Guidance for use of attachment Type A or Type B is provided in **Figure 4**. A thrie beam to W-beam asymmetrical transition section is used where thrie beam guide rail at a bridge attachment is transitioned to W-beam guide rail (see *Traffic Engineering Standard Details).* Type A, TL-3 attachments are used where the design speed is greater than 45 MPH. Type A, TL-2 attachments are used where the design speed is 45 MPH or less. The minimum length of W-beam guide rail required for a Type A, TL-2 or TL-3 attachment is shown in **Figure 3**.

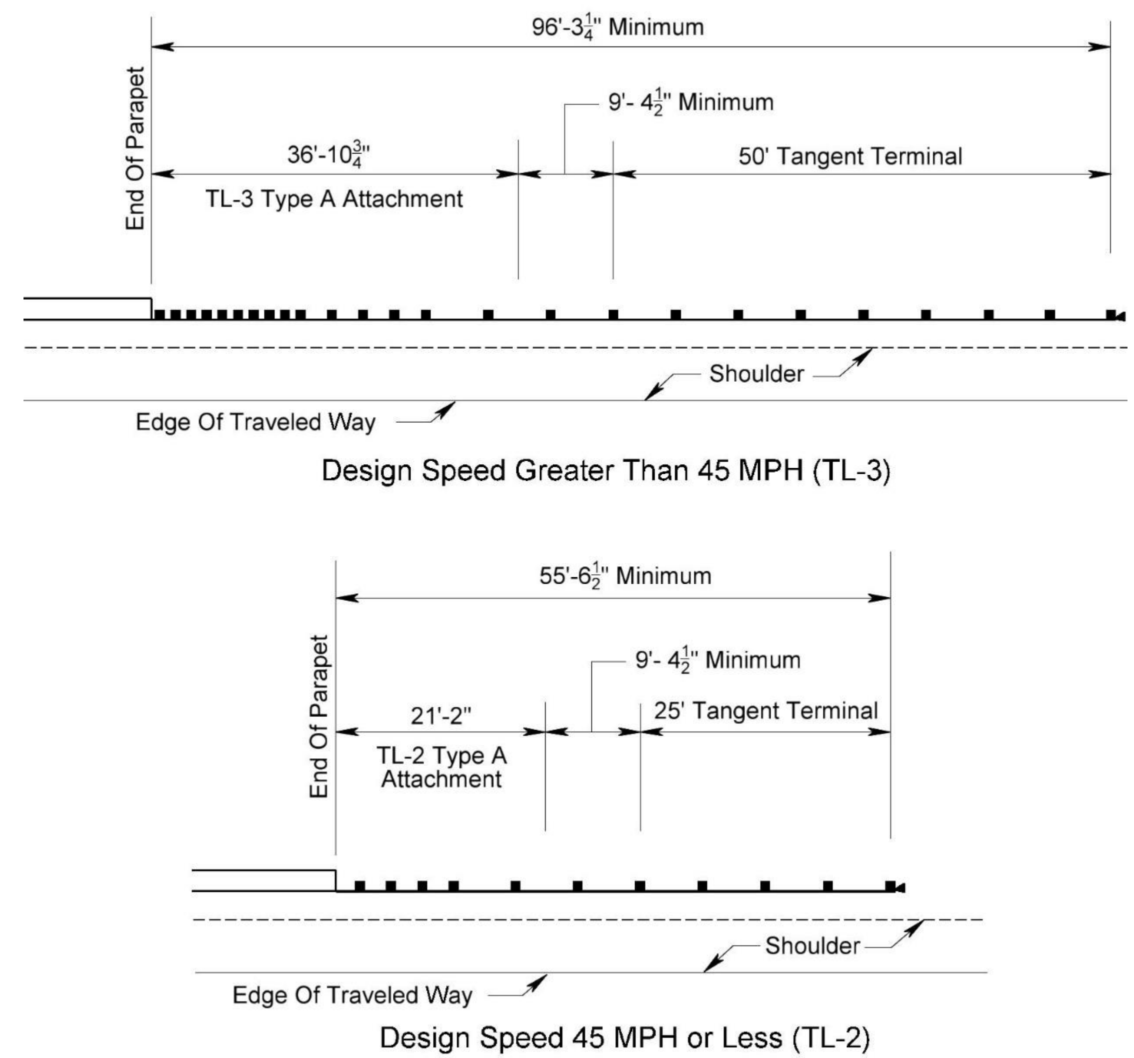


Figure 3 – Minimum Length of W-Beam Guide Rail at a Type A Bridge Attachment

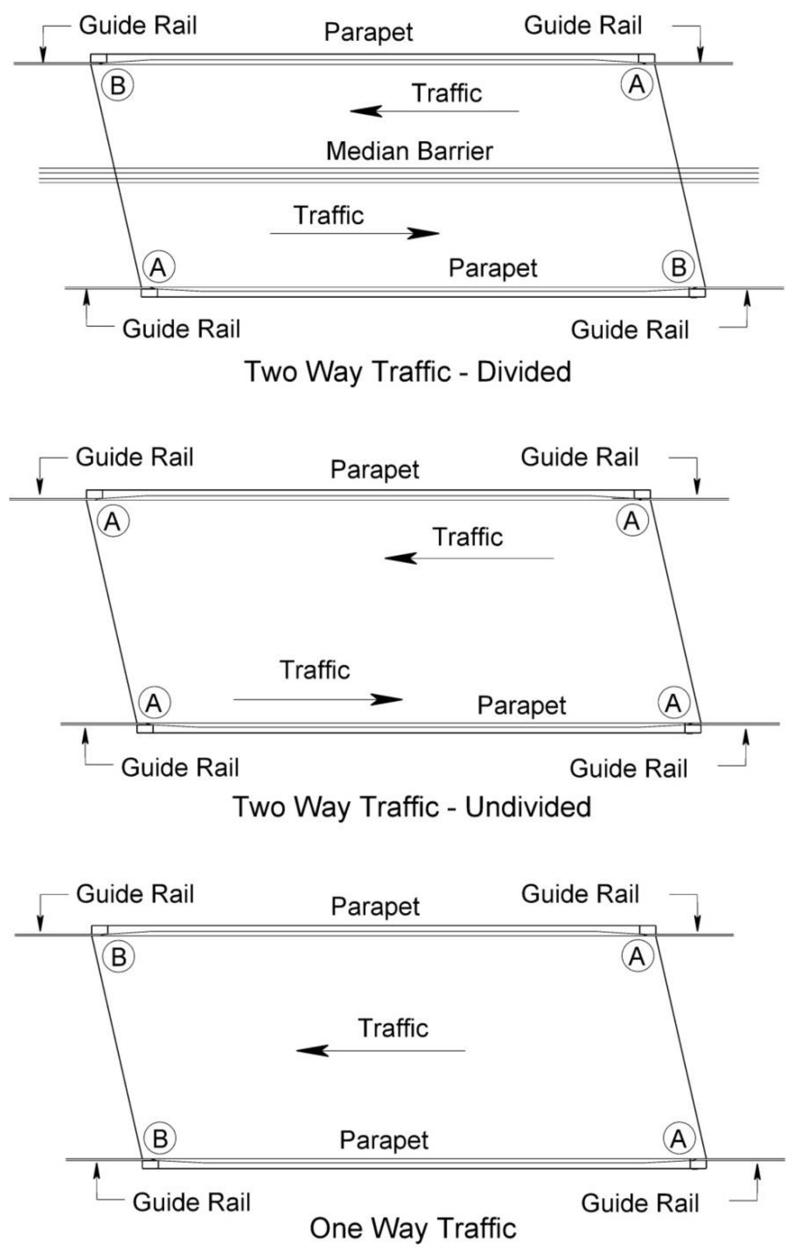


Figure 4 – W-Beam Type A and Type B Bridge Attachments

Attachment of W-beam guide rail to sidewalk on bridges shall be in accordance with the *Traffic Engineering Standard Details.*

6. Cross Slopes

The cross slope between the edge of pavement (or top of curb) and the slope break should be 10:1 or flatter. Where guide rail is located at the top of a foreslope steeper than 6:1, posts should be a minimum of 2 feet from the slope break to the back of the post as shown in **Figure 5**.

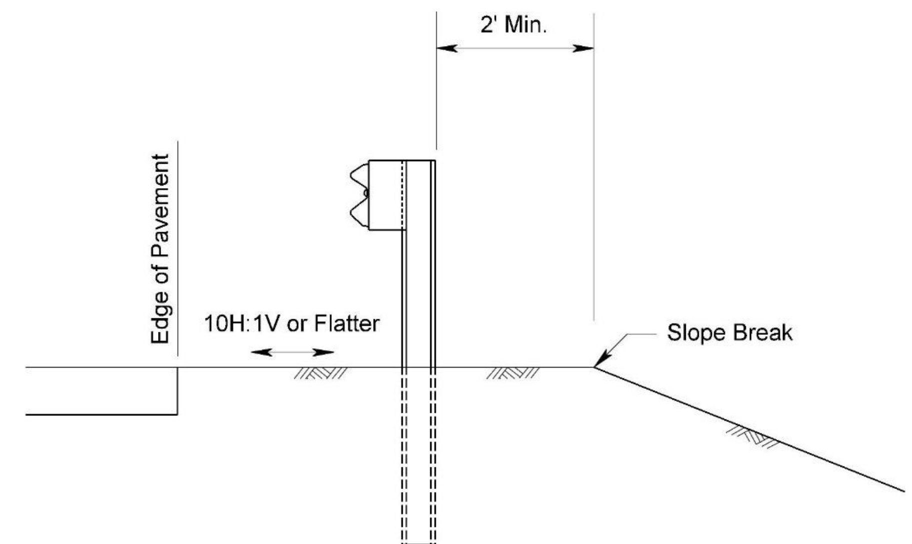


Figure 5 – Minimum Offset from Back of Post to Slope Break

Where less than 2 feet is provided, the post lengths for W-beam or modified thrie beam guide rail, shown in **Table 6**, should be used. For box beam guide rail the 10:1 or flatter slope should be maintained for 2' behind the post.

Slopes behind the post at W-beam Type A bridge attachments shall be at a 2% slope or flatter for a minimum distance of 2 feet, then no steeper than 2H:1V for a minimum distance of 4 feet. See *Traffic Engineering Standard Details*.

Table 6 Additional Post Length Requirements for W-Beam or Modified Thrie Beam Guide Rail Where Distance from Slope Break to Back of Post is Less Than 2 Feet		
	Foreslope	**Additional Post Length (feet)**
Less than 2' but greater than or equal to 1'	6H:1V or flatter	No Change
	Steeper than 6H:1V to 3H:1V	1
	Steeper than 3H:1V to 2H:1V	2
Less than 1'	6H:1V or flatter	1
	Steeper than 6H:1V to 3H:1V	2
	Steeper than 3H:1V to 2H:1V	3

Where there is no curb and the rollover between the pavement slope and the berm area is greater than 10 percent, install guide rail flush with or 6" from the edge of pavement.

Grading in advance of, adjacent to, and behind a guide rail tangent terminal is required to allow the vehicle to remain stable after hitting the terminal. Where the approach slope is steeper than 4H:1V, the grading treatment for tangent terminals shown in **Figure 6** is required. The standard grading treatment should be used wherever practical, however, when upgrading existing guide rail sites or where there are site limitations at new guide rail locations, the alternate grading treatment may be used.

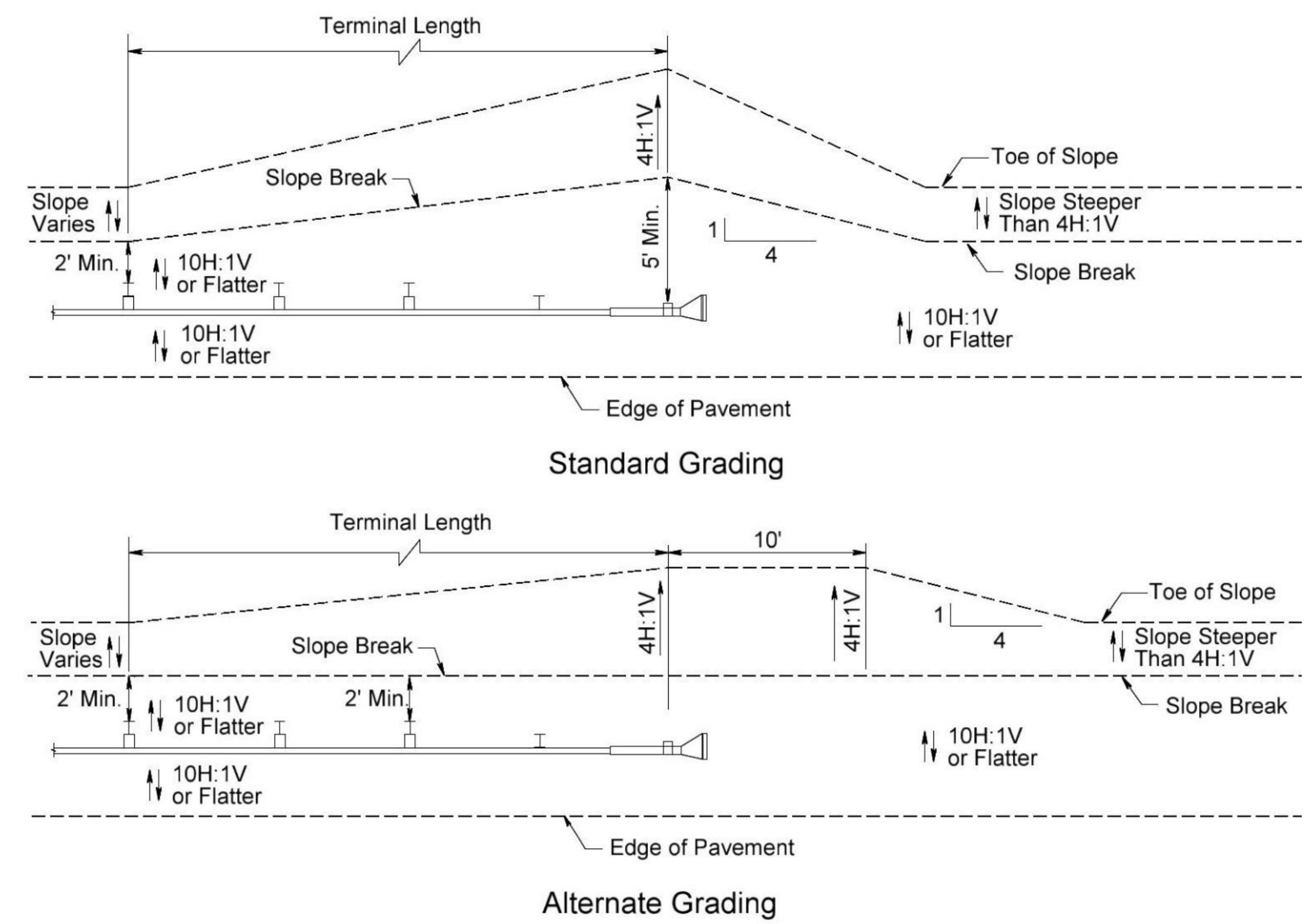


Figure 6 – Grading Treatment at W-beam and Box Beam Tangent Terminals

7. Roadside Recovery Area

Research has shown that over half of all fatal guide rail collisions involve a secondary event, either a second impact or a rollover. Many of these secondary events, e.g. trees, poles, and rollovers, typically carry a much higher fatality risk than guide rail impact. Therefore, a roadside recovery area void of fixed objects is desirable in advance, adjacent to, and behind the approach guide rail terminal. **Figure 7** shows the desirable roadside recovery area that should be provided at tangent guide rail terminals.

The roadside recovery area behind the guide rail should extend 25 feet in advance of the guide rail terminal to the obstruction (cross hatched area in **Figure 7)**. However, where it is not practical to provide the desirable area, a minimum recovery area as shown in **Table 7** should be provided behind the guide rail and 25' in advance of the terminal (shaded area in **Figure 7**).

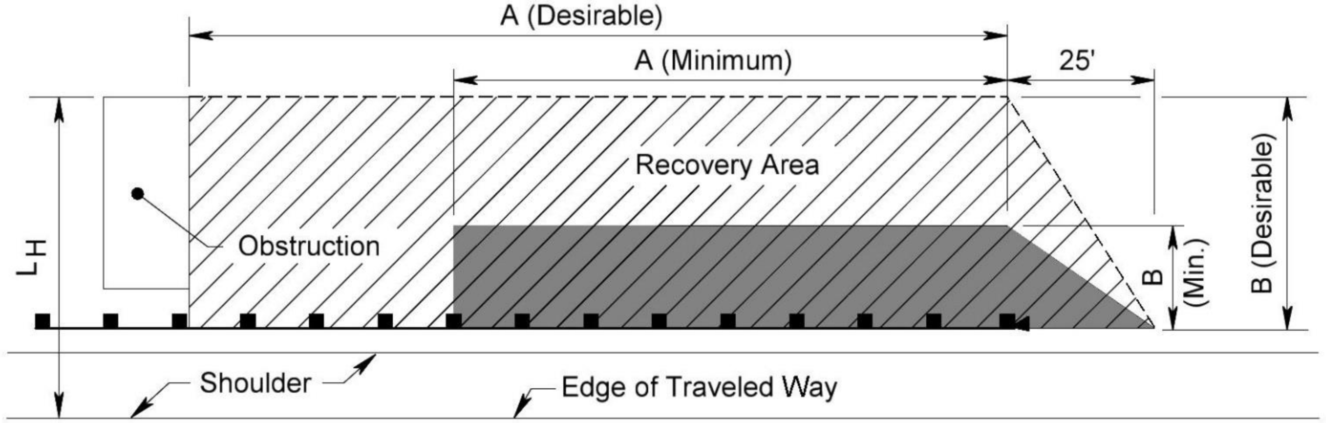


Figure 7 – Roadside Recovery Area at Tangent Terminals

Table 7 Minimum Adjacent Recovery Area Behind Guide Rail		
Design Speed (MPH)	**A (feet)**	**B (feet)**
40 or less	50	10
45	55	12
50	60	15
55	65	18
60 or greater	75	20

On roadways where the length of guide rail in advance of the obstruction is restricted due to the location of driveways, intersecting streets or other features, and the roadside recovery area in advance of the guide rail terminal shown in **Figure 7** cannot be provided, the roadside recovery area should extend from the guide rail terminal to the obstruction. If the distance from the edge of traveled way to the back of the obstruction (L_H) extends beyond the clear zone or R.O.W. line, the roadside recovery area should be limited to the clear zone or R.O.W. line, whichever is less. The location of utility poles should comply with the criteria in **Section II.A.2.b.ii**, "Utility Poles".

If the typical roadside in advance of the terminal does not have the minimum roadside recovery area, the clear area behind the guide rail can be reduced if it is consistent with that available elsewhere along the roadway.

8. Approach Length of Need (L.O.N.)

a. General

The approach length of need (L.O.N.) is the minimum length of guide rail required in front of the warranting obstruction to shield it effectively. **Table 8** provides Runout Lengths (L_R) for various design speeds and traffic volumes to be used with length of need calculations described in this Section.

The length of need is determined graphically as shown in **Figure 8** as follows:

- Locate the back of the obstruction. If the obstruction extends beyond the clear zone, use the clear zone. (if the obstruction is a critical slope, see **Figure 10**).
- From **Table 8**, obtain L_R and measure L_R along edge of traveled way (On horizontal curves, L_R is measured along the curve of the edge of traveled way).
- Construct a line connecting the intersection of L_R and the edge of traveled way with the back of obstruction. The L.O.N. is where this line intersects the proposed guide rail offset.
- Post #1 of the tangent terminal extends 12.5 feet from the L.O.N. for W-beam guide rail and 15.5 feet for box beam guide rail.
- Where a tangent terminal is tapered for a 1 foot or 2 foot offset, adjust the L.O.N. accordingly.

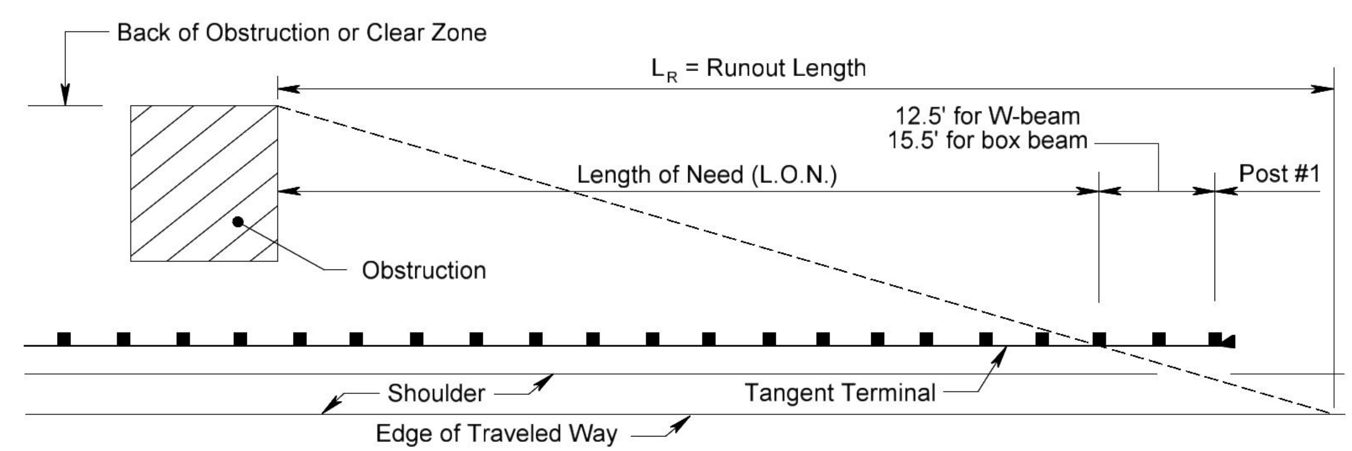


Figure 8 – Approach Length of Need on a Tangent

Table 8 Runout Lengths (L_R) for Guide Rail Design (feet)				
Design Speed (mph)	Traffic Volume (ADT)			
	Over 10,000	5,000 – 10,000	1,000 – 5,000	Under 1,000
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

SOURCE: Chapter 5, "Roadside Barriers", *Roadside Design Guide, AASHTO, 4th Edition, 2011*

For undivided roadways or roadways divided with a traversable median, a tangent guide rail terminal shall be used if the guide rail or the obstruction is within the clear zone for opposing traffic as shown in **Figure 9**. The clear zone for the opposing traffic should also be adjusted for horizontal curvature (**Table 2**). On two lane roadways where passing is permitted, the clear zone should be measured from the outside edge of the approaching traffic lane. If guide rail is outside the clear zone, use a W- beam guide rail anchorage or a box beam Type I End Assembly.

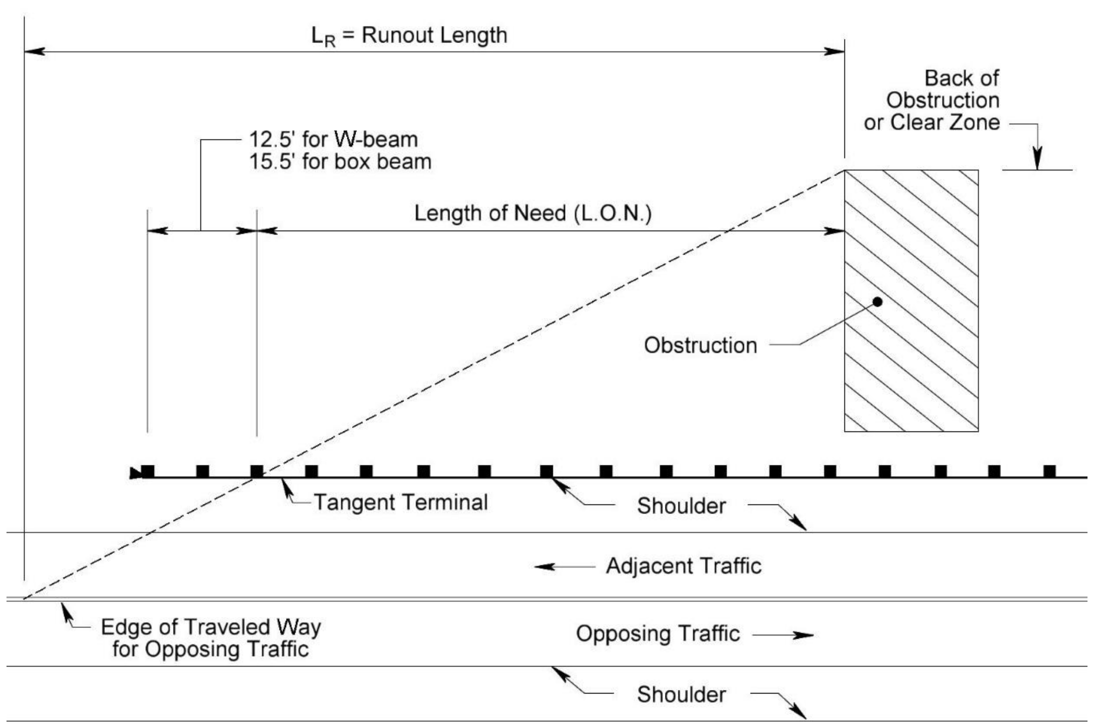


Figure 9 – Length of Need for Opposing Traffic

b. On Foreslopes (Fill)

If a critical slope (steeper than 3H:1V) begins within the clear zone, guide rail is warranted. The approach L.O.N. on foreslopes steeper than 3H:1V begins at the toe of the critical slope as shown in **Figure 10**. See **Figure 6** for standard and alternate grading treatments for tangent terminals.

For undivided roadways or roadways divided with a traversable median, a tangent terminal may be required for both directions of traffic. See **Figure 9** to determine the approach L.O.N. for opposing traffic.

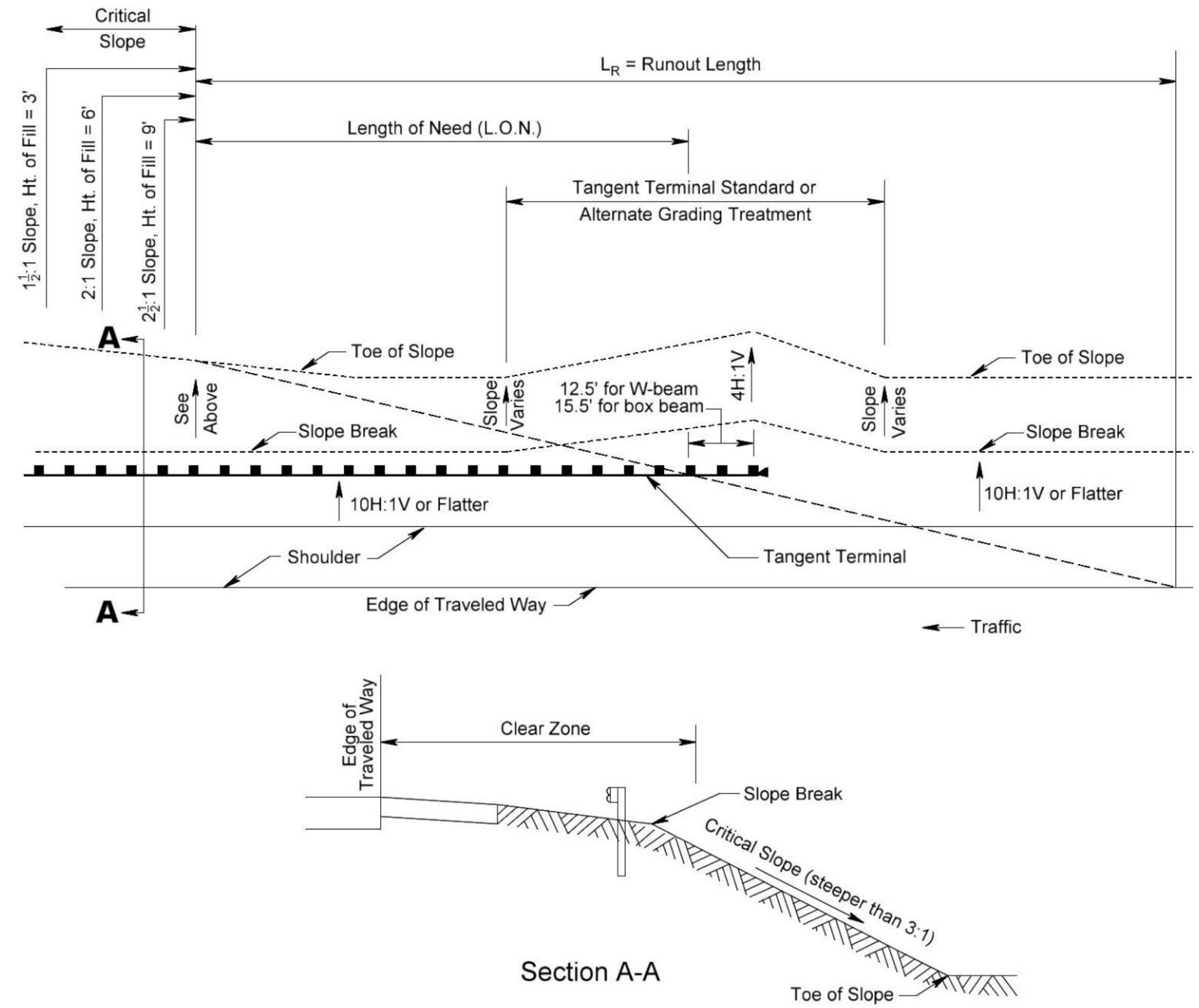


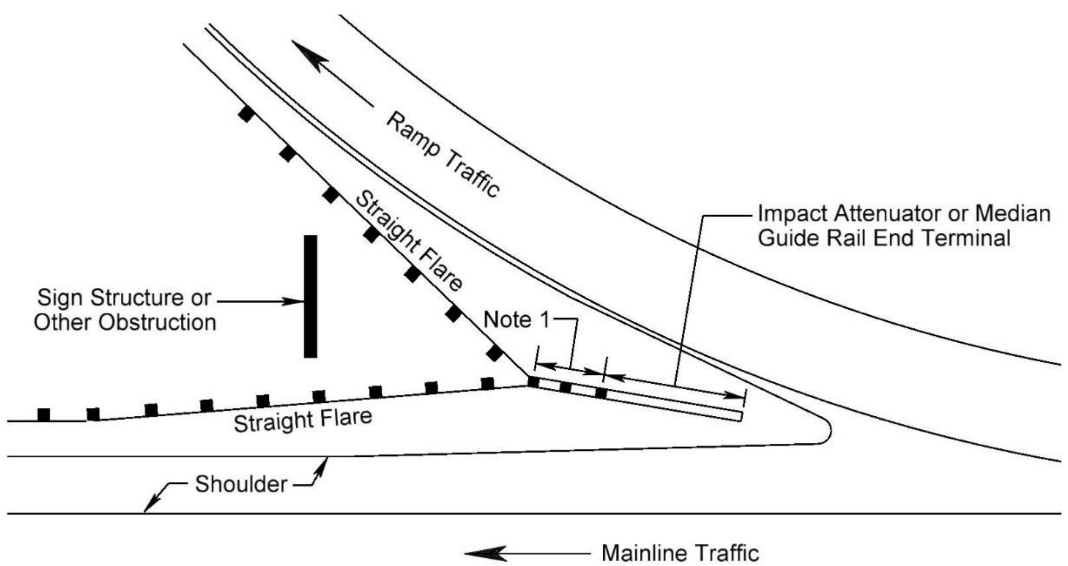
Figure 10 – Approach Length of Need for Critical Foreslopes

c. On Backslopes (Cut)

See **Section II.A.2.a.ii** for guidance regarding guide rail warrants for backslopes.

d. At Gore Areas

It is desirable to provide a traversable and unobstructed gore area since the gore area may serve as a recovery area for errant vehicles. Every effort should be made to keep the gore area clear of warranting obstructions. However, structures, urban areas, wetlands, parklands, etc. can put restrictions on this policy by placing warranting obstructions, such as critical foreslopes, parapets or abutments close to gore areas. **Figure 11** shows a W-beam guide rail treatment example for gore areas.



Note 1 For a median guide rail end terminal, a minimum of 9'-4½" of tangent dual faced W-beam guide rail is required before a flare. For an impact attenuator, the transition to W-beam guide rail varies per manufacturer.

Note 2 Recommended flare rates are obtained from **Table 13.**

Figure 11 – Example of W-beam Guide Rail Treatment in Gore Area

9. Guide Rail Details

The dimensions and other characteristics of W-beam guide rail, box beam guide rail and modified thrie beam guide rail posts, rail elements, fasteners, etc., are shown in the *Traffic Engineering Standard Details*.

10. Other Design Considerations

Other design considerations for guide rail design are as follows:

- Guide rail should not restrict sight distance. Sight distances should be checked where the guide rail is to be installed at intersections, ramp terminals, driveways, along sharply curving roadways, etc. If the sight distance is determined to be inadequate, the guide rail placement should be adjusted where feasible.
- Wherever part of an existing guide rail run is lengthened, reset or upgraded, the entire run where practical shall be upgraded to current standards including the bridge attachments.
- Gaps of 200 feet or less between individual guide rail installations should be avoided where possible.
- Where existing driveways are located within the length of need and cannot be relocated, appropriate end treatments should be used at the driveway opening as shown in **Figure 17**.
- Proposed W-beam guide rail set flush with the curb line along intersection radius returns should be checked with a truck turning template. Existing W-beam guide rail or box beam guide rail along radius returns that experience truck overhang or oversteering crashes shall either be reset farther from the curb line or redesigned to provide a radius for a larger design vehicle.
- End treatments on contract drawings may be located by providing a dimension from physical objects such as the lateral offset from edge of pavement or by station and offset.
- The grading work necessary for the construction of the guide rail end treatments shall be shown on the contract drawings. Where the approach slope is steeper than 4H:1V, the grading treatment for tangent terminals shown in **Figure 6** is required.
- Where guide rail posts conflict with a below grade rock line, the method of drilling holes in rock for post embedment is shown in **Figure 18** and **Figure 19**.
- In parking lots, W-beam Barricade Type A and Type B may be used to delineate boundaries or serve as a barricade in front of critical infrastructure such as electrical hardware. In these cases, the roadside design guidelines contained herein do not apply. W-beam barricades are not considered roadside barriers. The designer should use this Design Guide and the *Traffic Engineering Standard Details* in conjunction with engineering judgment to develop an appropriate design.
- Where the downstream guide rail is flared toward the roadway, the recommended flare rate is shown in **Table 13.**

- Where curb 2 inches in height at guide rail end treatments and W-beam omitted posts is transitioned to other curb heights, a 10’ curb transition is typically used. A typical detail of 2-inch curb is shown in **Figure 12**.

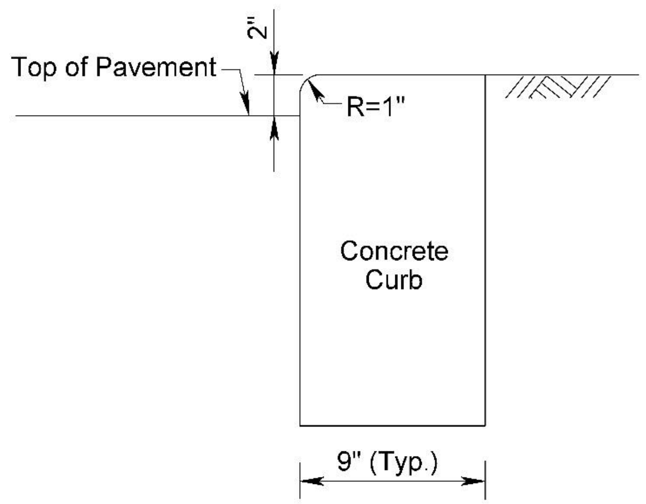


Figure 12 – Typical Detail of Curb 2 Inches in Height

11. Underground Conflicts

Where there is a conflict between a W-beam post and an inlet or underground obstruction (utility, pipe, etc.), W-beam guide rail may be attached to a concrete pad, multiple blockouts may be used, or one, two or three posts may be omitted to avoid the conflict. Where a box beam guide rail post conflict occurs, post spacing may be increased. Roadside concrete barrier may also be used in lieu of guide rail to avoid guide rail post conflicts.

a. Concrete Pad

Where W-beam guide rail is attached to a concrete pad, reduced post spacing and double rail element is required along the attachment and on the approach to the concrete pad attachment. A minimum 8-inch-thick concrete pad is required. See *Traffic Engineering Standard Details*.

b. Multiple Blockouts

Two 8-inch blockouts (total blockout depth of 16 inches) may be provided at each W-beam post. A combination of blockouts up to a total blockout depth of 24 inches (three 8 inch or two 12 inch) may be used, but this combination is limited to only one post in any 75 feet of W-beam guide rail. Multiple blockouts are not permitted within the limits of guide rail terminals.

c. Omitting One W-Beam Post

Where one post is omitted (a 12’-6” unsupported span), the clear area free of obstructions behind the guide rail is increased to 5 feet. Where there is curb, the maximum curb height is 2 inches in advance of and on the trailing end of the omitted post. Curb restrictions and additional criteria for an omitted post are shown on **Figure 13**.

Where it is necessary to eliminate a post to avoid a conflict with an inlet, manhole, underground utility or underground structure, the following apply:

- A minimum of 56.25 feet (nine 6’-3” post spaces) between two consecutive post omissions.
- The omitted post must be a minimum of 62.5 feet (ten 6’-3” post spaces) from the approach end of a tangent terminal and 31.25 feet (five 6’-3” post spaces) from the beginning of a flare or reduced post spacing.
- An omitted post must be a minimum of 62.5 feet (ten 6’-3” post spaces) from the last post of an end anchorage.
- The omitted must be a minimum of 37.5 feet (six 6’-3” post spaces) from the upstream end of a thrie beam to W-beam asymmetrical transition.
- The omitted post must be at least 43.25 feet (seven 6’-3” post spaces) from an outer CRT post of an 18’-9” or 25-0”’ unsupported span.
- Fixed objects within the limits of the unsupported span must be a minimum of 5 feet behind the face of rail as shown in **Figure 13**.
- Where there is curb within the unsupported span with one omitted post, 2-inch curb height shall be used. The 2-inch curb height shall extend a minimum of 18’-9” on both the approach and trailing end of the omitted post
- The location of a proposed 12’-6” unsupported span shall be shown on the contract drawings.

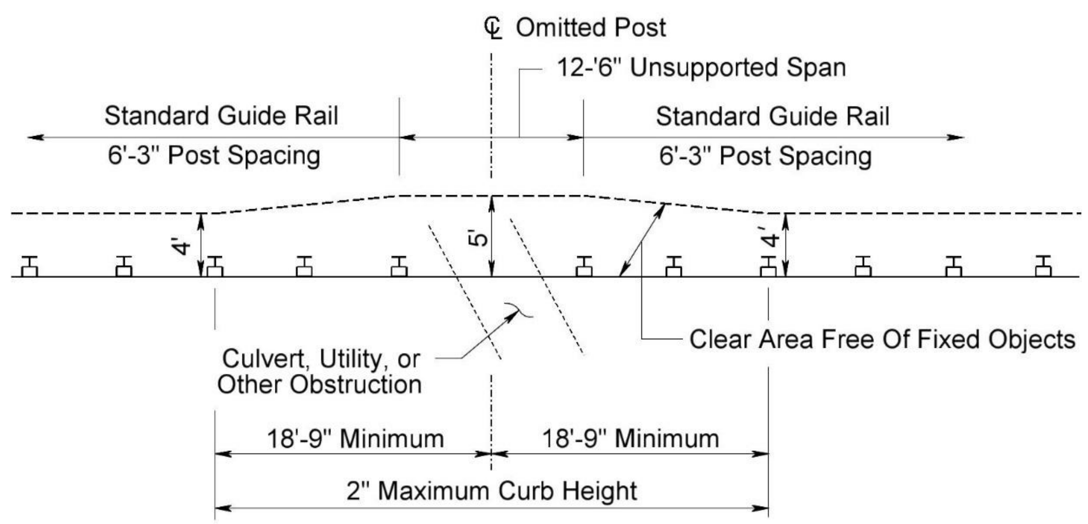


Figure 13 – W-Beam Guide Rail with One Omitted Post

d. Omitting Two or Three W-Beam Posts

Where two or three posts are omitted, the clear area free of obstructions behind the guide rail is increased to 7 feet for a two post omission (an 18’-9” unsupported span) and to 8 feet for a three post omission (a 25’-0” unsupported span). In addition, three modified CRT posts with blockouts are required on the approach and trailing end of the unsupported span as shown in **Figure 14**. Where there is curb, the maximum curb height is 2 inches in advance of and on the trailing end of the omitted posts. Curb restrictions and additional criteria for omitting two or three posts are shown in **Figure 15**.

Where it is necessary to eliminate two or three posts to avoid an inlet or underground structure the following apply:

- A minimum of 62.5 feet (ten 6’-3” post spaces) of tangent guide rail is required between the outer CRT posts of consecutive unsupported spans.
- The outer CRT posts must be a minimum of 62.5 feet (ten 6’-3” post spaces) from the approach end of a tangent terminal.
- The outer CRT posts must be a minimum of 50 feet (eight 6’-3” post spaces) from the beginning of a guide rail flare.
- The outer CRT posts must be a minimum of 62.5 feet (ten 6’-3” post spaces) from the last post of an end anchorage.
- The outer CRT posts must be a minimum of 37.5 feet (six 6’-3” post spaces) from a thrie beam to W-beam asymmetrical transition section.
- Fixed objects within the limits of the unsupported spans shall be a minimum of 7 feet behind the face of rail for an unsupported length of 18’-9” and 8 feet for an unsupported span length of 25’-0”.
- Where there is curb within the unsupported span with two or three omitted posts, 2-inch curb height shall be used. The 2-inch curb height should begin a minimum of 25 feet in advance of the first CRT post on the approach end and continue for a minimum of 25 feet past the last CRT post on the trailing end as shown in **Figure 15**.
- If the unsupported span is over a culvert, the culvert headwalls shall not extend more than 2 inches above the ground line.
- If there is a foreslope behind the CRT posts on either side of the unsupported length, a minimum of 2 feet must be provided between the back of post and the slope break of the foreslope.
- If there is a vertical drop off behind the unsupported span, the face of rail must be a minimum of 3 feet from the drop off.
- The location and length of a proposed 18’-9” or 25’-0” unsupported span including the modified CRT post detail shall be shown on the contract drawings.

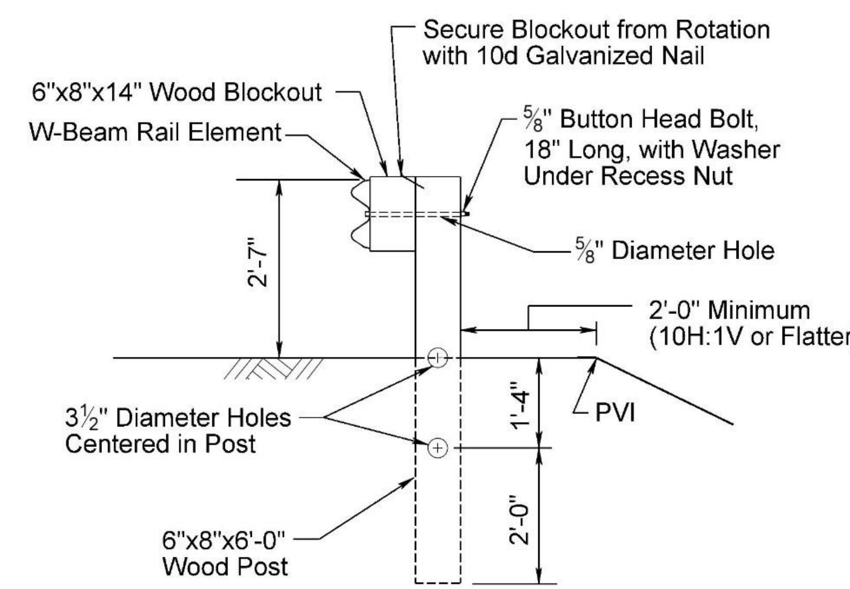
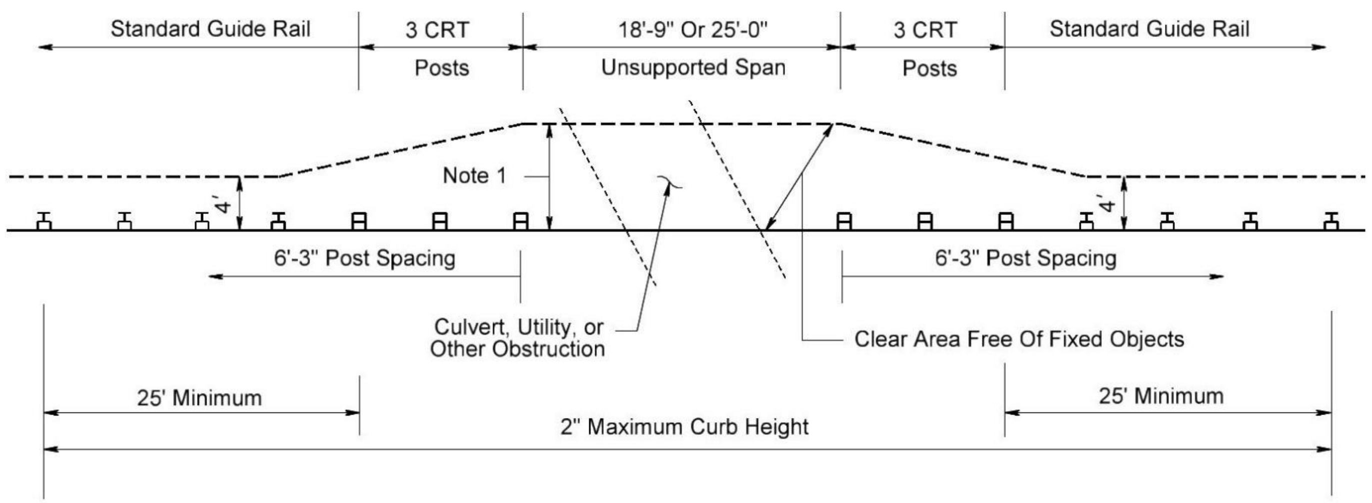


Figure 14 – Modified CRT Post with Blockout



Note 1 The required clear area free of fixed objects is 7 feet for an 18'-9" unsupported span and 8 feet for a 25'-0" unsupported span.

Figure 15 – W-Beam Guide Rail with Two or Three Omitted Posts

e. Box Beam Increased Post Spacing

Where box beam guide rail posts conflict with an obstruction as shown in **Figure 16**, post spacing may be increased as follows:

- Where a box beam rail splice is located within the increased post spacing, the post spacing may be increased to 8 feet.
- Where a box beam rail splice is not located within the increased post spacing, the post spacing may be increased to 10 feet.

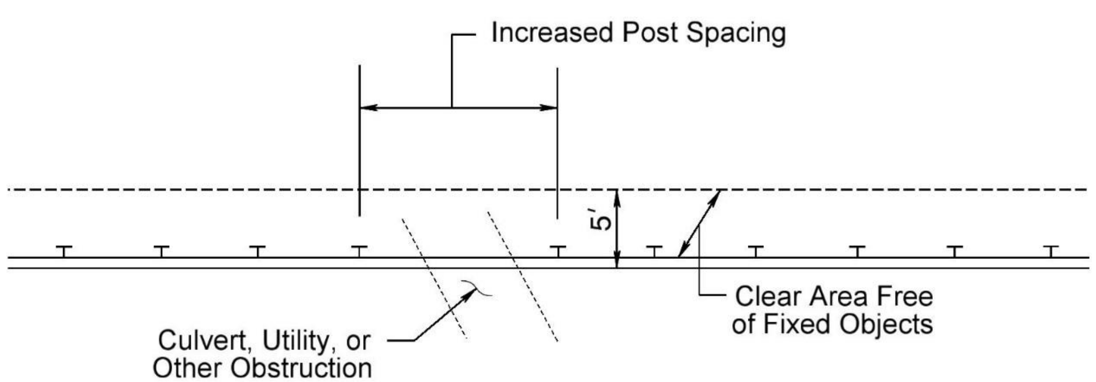
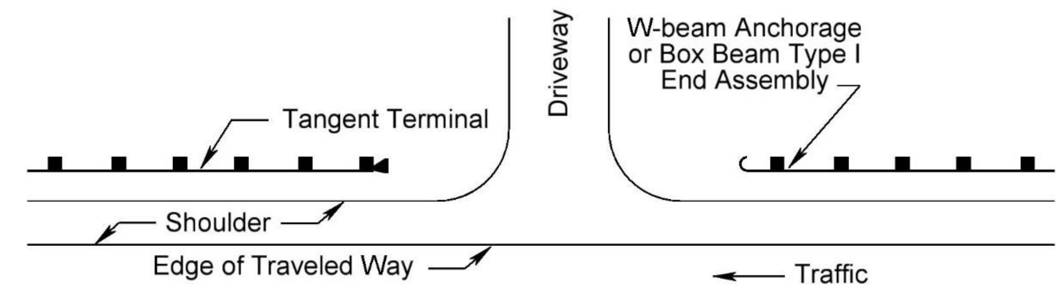


Figure 16 – Box Beam Increased Post Spacing at Obstructions



Note 1 If the W-beam anchorage or the box beam Type I End Assembly is within the clear zone of opposing traffic, see **Figure 9**.

Figure 17 - Guide Rail Treatment at Driveways within the Length of Need

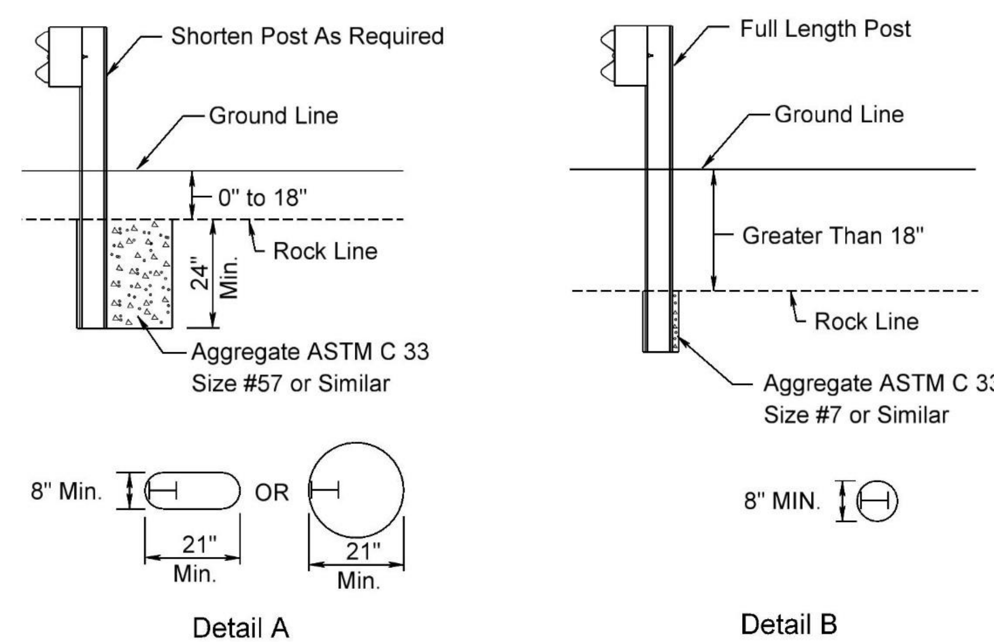


Figure 18 – W-Beam Guide Rail Post in Rock

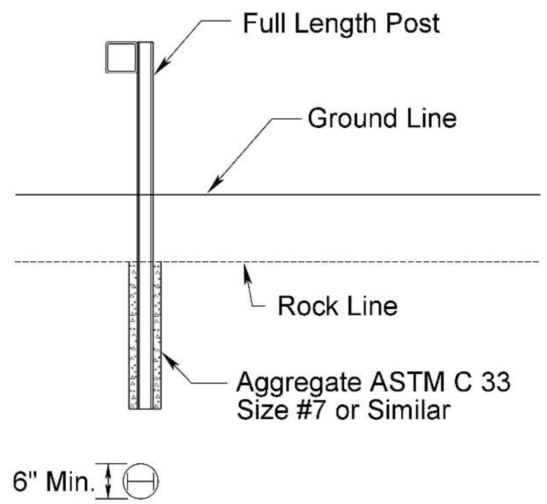


Figure 19 – Box Beam Guide Rail Post in Rock

f. Concrete Barrier

Roadside concrete barrier may be used in lieu of guide rail where guide rail post conflicts occur. The approach end of concrete barrier shall be terminated with either an impact attenuator or an attachment to guide rail as shown in the *Traffic Engineering Standard Details*.

12. Nonvegetative Surface Under Guide Rail

In order to reduce soil erosion and reduce maintenance associated with herbicides or trimming vegetation underneath guide rail, nonvegetative surfaces may be constructed underneath the guide rail where desired. Salt splash and asphalt are commonly used as nonvegetative surfaces. Suggested limits of nonvegetative surface are shown in the *Traffic Engineering Standard Details.*

For W-beam guide rail, a leave out in the nonvegetative surface may be required depending on the type of nonvegetative surface used. Leave outs are required for W-beam guide rail where non-porous asphalt 4 inches or greater in thickness is used as a nonvegetative surface. Leave outs are not required for W-beam guide rail where porous asphalt or salt splash is used as a nonvegetative surface. The leave out is a 15-inch diameter round or a 15-inch square opening in the non-porous asphalt nonvegetative surface around the guide rail post as shown in the *Traffic Engineering Standard Details*.

Where leave outs are required for W-beam guide rail, they should be filled with low strength concrete mix (flowable fill) with a 28-day compressive strength not to exceed 120 psi.

Leave outs are not required for box beam guide rail or modified thrie beam guide rail.

See the *Traffic Engineering Standard Details* for additional nonvegetative surface details.

13. Concrete Barrier

Concrete barrier should be considered for roadside barrier applications where minimal deflection is desired and/or where a higher test level is desired to protect critical infrastructure (overhead sign supports, electrical hardware, etc.) Full section concrete barrier 42 inches high is considered MASH TL-5 compliant.

Where concrete barrier is used as a roadside barrier it should be located flush with the edge of pavement. The approach end of concrete barrier shall be protected with an impact attenuator or transitioned to W-beam or box beam guide rail in accordance with the *Traffic Engineering Standard Details*. For transitioning to W-beam guide rail, attachment Type A shall be used on the approach end of all roadside concrete barriers and on the trailing end of roadside barriers that are within the clear zone of opposing traffic. Attachment Type B is used for W-beam guide rail attachments on the trailing end of roadside concrete barriers that are outside the clear zone of opposing traffic, or where the trailing end is separated from the opposing traffic by a non-traversable median. For transitioning from concrete barrier to box beam see *Traffic Engineering Standard Details*.

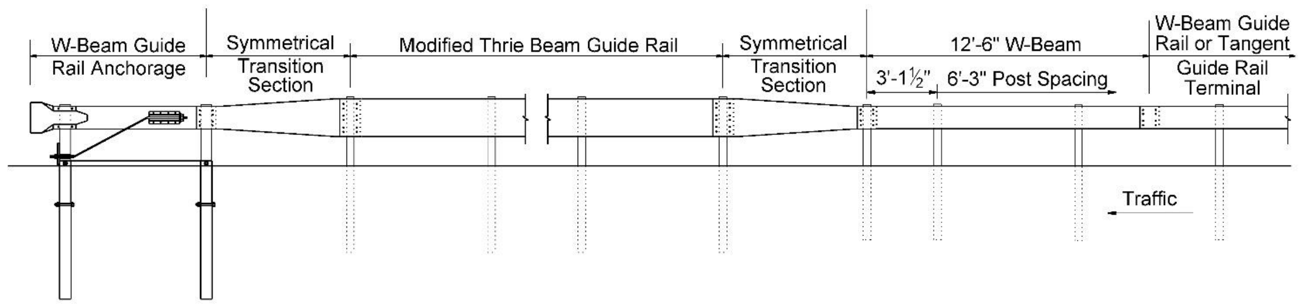
14. Coordination with the Civil Discipline

The designer shall provide the following information to the Civil Discipline for inclusion in the Civil contract drawings:

- The limits and the proposed curb type and height adjacent to guide rail in accordance with **Section II.C.2** “Curb or Raised Berm in Front of Guide Rail”
- Grading information at tangent guide rail terminals in accordance with **Section II.C.6** “Cross Slopes” and **Figure 6**
- The limits of 2-inch curb height for unsupported spans in accordance with **Section II.C.11** “Underground Conflicts”
- The limits of 2-inch curb height for the approach to tangent terminals in accordance with **Section II.D.1** “W-beam Tangent Guide Rail Terminal”, **Section II.D.2** “Box Beam Tangent Guide Rail Terminal” and **Table 9**
- The limits of 2-inch curb height for W-beam anchorages in accordance with **Section II.D.5** “Guide Rail Trailing End Treatments” and **Table 11**
- The location and length of curb transitions relative to guide rail design
- The location and length of concrete barrier to curb transitions

D. End Treatments

An approach end treatment is required if the approach end of the guide rail terminates within the clear zone. Where modified thrie beam is used, a thrie beam to W-beam symmetrical transition section as shown in **Figure 20** is required to transition to the W-beam end treatments.



Note 1 The minimum length of W-beam guide rail required between the symmetrical transition section and a tangent terminal is 12'-6".

Figure 20 – Modified Thrie Beam to W-Beam Transition at End Treatments

1. W-Beam Tangent Guide Rail Terminal

A W- beam tangent guide rail terminal is an approach end terminal for W-beam guide rail installations terminating within the clear zone. The MASH compliant W-beam tangent terminals approved for use on roadways within the Port Authority's jurisdiction are as follows:

- The TL-2 MSKT-SP-MGS for design speeds less than or equal to 45 MPH
- The TL-3 MSKT-SP-MGS for design speeds greater than 45 MPH

Where W-beam guide rail downstream of the tangent terminal is placed greater than 1 foot from the edge of pavement, the tangent terminal can be constructed parallel to the roadway without an approach end offset. Where W-beam guide rail downstream of the tangent terminal is placed 1 foot or less from the edge of pavement, a W-beam tangent terminal shall be constructed with a straight taper and offset so that the impact head does not protrude into the roadway (see *Traffic Engineering Standard Details*).

A tangent terminal offset is defined as the increase in distance from the guide rail offset from the edge of pavement downstream of the tangent terminal as compared to the guide rail offset at tangent terminal post #1. The offset of the guide rail at post #1 of the tangent terminal shall be shown on the contract drawings.

Options for tapering a W-beam tangent terminal are as follows:

- A straight taper for the 25-foot length of a TL-2 W-beam tangent terminal for a 1 foot tangent terminal offset
- A straight taper for the 50-foot length of a TL-3 W-beam tangent terminal for a 2 foot tangent terminal offset

Additional design guidance for W-beam tangent terminals is as follows:

- The W-beam tangent terminal taper length and offset from the edge of pavement at post #1 shall be shown on the contract drawings.
- Where feasible, a roadside recovery area should be provided behind a W-beam tangent guide rail terminal installation (see **Section II.C.7**, "Roadside Recovery Area").
- Where a W-beam tangent terminal is proposed on the approach to a Type A bridge attachment, the minimum distance between the bridge attachment and the terminal is shown in **Figure 3.**
- The approach end of the W-beam tangent terminal shall be placed a minimum distance of 12.5 feet beyond the length of need as shown in **Figure 8**.
- Where a W-beam tangent guide rail terminal is installed along a horizontal curve, see **Figure 22, Figure 23,** and **Section II.D.3**.
- The maximum curb height for new construction along the length of the tangent terminal and in advance of the terminal varies based on offset and posted speed as shown in **Table 9** (see **Figure 21**, **Figure 22**, and **Figure 23**). Replacement of existing curb in accordance with this guidance should be considered.
- Reduced post spacing shall not be used within the length of a TL-2 or TL-3 W-beam tangent terminal.
- See **Figure 6** for grading treatment at tangent terminals.

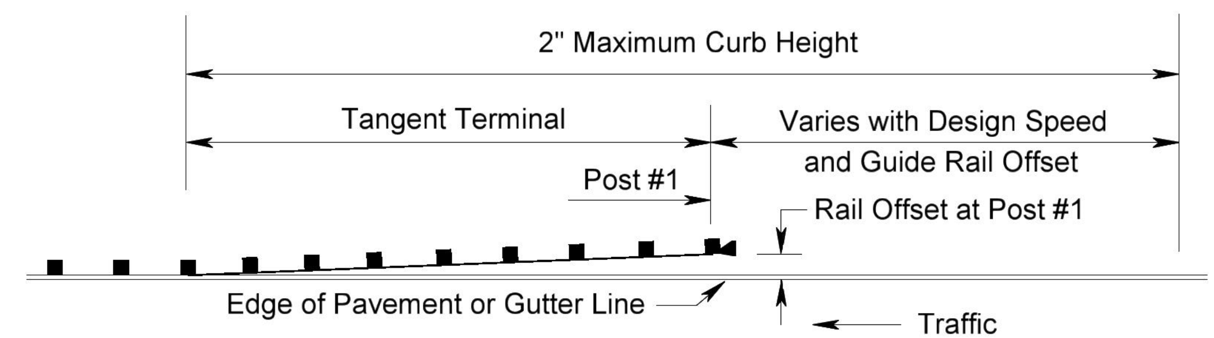


Figure 21 – Tangent Guide Rail Terminal on Tangent Roadways

Table 9 Maximum Curb Height at W-beam and Box Beam Tangent Guide Rail Terminals for New Construction			
Terminal Approach End Offset from Gutter Line	**Maximum Curb Height Design Speed > 45 MPH**	**Maximum Curb Height Design Speed ≤ 45 MPH**	**Minimum Length of Curb Height Restriction in Advance of a Terminal**
0' to 2'	2"	2"	30'
2.5' to 3.5'	2"	2"	35'
4' to 5'	2"	4"	40'
6' to 7'	2"	4"	50'
8' to 10'	2"	4"	60'
> 10'	2"	4"	75'

2. Box Beam Tangent Guide Rail Terminal

A box beam tangent guide rail terminal is an approach end terminal for box beam guide rail installations terminating within the clear zone.

Where box beam guide rail downstream of the tangent terminal is placed greater than 1 foot from the edge of pavement, the tangent terminal can be constructed parallel to the roadway without an approach end offset. Where box beam guide rail downstream of the tangent terminal is placed 1 foot or less from the edge of pavement, a box beam tangent terminal shall be constructed with a 50' straight taper and offset so that the impact head does not protrude into the roadway (see *Traffic Engineering Standard Details*).

A tangent terminal offset is defined as the increase in distance from the guide rail offset from the edge of pavement downstream of the tangent terminal as compared to the guide rail offset at tangent terminal post #1. The offset of the guide rail at post #1 of the tangent terminal shall be shown on the contract drawings. Where a taper and offset is used, the box beam tangent terminal shall be constructed with a 2-foot offset at post #1 as shown in the *Traffic Engineering Standard Details*.

Additional design guidance for box beam tangent terminals is as follows:

- The box beam tangent terminal taper length and offset at post #1 shall be shown on the contract drawings.
- Where feasible, a roadside recovery area should be provided behind a box beam tangent guide rail terminal installation (see **Section II.C.7**, "Roadside Recovery Area").
- The approach end of a box beam tangent terminal shall be placed a minimum distance of 15.5 feet beyond the length of need (see **Figure 8, Figure 9,** and **Figure 10**).
- Where a box beam tangent terminal is installed along a horizontal curve, see **Figure 22, Figure 23,** and **Section II.D.3**.
- The maximum curb height for new construction along the length of the box beam tangent terminal and in advance of the terminal varies based on offset and posted speed as shown in **Table 9** (see **Figure 21, Figure 22,** and **Figure 23**). Replacement of existing curb in accordance with this guidance should be considered.
- See **Figure 6** for grading treatment at tangent terminals.

The Box beam tangent terminal approved for use is the 30-foot long MASH compliant MBEAT.

3. Tangent Guide Rail Terminals on Horizontal Curves

On horizontal curves, the tangent terminal offset is measured relative to the downstream guide rail offset. **Figure 22** shows guide rail on the outside of a curve and **Figure 23** shows guide rail on the inside of a curve. The rail offset at post #1 shown in **Figure 22** and **Figure 23** is determined by the downstream guide rail offset. For example, for a 2-foot offset for a W-beam TL-3 tangent terminal, the rail offset at post #1 would be the downstream guide rail offset plus 2 feet. The downstream guide rail offset and the rail offset of the tangent terminal at post #1 shall be shown on the contract drawings. The tangent terminal is constructed in a straight line. It does not follow the horizontal curve.

On outside horizontal curves, the designer must graphically confirm that the tangent terminal does not encroach into the roadway. This may occur where the downstream guide rail offset and radius are minimal. In no case shall the rail offset at post #1 be greater than the downstream guide rail offset plus the straight taper offset. If it is determined that a tangent terminal is encroaching into the roadway, options include increasing the downstream offset and/or continuing the downstream guide rail to a tangent or flatter curve.

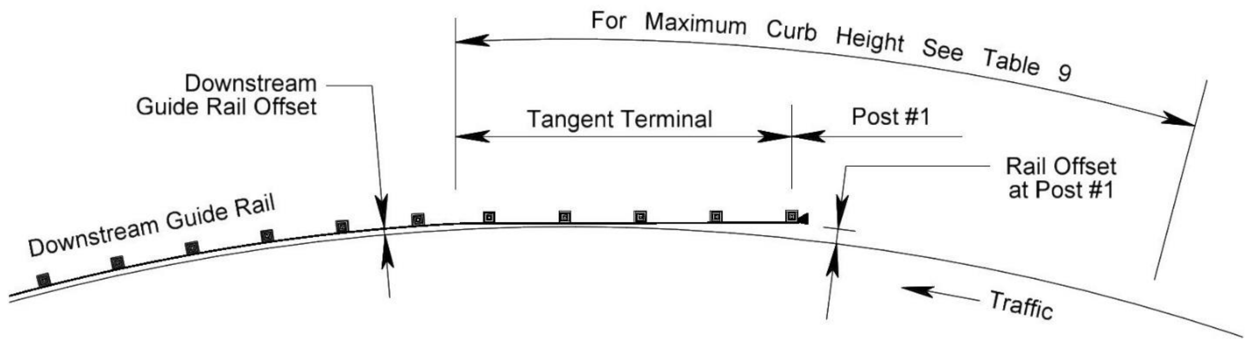


Figure 22 – Tangent Guide Rail Terminal on an Outside Horizontal Curve

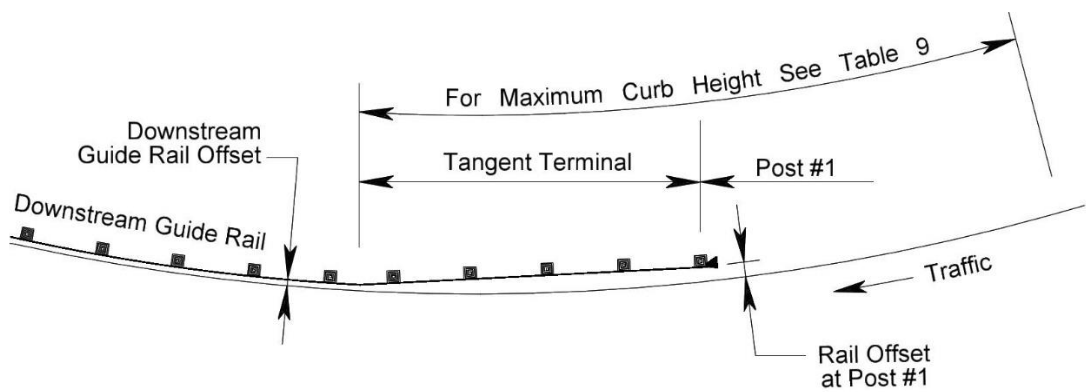


Figure 23 – Tangent Guide Rail Terminal on an Inside Horizontal Curve

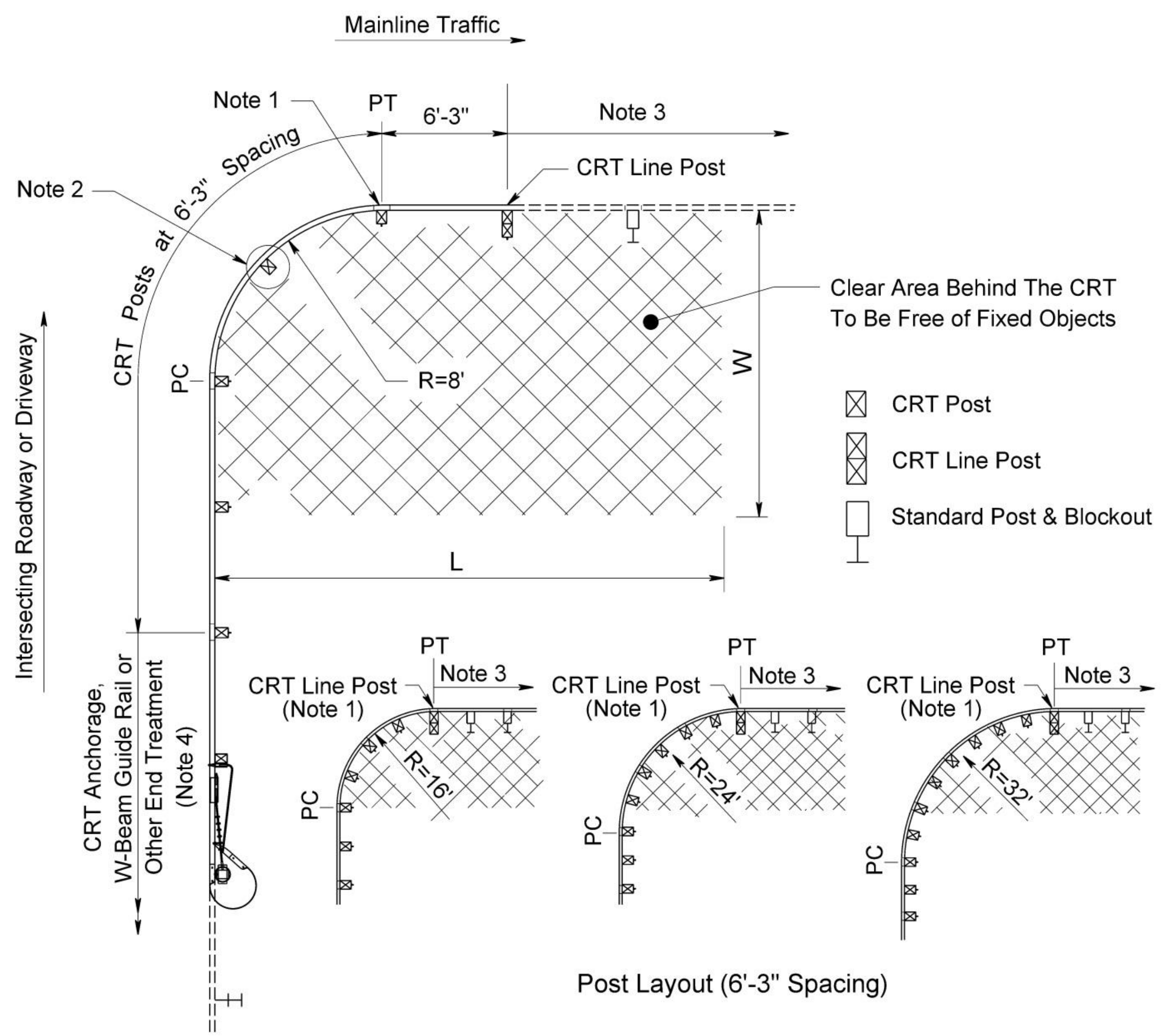
4. W-Beam Controlled Release Terminal (CRT)

Where an intersection is located near an obstruction and there is insufficient length to construct a W-beam tangent terminal, a Controlled Release Terminal may be used as shown in **Figure 24**. The clear area behind the CRT shall be free of any obstructions and graded 2H:1V or flatter. A raised berm in front of a CRT must be 10H:1V or flatter. Where there is curb in front of the CRT, the curb shall be no higher than 2 inches. This guide rail treatment should not be used where sidewalk is located behind the guide rail.

The required area free of fixed objects and the number of CRT posts for various radii is provided in **Table 10**. The radii shown assume a 90-degree intersection to provide an arc length evenly divisible by the rail element length of 12’-6”. If the intersection is significantly greater or less than 90 degrees, the designer should calculate the radius required to provide an arc length equal to or in multiples of 12’-6” so that only full sections of w-beam rail elements will be shop bent. See *Traffic Engineering Standard Details* for CRT post, CRT line post and anchorage details. The CRT is NCHRP 230 approved.

Table 10
W-Beam Controlled Release Terminal

Radius	Number of CRT Posts	Required Area Free of Fixed Objects (L x W)
8’	5	25’ x 15’
16’	6	30’ x 15’
24’	8	40’ x 20’
32’	10	50’ x 20’



Note 1 A rail splice is located at the PT of the curved section.

Note 2 When the curved section of guide rail is one 12’-6” section, the rail element is not bolted to the CRT post at the center of the 12’-6” curved section.

Note 3 The CRT rail mounting height is 2’-3¼”. A 25-foot minimum vertical transition to standard W-beam guide rail with a 2’-7” mounting height is required. See *Traffic Engineering Standard Details* for the vertical transition detail.

Note 4 If the intersecting roadway posted speed is greater than 25 MPH, use a W-beam tangent terminal. Otherwise, a Controlled Release Terminal Anchorage should be used. See *Traffic Engineering Standard Details*.

Figure 24 – W-Beam Controlled Release Terminal (CRT)

5. Guide Rail Trailing End Treatments

An approach end treatment is not required for:

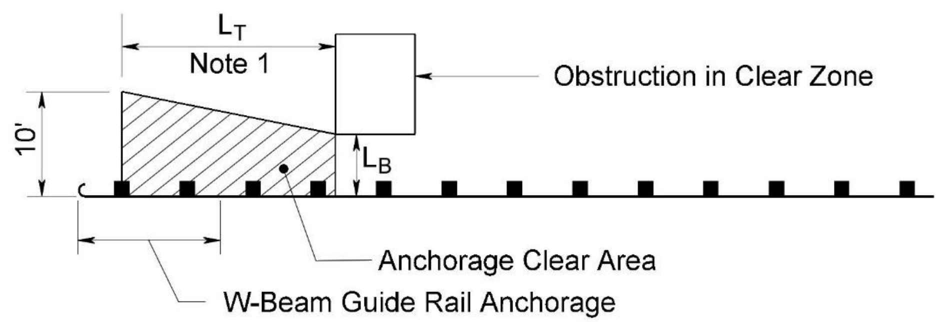
- A trailing end of guide rail on a one-way roadway
- A trailing end of guide rail on a divided roadway with a non-traversable median
- An approach end of guide rail that is located behind another barrier (e.g., the trailing end of concrete barrier)

Where one of these conditions exists, the following applies:

- W-beam guide rail installations should be terminated with a W-beam Guide Rail Anchorage (see *Traffic Engineering Standard Details*). W-beam guide rail terminating with an anchorage on the trailing end should extend beyond the obstruction as shown in **Figure 25**. The maximum curb height for new construction along the length of the anchorage varies based on offset and posted speed as shown in **Table 11**. Replacement of existing curb in accordance with this guidance should be considered.
- Box beam guide rail should be terminated with a Type I End Assembly or a Buried End Treatment (see *Traffic Engineering Standard Details*). Box beam guide rail should extend past the obstruction so that no part of the trailing end treatment is in front of the obstruction.

Table 11
Maximum Curb Height at a W-Beam Guide Rail Anchorage for New Construction

Anchorage Offset from Gutter Line	Maximum Curb Height Design Speed > 45 MPH	Maximum Curb Height Design Speed ≤ 45 MPH
<4’	2”	2”
≥4’	2”	4”



Note 1 Where a W-beam guide rail anchorage is used to terminate guide rail past an obstruction, the guide rail should be extended so that the obstruction is outside of the anchorage clear area. The distance from the last post of the anchorage to the obstruction (L_T) shall not be less than 12'-6". See **Table 12.**

Figure 25 – W-Beam Guide Rail Anchorage Clear Area

Table 12
W-Beam Guide Rail Anchorage Clear Area

Distance from Face of Rail to Obstruction (L_B)	Minimum Distance from Last Post of the Anchorage to the Obstruction (L_T)
2.5' or less	37.5'
3'	35'
4'	30'
5'	25'
6'	20'
7'	15'
7.5' or greater	12.5'

Table 13
Recommended Flare Rates for Guide Rail and Concrete Barrier

Design Speed (mph)	Guide Rail	Concrete Barrier
60	14:1	18:1
55	12:1	16:1
50	11:1	14:1
45	10:1	12:1
40	8:1	10.1
30	7:1	8:1

SOURCE: Chapter 5, "Roadside Barriers", *Roadside Design Guide, AASHTO, 4th Edition, 2011*

6. Existing Extruder Terminals (ET-2000, ET-2000 PLUS, ET PLUS), Slotted Rail Terminal (SRT), Breakaway Cable Terminal (BCT), Eccentric Loader Terminal (ELT), Box Beam Buried End, Box Beam End Assembly Type I, Type II, or Type IIA Installed as an Approach End Treatment

Any existing ET-2000, ET-2000 PLUS, ET PLUS, SRT, BCT, ELT, Box Beam Buried End, or Box Beam End Assembly Type I, Type II or Type IIA installed as an approach end treatment shall be replaced with an approved end treatment in accordance with this Design Guide as follows:

- An ET-2000, ET-2000 PLUS, ET PLUS, SRT, BCT, ELT, Box Beam Buried End, or a Box Beam End Assembly Type I, Type II or Type IIA that must be replaced due to crash damage shall be replaced.
- An ET-2000, ET-2000 PLUS, ET PLUS, SRT, BCT, ELT, Box Beam Buried End, or Box Beam End Assembly Type I, Type II, or Type IIA installed within the clear zone shall be replaced in conjunction with roadway work in the same area.

7. Roadside Concrete Barrier End Treatment

Where the approach end of concrete barrier terminates within the clear zone, an impact attenuator or a transition to guide rail in accordance with the *Traffic Engineering Standard Details* shall be used.

Where roadway curb meets concrete barrier at the trailing end or at the approach end of a guide rail attachment to concrete barrier, a 10' curb transition should be provided to transition the roadway curb face to the barrier shape.

III. Median Barrier

A. Median Barriers Warrants

A median barrier is a longitudinal barrier system used to prevent an errant vehicle from crossing that portion of a divided highway separating traveled ways for traffic in opposite directions.

1. Limited Access Roadways

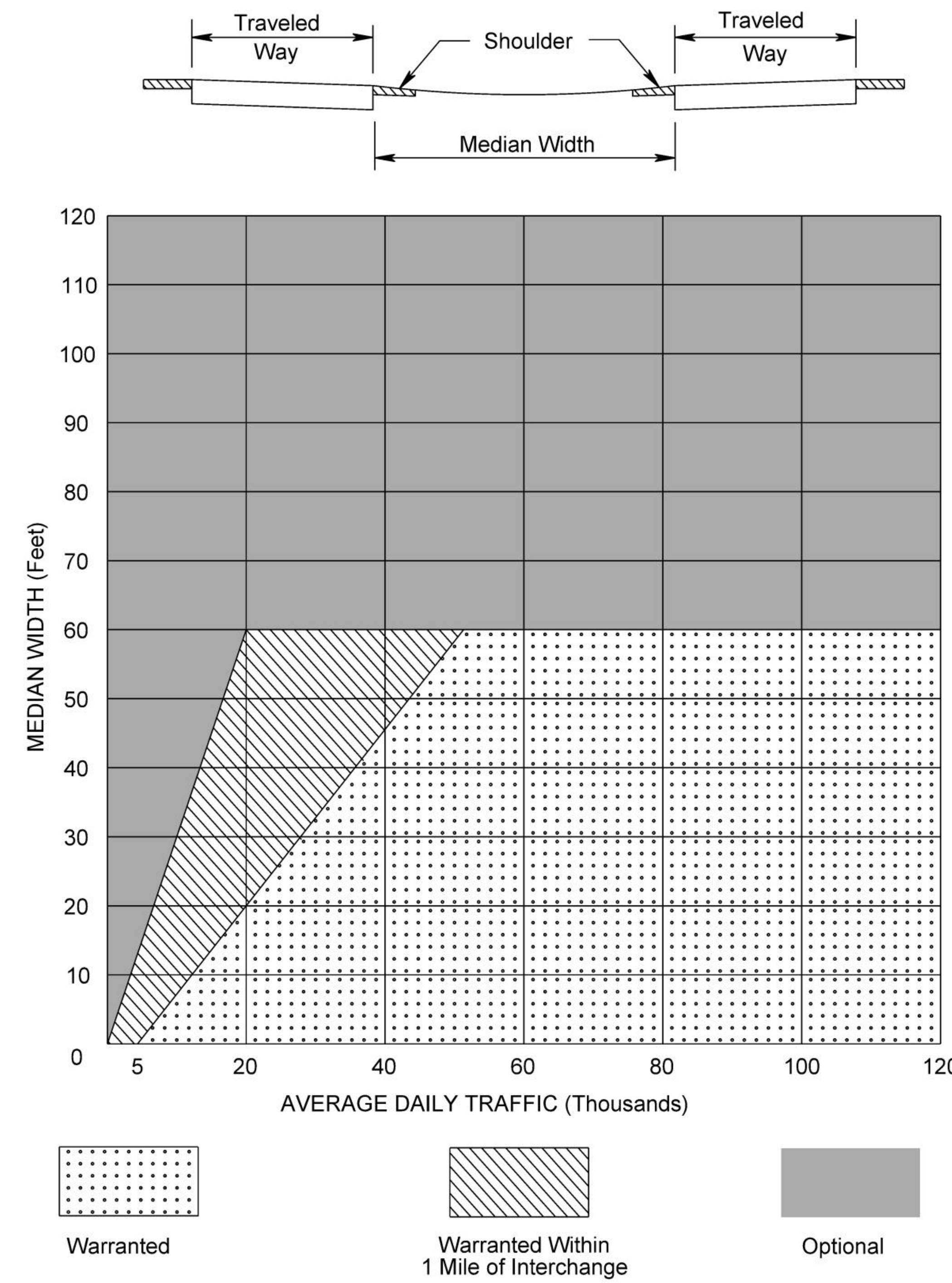
The warrants for median barriers on high speed, access-controlled roadways with traversable slopes 10H:1V or flatter are shown in **Figure 26**.

When the need for a median barrier is determined to be optional from **Figure 26** an evaluation of the cross median crash history should be made to determine if a median barrier is warranted regardless of the median width and volume. The warrant for a median barrier based on crash history should meet one of the following conditions. These criteria require a minimum of three crashes occurring within a 5-year period.

- 0.50 cross median crashes per mile per year of any crash severity
- 0.12 fatal cross median crashes per mile per year

Research of cross median crashes indicates that crashes are more likely to occur within one mile of an interchange and this factor has been included as a median barrier warrant in **Figure 26**.

Figure 26 depicts the relationship of low ADT's to median widths less than 60 feet to determine if a median barrier is warranted. For example, if the median width is 60 feet or less and the ADT is greater than 50,000 a median barrier is warranted. At low ADT's, the probability of a vehicle crossing the median is relatively small. Thus, for ADT's less than 20,000 and median widths within the optional areas of **Figure 26**, a median barrier is warranted only if there has been a history of cross-median crashes. Likewise, for relatively wide medians the probability of a vehicle crossing the median is also low. Thus, for median widths greater than 60 feet and within the optional area of **Figure 26**, a median barrier may or may not be warranted, again depending on the cross-median crash history.



SOURCE: Section 8, "Guide Rail Design and Median Barriers", *Roadway Design Manual,* NJDOT

Figure 26 – Median Barrier Warrants for High Speed Access Controlled Roadways

2. **Access Permitted Roadways**

Careful consideration should be given to the installation of median barriers on access permitted roadways or other roadways with partial control of access. Problems are created at each intersection or median crossover because the median barrier must be terminated at these points.

An evaluation of the number of crossovers, crash history, alignment, sight distance, design speed, traffic volume and median width should be made before installation of median barriers on access permitted roadways. Each location should be looked at on a case-by-case basis. If the crash history meets either of the conditions listed above for limited access roadways, a median barrier should be installed. For the clear zone for median cross over protection on access permitted roadways, see **Table 1**.

B. Median Barrier Types

Median barriers approved for use are as follows:

- Box Beam Median Barrier (MASH TL-3)
- Dual Faced W-Beam Guide Rail (MASH TL-3)
- Dual Faced Modified Thrie Beam Guide Rail (MASH TL-3)
- 42” F Shape Concrete Barrier (MASH TL-5)
- 42” Single Slope Concrete Barrier (MASH TL-5)

Median barrier type, where warranted, is related to median width (distance between the edge of the traveled way of opposing lanes). Suggested median barrier types relative to the median width are shown in **Table 14.**

Table 14
Median Width vs. Median Barrier Type

Median Width	Median Barrier Type
12 feet or less	Concrete Barrier
over 12 feet to 26 feet	Concrete Barrier Dual Faced W-beam Guide Rail Dual Faced Modified Thrie Beam Guide Rail Box Beam Median Barrier
greater than 26 feet	Dual Faced W-beam Guide Rail Dual Faced Modified Thrie Beam Guide Rail Box Beam Median Barrier

Where the approach end of guide rail or concrete barrier is tapered, recommended flare rates are shown in **Table 13**.

1. **Median Guide Rail**

Where median guide rail is proposed, it is recommended to use dual faced modified thrie beam guide rail, in lieu of dual faced W-beam guide rail or box beam median barrier where one of the following occurs:

- There are 12 percent or more trucks in the project area
- The traffic volume is greater than 15,000 vehicles per lane (i.e., 4 lane section > 60,000 AADT)
- The horizontal radius of the roadway is less than 3000 feet
- There is a split profile with 6H:1V side slopes or steeper creating opposing roadways with different elevations
- Where median guide rail is placed flush with the edge of an inside shoulder 5 feet or less in width

2. **Median Concrete Barrier**

Where a wide concrete barrier is used to accommodate lighting poles or overhead signs structures, or where there is a split profile, a variable width concrete barrier may be used (see *Traffic Engineering Standard Details*).

Where piers in the median are directly behind proposed concrete median barrier, a transition from 42” to 54” concrete barrier in the vicinity of the piers should be considered. AASHTO’s *Load Resistance Factor Design Bridge Design Specifications (LRFD)* recommends that bridge piers within 30 feet of the traveled way be designed to withstand a 600 kip impact load or be shielded with a 54” high barrier located 10 feet or less from the pier or a 42” high barrier located more than 10 feet from the pier. Additional information is provided in AASHTO’s *Roadside Design Guide, 4th Edition (Section 5.5.2)*.

C. End Treatments

1. **Median Guide Rail**

a. General

Where terminating the approach end of dual faced W-beam guide rail, dual faced modified thrie beam guide rail, or box beam median barrier within the clear zone, a crashworthy end treatment shall be used.

A median guide rail end terminal shall be installed on a 10H:1V or flatter cross slope. Where there is curb in the direction of approaching traffic, maximum curb height along the length of the median guide rail end terminal and in advance of the median guide rail end terminal shall be in accordance with **Table 9**.

b. Box Beam Median Barrier

A box beam median barrier tangent terminal shall be used where box beam median barrier is terminated within the median. The box beam median barrier tangent terminal approved for use is the 32-foot Bursting Energy Absorbing Terminal (BEAT-MT). The terminal is NCHRP 350 approved. Where terminating the trailing end of box beam median barrier separating same direction traffic, an End Treatment Type A should be used (See *Traffic Engineering Standard Details).*

c. Dual Faced W-Beam or Dual Faced Modified Thrie Beam Guide Rail

A median guide rail end terminal shall be used where dual faced W-beam guide rail or dual faced modified thrie beam guide rail is terminated within the median. The approved median guide rail end terminal is the MASH compliant Max-Tension Median terminal. A typical median application for terminating dual faced guide rail is shown in **Figure 27**. Where modified thrie beam guide rail is used, a transition to W-beam guide rail is needed prior to termination with a median guide rail end terminal.

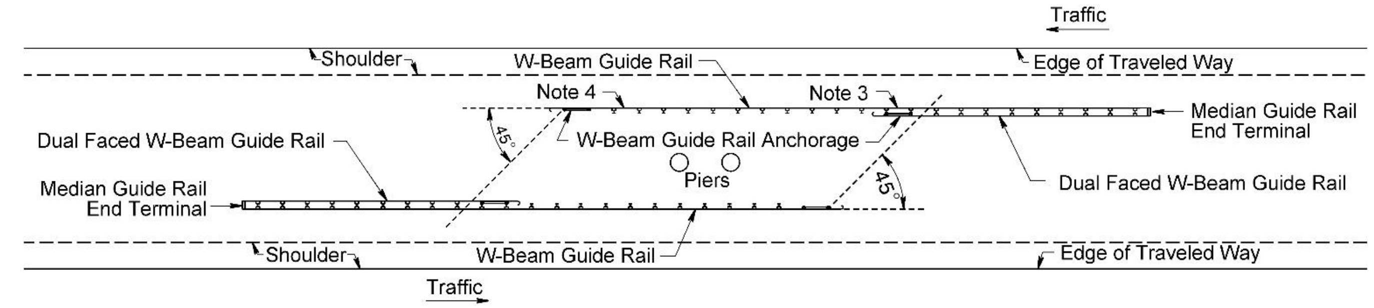
Examples of median guide rail treatments for dual faced W-beam guide rail or dual faced modified thrie beam guide rail where there is a fixed object such as a bridge pier or overhead sign support in the median are shown in **Figure 28** and **Figure 29**.

2. Median Concrete Barrier

Where the approach end of concrete barrier terminates within the clear zone, an impact attenuator or a transition to median guide rail in accordance with the *Traffic Engineering Standard Details* shall be used.

Where roadway curb meets concrete barrier at the trailing end or at the approach end of a guide rail attachment to concrete barrier, a 10' curb transition should be provided to transition the roadway curb face to the barrier shape.

At intersections where impact attenuators are used to protect the opening in concrete median barrier, the barrier opening width should be sufficient to accommodate the turning characteristics of the design vehicle.



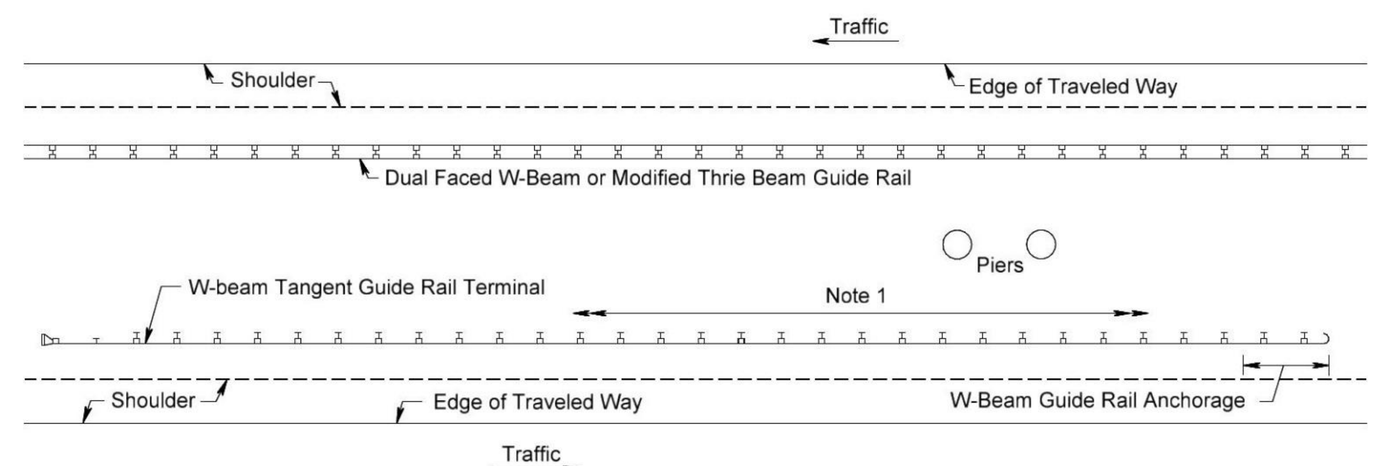
Note 1 10H:1V or flatter slopes in the median are required beginning a minimum of 100' in advance of the approach end of the terminal.

Note 2 Where the distance from the face of the rail to the obstruction is less than 4 feet, reduced post spacing is required. See **Figure 2A**.

Note 3 Extend dual faced guide rail a minimum of one 6'-3" space (two posts) beyond a 45-degree line extended from the last post of the guide rail anchorage

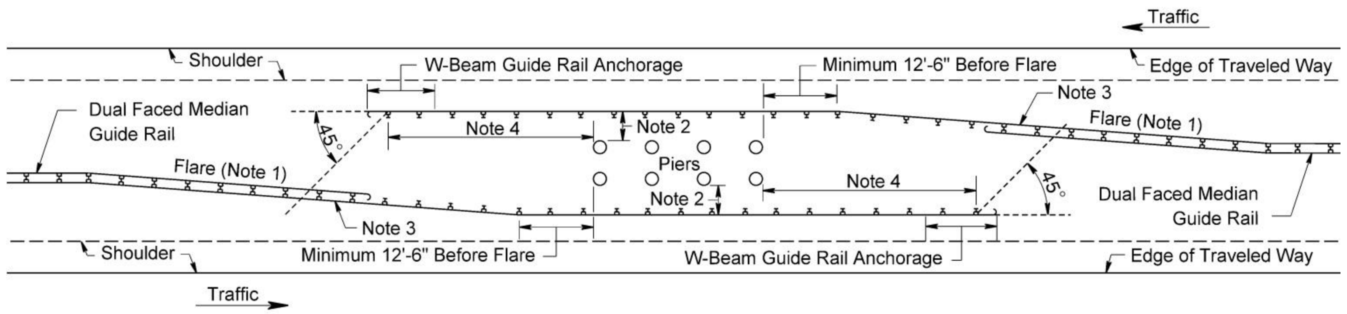
Note 4 See **Figure 25** for W-beam guide rail anchorage clear area.

Figure 27 – W-Beam Median Guide Rail End Terminal



Note 1 See **Section II** for the required approach and trailing length of guide rail.

Figure 28 – W-Beam Dual Faced Median Guide Rail - Example 1



Note 1 See **Table 13** for recommended guide rail flare rate.

Note 2 Where clearance from the face of rail to the obstruction is less than 4 feet, reduced post spacing is required. See **Figure 2**.

Note 3 Extend dual faced guide rail a minimum of one 6'-3" space (two posts) beyond a 45-degree line extended from the last post of the guide rail anchorage.

Note 4 See **Figure 25** for required length of guide rail beyond the obstruction.

Note 5 Where modified thrie beam guide rail is used, a transition to W-beam guide rail is required prior to termination with a guide rail anchorage (See **Figure 20**).

Figure 29 – W-Beam Dual Faced Median Guide Rail - Example 2

D. Median Barrier Location

Roadside slopes between the traveled way and the median barrier can have a significant effect on the barrier's impact performance. When a vehicle traverses a roadside slope in the median, the vehicle's suspension system can be compressed or extended. As a result, a vehicle that traverses a roadside slope prior to impact with guide rail may go over or under the rail, or snag on the support posts. For concrete barrier, a vehicle could go over the barrier, or the barrier could impart an additional roll moment thus increasing the potential for vehicle rollover.

1. Concrete Barrier

Concrete barrier is normally placed at or near the centerline of the median. The area between the traveled way and the concrete barrier should be paved and the slope should not exceed 10 percent.

2. Dual Faced W-Beam Guide Rail, Dual Faced Modified Thrie Beam Guide Rail, or Box Beam Median Barrier

a. Medians Without Curb or Raised Berm

In medians without curb or raised berm, dual faced W-beam, dual faced modified thrie beam, or box beam median guide rail should be placed a minimum of 6 feet from the centerline of the median swale where the median slopes are 10H:1V or flatter (**Figure 30A**). The centerline of the median swale is determined by the centerline of the median inlets.

For proposed guide rail installations on 6H:1V side slopes, dual faced W-beam or dual faced modified thrie beam guide rail should be installed a minimum of 2 feet in advance of the slope break with rub rail installed on the swale side of the barrier (**Figure 30B**).

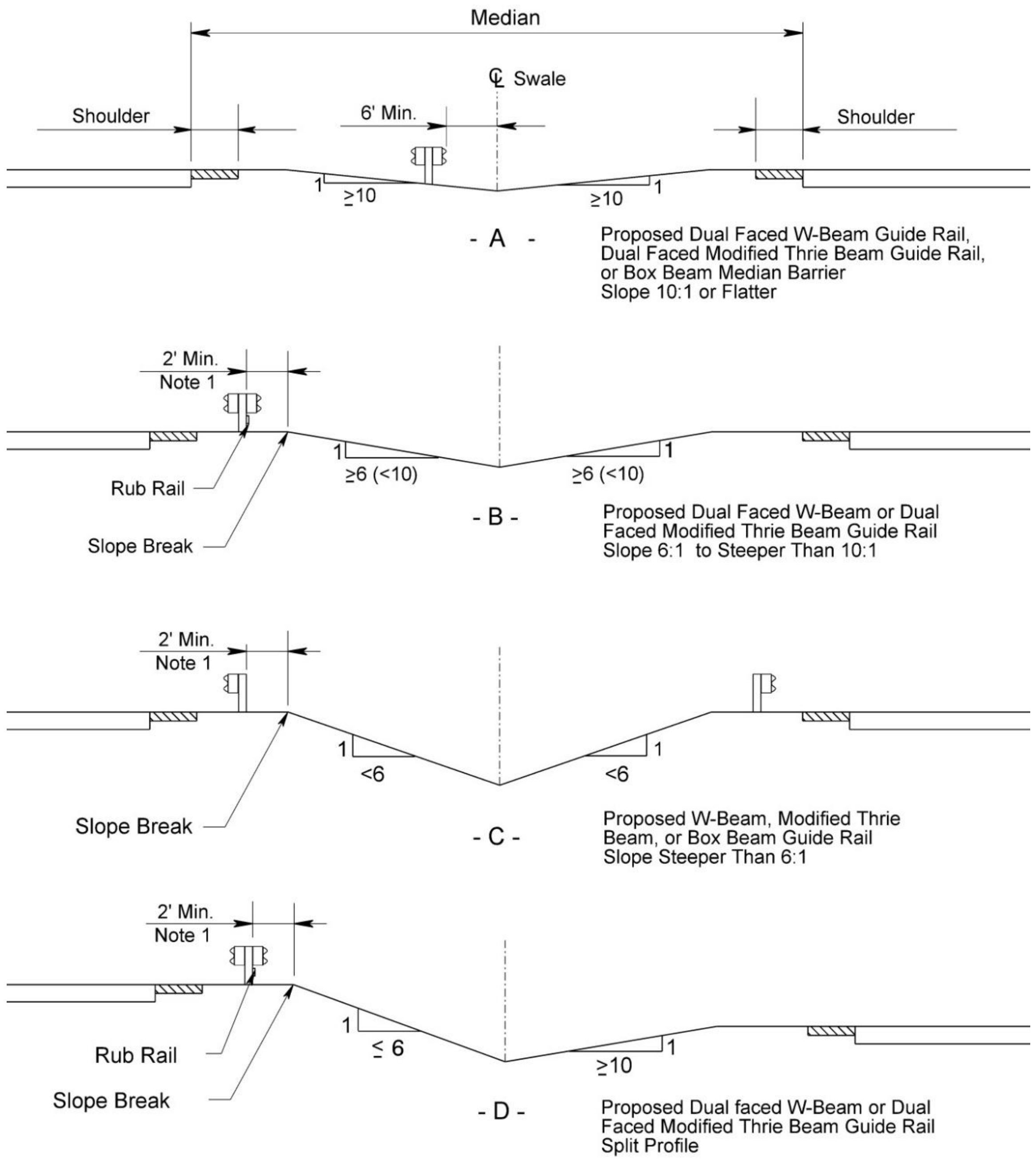
For median slopes that are steeper than 6H:1V, W-beam, modified thrie beam, or box beam guide rail should be placed on both sides of the median a minimum of 2 feet in advance of the slope break (**Figure 30C**).

Where the median is on a split profile (opposing roadways constructed with different elevations) and the cross slope from the higher roadway is equal to or steeper than 6H:1V, dual faced W-beam or dual faced modified thrie beam guide rail should be placed on the high side of the median a minimum of 2 feet in advance of the slope break with the rub rail installed on the swale side of the barrier. (**Figure 30D**).

Where there is insufficient width between the edge of shoulder and the slope break to provide the 2 foot offset, use W-beam or modified thrie beam guide rail and place the face of the barrier flush with the edge of shoulder using additional post lengths in accordance with **Table 6**.

b. Medians with Curb or Raised Berm

Dual faced W-beam guide rail, dual faced modified thrie beam, or box beam median barrier should not be used in medians with curb or raised berm. Where curb is required in the median on high speed roadways, the preferred treatment is to use concrete barrier in lieu of curb.



Note 1 If the distance from the back of the post to the slope break is less than 2 feet, use W-beam with additional post length. See **Table 6**.

Figure 30 – W- Beam and Modified Thrie Beam Median Guide Rail Placement

APPENDIX A

Test Level Matrices

Test Level	NCHRP Report 350 Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg (lbs.)	Speed km/h (mph)	Angle degrees
1	820C (Passenger Car) 2,000P (Pickup Truck)	820 (1,800) 2,000 (4,400)	50 (31) 50 (31)	20 25
2	820C (Passenger Car) 2000P (Pickup Truck)	820 (1,800) 2,000 (4,400)	70 (44) 70 (44)	20 25
3	820C (Passenger Car) 2,000P (Pickup Truck)	820 (1,800) 2,000 (4,400)	100 (62) 100 (62)	20 25
4	820C (Passenger Car) 2,000P (Pickup Truck) 8,000S (Single-Unit Truck)	820 (1,800) 2,000 (4,400) 8,000 (17,600)	100 (62) 100 (62) 80 (50)	20 25 15
5	820C (Passenger Car) 2,000P (Pickup Truck) 36,000V (Tractor Trailer)	820 (1,800) 2,000 (4,400) 36,000 (80,000)	100 (62) 100 (62) 80 (50)	20 25 15
6	820C (Passenger Car) 2,000P (Pickup Truck) 36,000T (Tractor-Tanker Trailer)	820 (1,800) 2,000 (4,400) 36,000 (80,000)	100 (62) 100 (62) 80 (50)	20 25 15

Table A-1 – NCHRP Report 350 Crash Test Matrix for Longitudinal Barriers*

Test Level	MASH Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg (lbs.)	Speed km/h (mph)	Angle degrees
1	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 (2,420) 2,270 (5,000)	50 (31) 50 (31)	25 25
2	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 (2,420) 2,270 (5,000)	70 (44) 70 (44)	25 25
3	1,100C (Passenger Car) 2,270P (Pickup Truck)	1,100 (2,420) 2,270 (5,000)	100 (62) 100 (62)	25 25
4	1,100C (Passenger Car) 2,270P (Pickup Truck) 10,000S (Single-Unit Truck)	1,100 (2,420) 2,270 (5,000) 10,000 (22,000)	100 (62) 100 (62) 90 (56)	25 25 15
5	1,100C (Passenger Car) 2,270P (Pickup Truck) 36,000V (Tractor-Van Trailer)	1,100 (2,420) 2,270 (5,000) 36,000 (79,300)	100 (62) 100 (62) 80 (50)	25 25 15
6	1,100C (Passenger Car) 2,270P (Pickup Truck) 36,000T (Tractor-Tanker Trailer)	1,100 (2,420) 2,270 (5,000) 36,000 (79,300)	100 (62) 100 (62) 80 (50)	25 25 15

Table A-2 – MASH Crash Test Matrix for Longitudinal Barriers*

*SOURCE: Chapter 5, “Roadside Barriers”, *Roadside Design Guide, AASHTO, 4th Edition, 2011*

APPENDIX B

Reference Publications

American Association of State Highway and Transportation Officials - *Roadside Design Guide, 4th Edition, 2011*

American Association of State Highway and Transportation Officials - *A Policy on Geometric Design of Highways and Streets, 6th Edition, 2011*

The Port Authority of New York & New Jersey - *Traffic Standard Details, Latest Edition*

New Jersey Department of Transportation - *Roadway Design Manual* and *Standard Construction Details, Latest Edition*

New York State Department of Transportation - *Highway Design Manual* and *New York State Standard Sheets, Latest Edition*

Transportation Research Board – National Cooperative Highway Research Program - Report 230 - *Recommended Procedures for the Safety Performance Evaluation of Highway Features, 1981*

Transportation Research Board – National Cooperative Highway Research Program - Report 350 - *Recommended Procedures for the Safety Performance Evaluation of Highway Features, 1993*

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APPENDIX F

PA ITS DESIGN GUIDELINES

Intelligent Transportation Systems (ITS) Design Guidelines

Traffic Engineering

LAST UPDATED

4/15/2022
For External Use

THE PORT AUTHORITY OF NY & NJ
Engineering Department

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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
American 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 Cybersecurity Policies, Standards and Guidelines	This document provides a series of policy statements and instructions on the use of any device or software that has access to or is installed on the PA’s Network.
PA CCTV Operational Policies, Standards and Specifications	These documents provide a series of policy statements and instructions on the use of Closed Circuit Television (CCTV) at PA Facilities.
PA Technical Specifications	The PA Technical Specifications are intended for use with the General Conditions of the contract. Contractors shall comply with every requirement of the PA Technical Specifications 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 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 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, in that they need to satisfy the agency's goals as well as being completed on schedule 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.

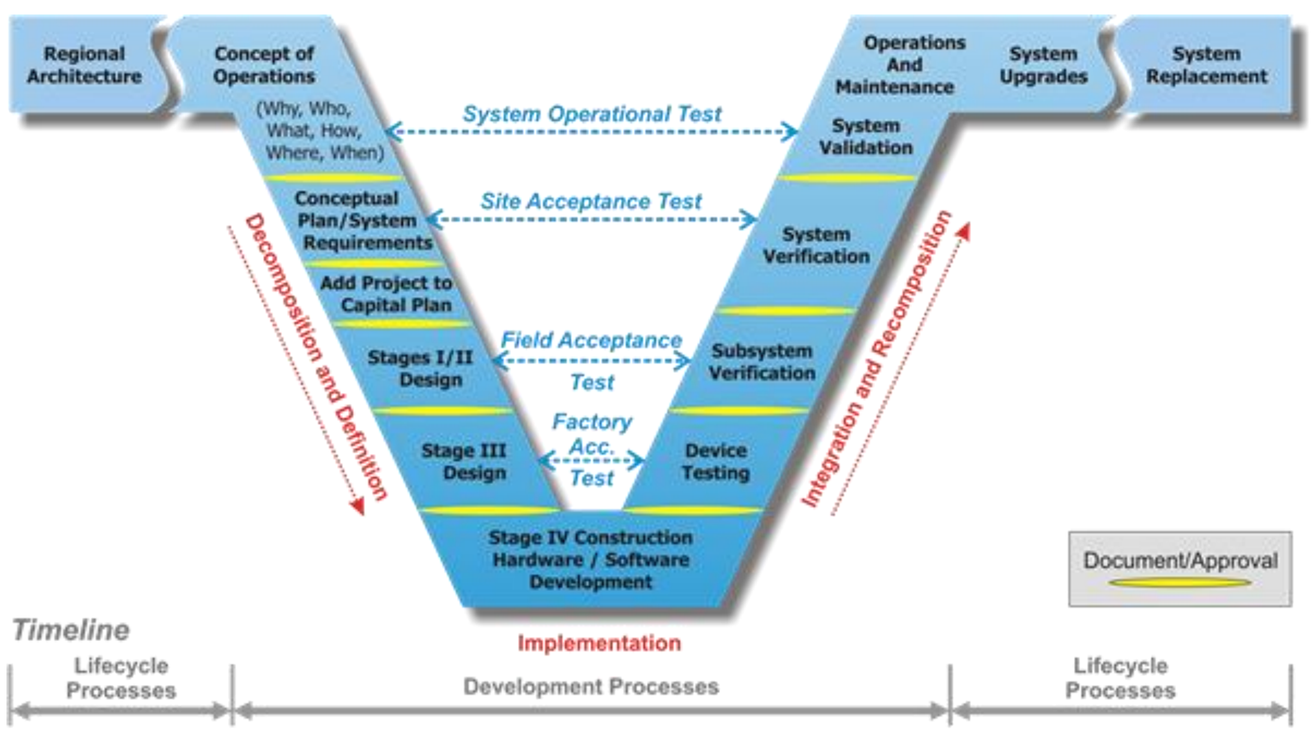

Figure 2-1: PA Systems Engineering "V" Diagram, PA ITS Strategic Plan

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
- Consult PA Specifications for requirements, as discussed in Section 2.2.2 Requirements

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

The Guidelines will assist the designer in developing the next step in the "V" 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.

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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. This ITS Architecture is documented 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".

2.2 ITS Master Plans

An ITS Master Plan is used by the PA to document the need for ITS deployment. In conformance with the SE approach, a Concept of Operations (ConOps), System Requirements and Conceptual ITS Plans are often included within an ITS Master Plan. These documents are part of the SE process and are used to add new ITS projects to the Capital Plan or add ITS components to existing Capital Projects.

2.2.1. *Concept of Operations (ConOps)*

A 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 PA 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".

2.2.2. 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?

2.3 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 the various phases of design. These usually take the form of design reviews where the PA and the project team review the design and obtain approvals to move to the next step in the development process (see appendix for the future Project Gate Review Process). In parallel with the development process, the project team must obtain any approvals required to deploy the project (i.e., roadway permits and environmental approvals).

2.4 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 "V" 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 types of testing may apply:

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

Generally, there are multiple levels of testing performed to comprise an entire test plan. The PA General ITS Specification contains requirements for each of the above levels 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 has historically been developed by the Contractors, or suppliers. This method of test documentation has proven to be limited in the equipment's functionality being tested, since minimal testing is to the Contractor's benefit. Specific ITS design specifications should include a list of functional testing requirements for each individual system at each level of testing mentioned in the PA general ITS specification section. Functional test requirements can 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 and 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.

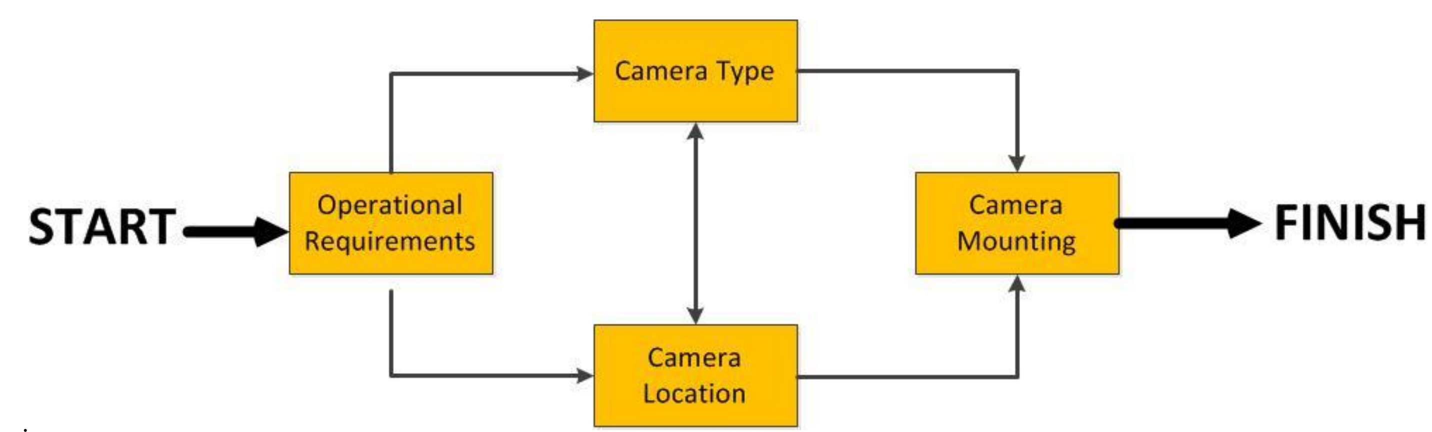


Figure 3-1: CCTV Design Flow Chart

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 Technical 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 Structural and Geotech.
Enclosure	PA ITS Specifications – ITS General Specifications
Design, Implementation and Operational	PA Agency CCTV Standards PA CCTV Operational Policies, Standards and Specifications

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 14.1, 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 and 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 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
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)
Operations	• 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	• 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 and 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 3.3 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 and 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. Additionally, see Table 4-1 for relevant DMS standards.

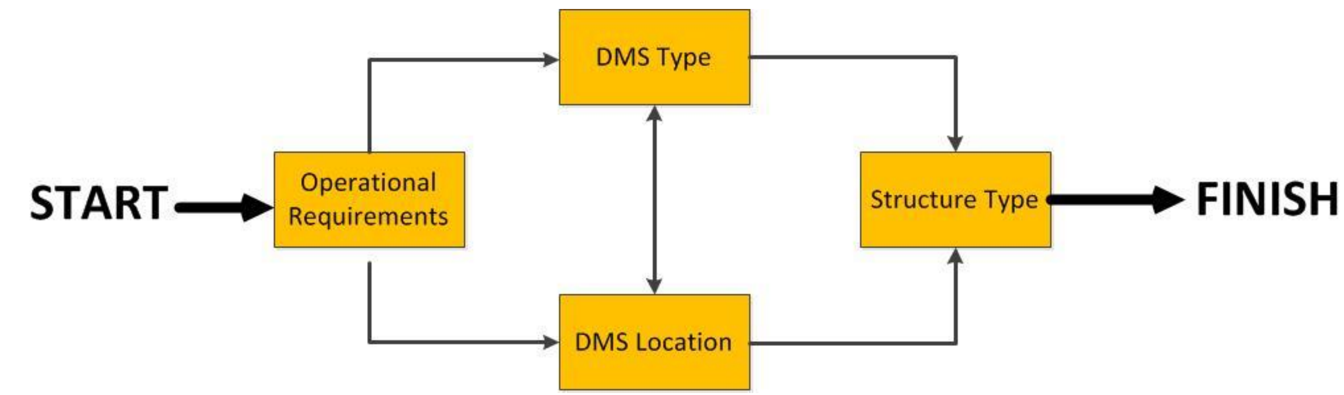


Figure 4-1: DMS Design Flow Chart

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 to ensure consistency with respect to PA DMS installations. Existing and planned systems should be compatible and interoperable, so procurement by sole source may need to be investigated.

For a design checklist, see Section 14.2, 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

- Has 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 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)

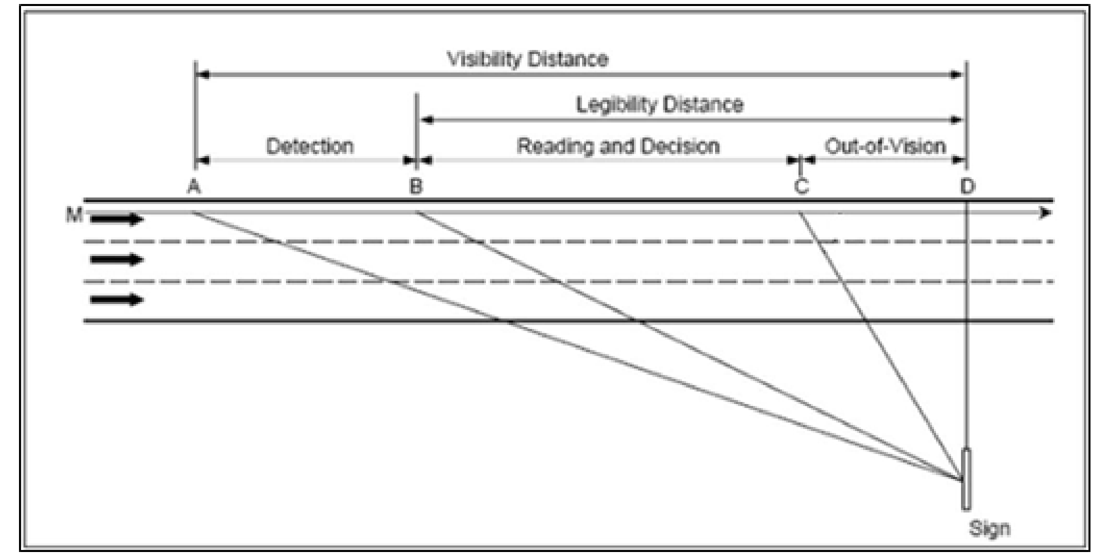


Figure 4-3: DMS Lateral and Longitudinal Visibility

- **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.

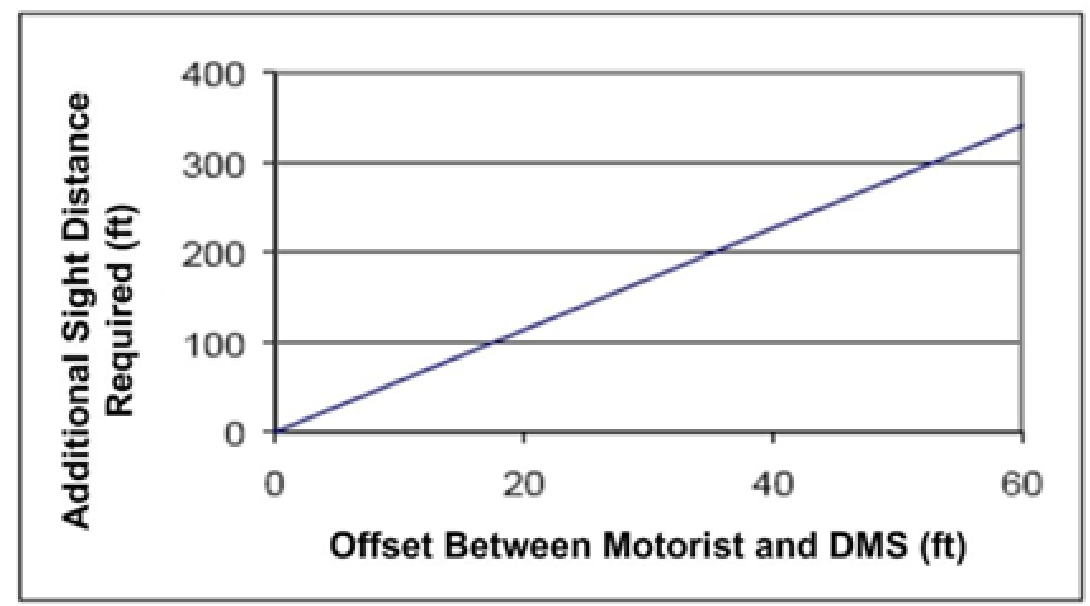


Figure 4-4: Lateral Offset vs. Required Sight Distance

- **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.

- Individual characters of 12" in height can be seen from approximately 650 feet away under normal conditions.
- 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	1,000 feet or more	1,000 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.

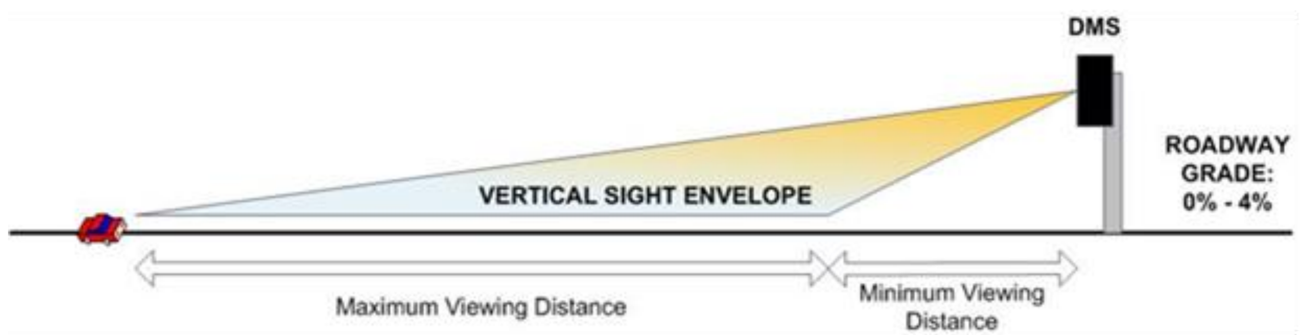


Figure 4-5: DMS Vertical Sight Envelope

4.4 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.

4.4.1. 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.

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

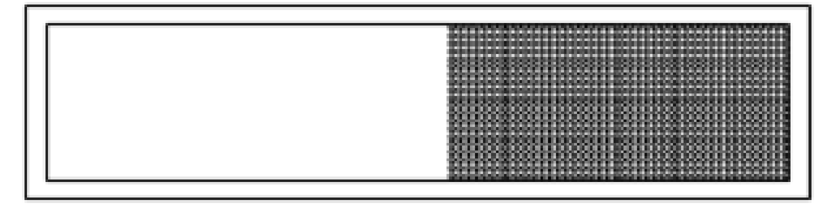


Figure 4-6: DMS Full Matrix

4.4.2. 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.

4.4.3. 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.

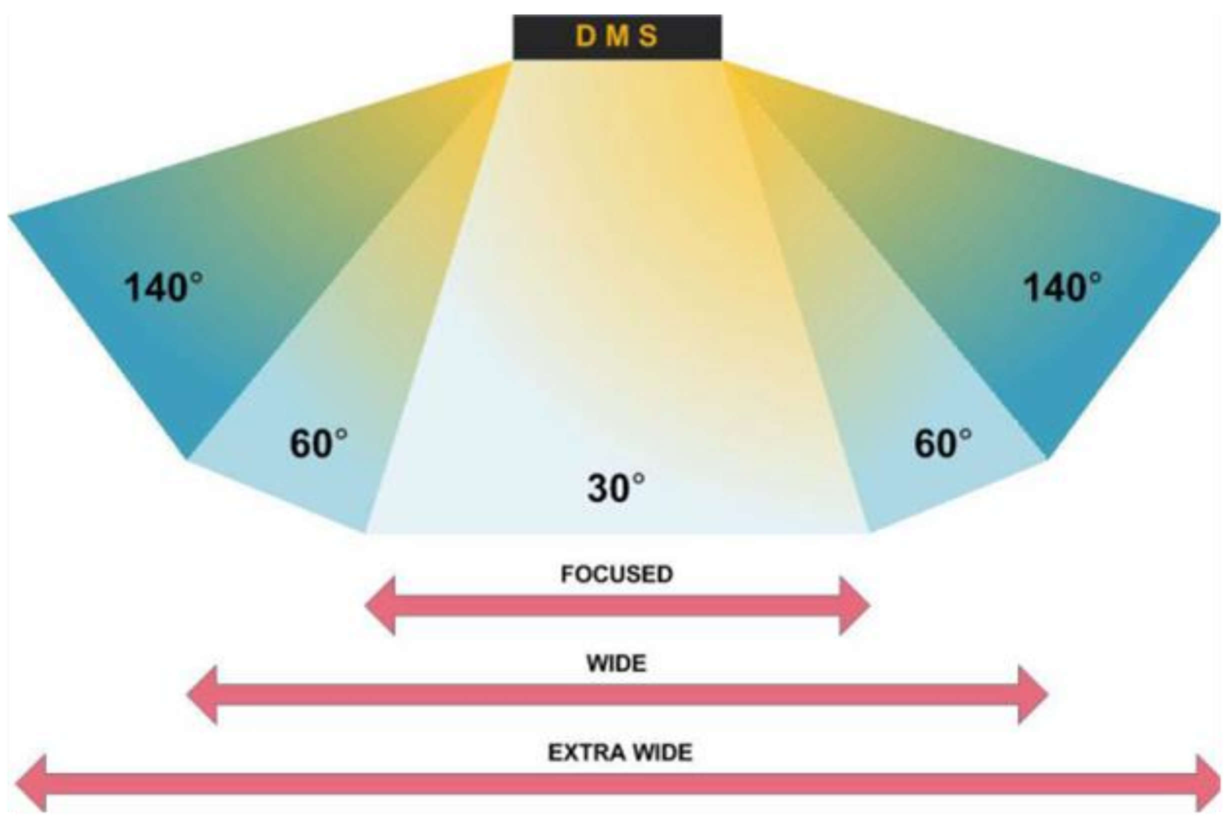


Figure 4-7: DMS Viewing Angles

4.4.4. 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 Table 4-7.

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

4.5 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.

4.5.1. *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.

4.6 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.

4.7 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 and Design Flow

Lane use control signals (LUCS) 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 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.

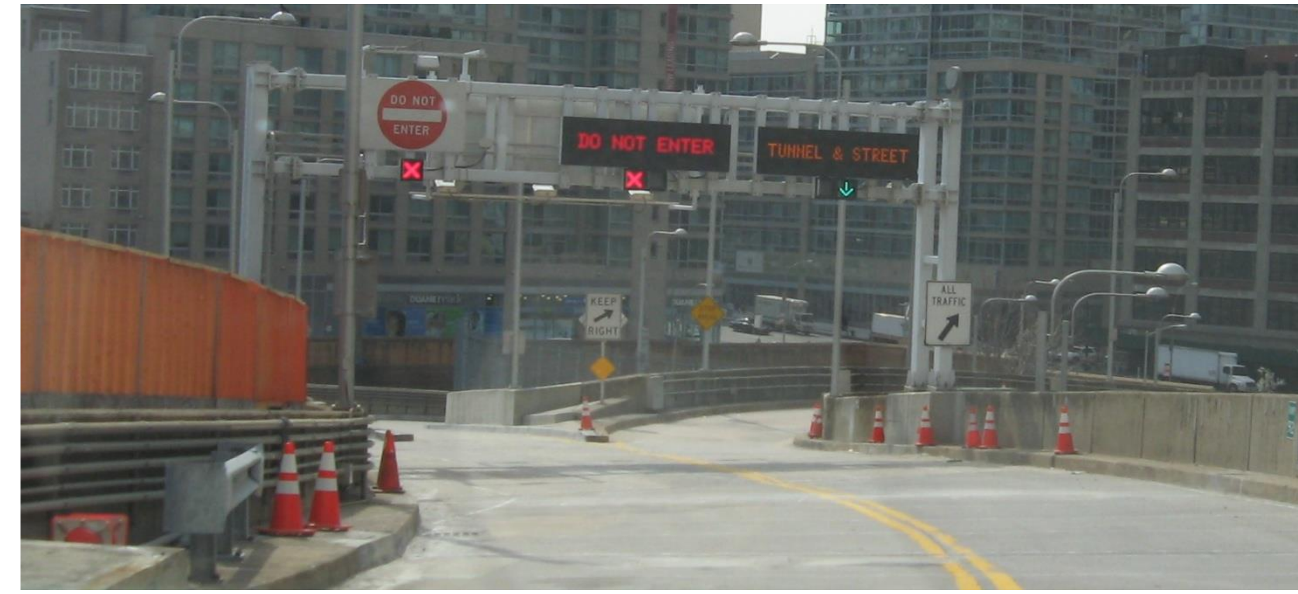


Figure 5-2: Existing LUCS

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 14.3 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 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.
  - 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.
  - 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.

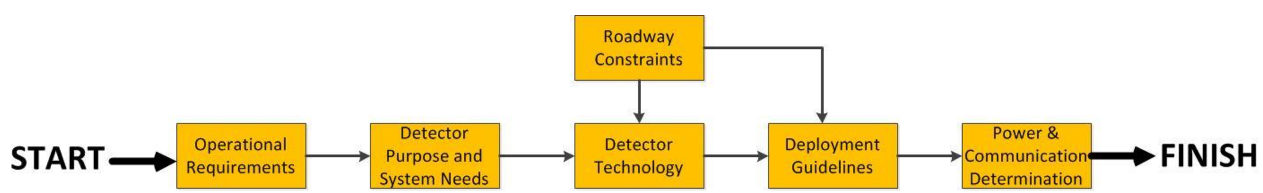


Figure 6-1: Detector Design Flow Chart

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 14.4, 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 Imaging 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/CommDesk)	• 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 System (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.

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

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 Vehicle Detection System (MVDS)*

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/CommDesk).

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

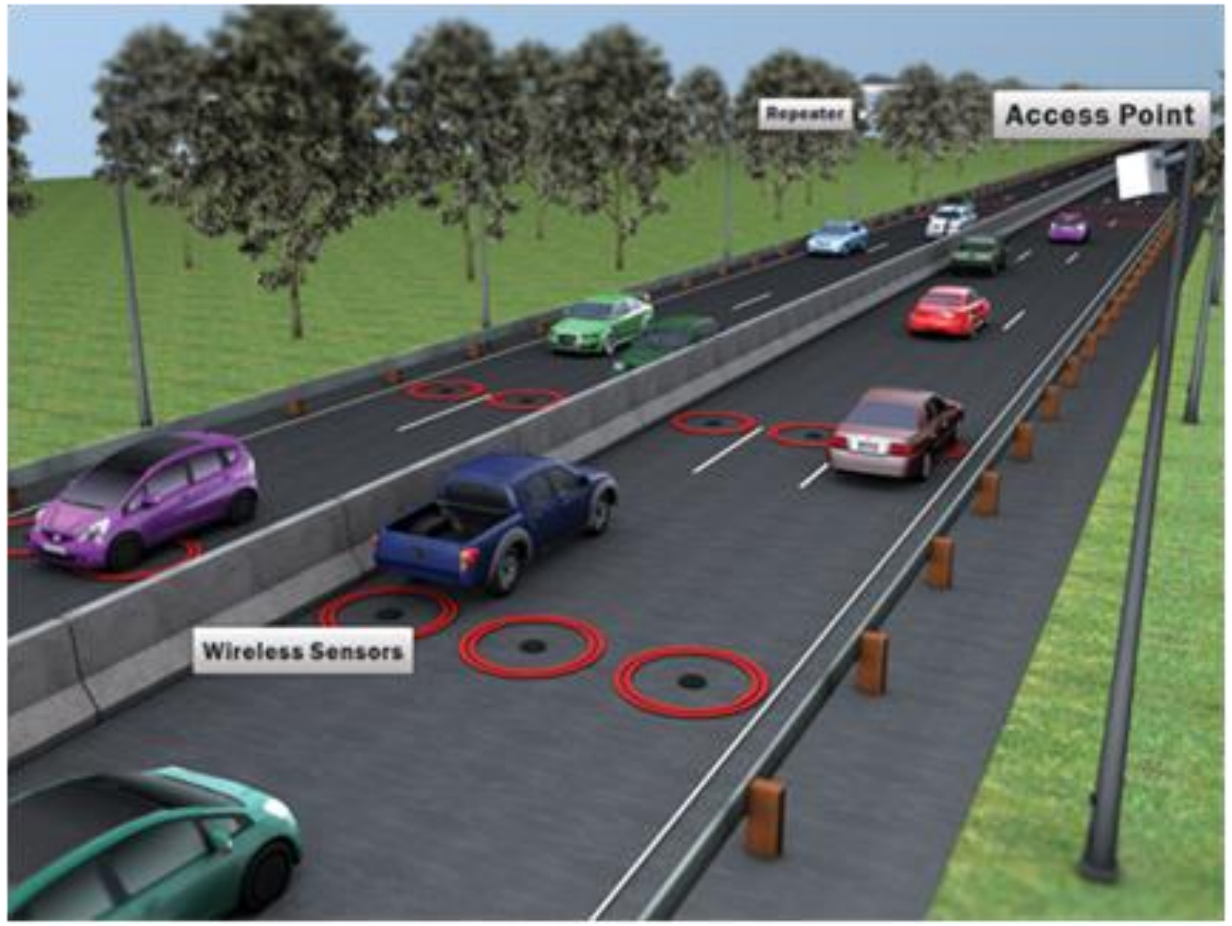


Figure 6-3: Typical Highway MVDS. Photo credit: Sensys Networks

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.
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.

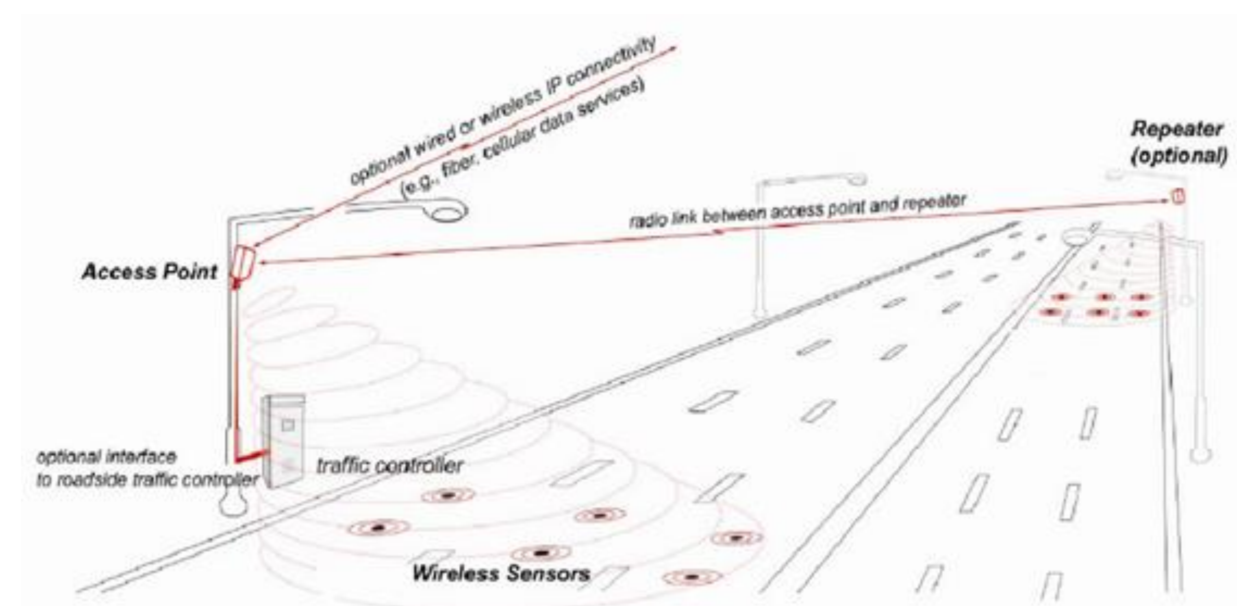


Figure 6-4: Typical MVDS and Communications. Photo Credit: Clearview Traffic

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.

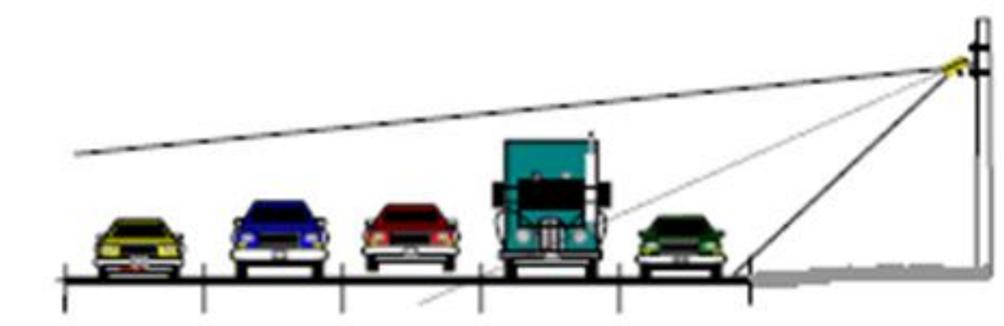


Figure 6-5: Side-Fire Radar Detector Orientation

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.

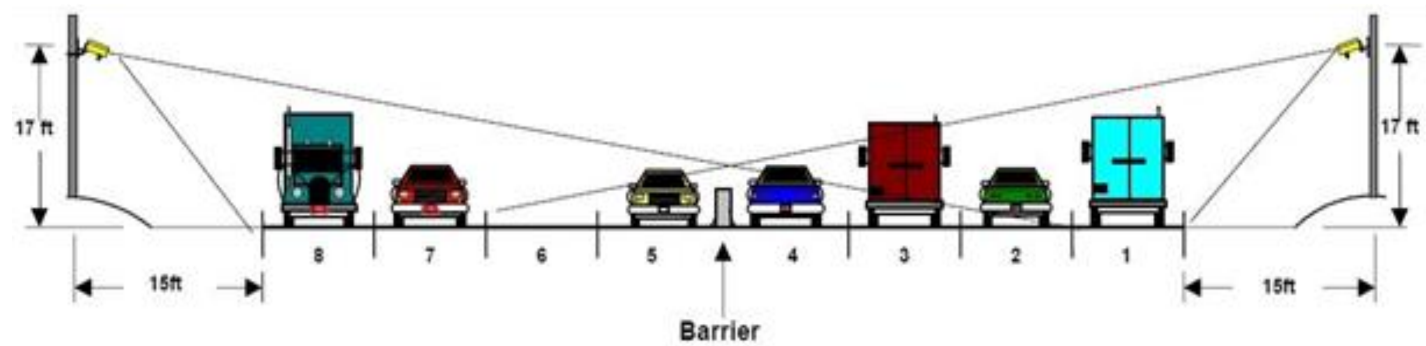


Figure 6-6: Side-Fire Detectors on Road with Barriers

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.

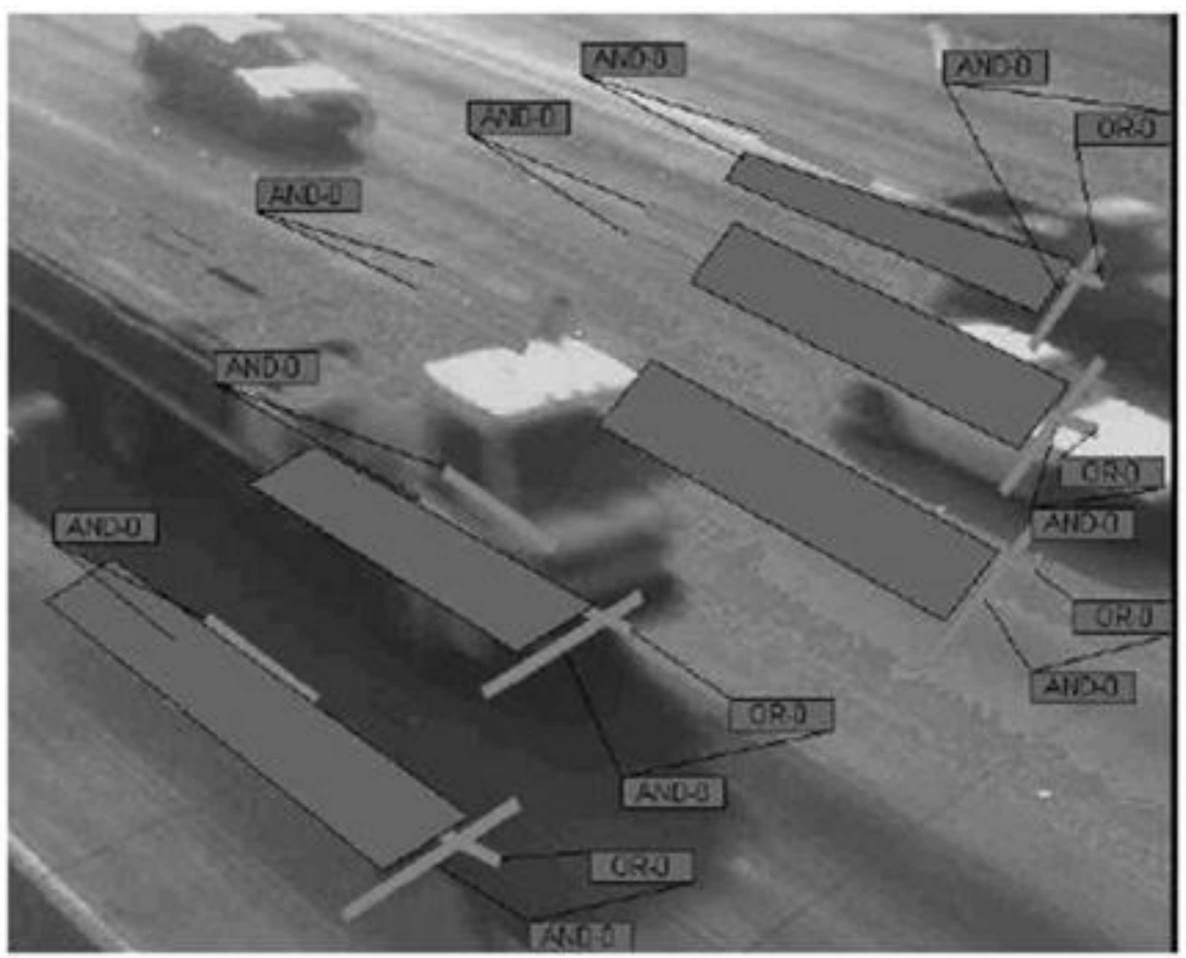


Figure 6-7: VIDS Camera Image and Detection Zones

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 Travel Time System (TTS)

6.6.1. *TRANSCOM's Travel Time System*

Travel time systems have become an important tool for providing information to the public, and travel time is an important metric for determining incident and construction impacts. The Port Authority has deployed and maintains a number of travel time subsystem (TTS) sites, which provide data to TRANSCOM's regional travel time system. The Port Authority in return receives information on travel times for larger regional trips that may span multiple agencies and connect the PA facilities. In this same manner, the information collected by the PA's TTS sites are available to the other regional transportation agencies for their use.

6.6.1.1. Data Fusion Engine (DFE)

DFE is an online portal created by TRANSCOM that analyzes travel time information from travel time system readers, member agency data and 3rd party data sources. The DFE fuses different sources of travel time data to create a regional view of near-real-time travel time information to the public. and The information gathered is also used to analyze traffic patterns by using the archived historical data.

For PA travel links in the DFE, priority is given to data that is being collected by the agency's TTS readers, which utilize *E-ZPass™* electronic toll collection tags as traffic probes. Other transportation agencies have different systems that can provide travel time, such as Sensys or Bluetooth readers. Third party transportation data such as Inrix and Navteq is also used at locations where agency devices are not deployed or as back up when a TTS site is down for maintenance. The DFE has algorithms that monitor the reliability of these various sources of data, and switch between the sources when they become unreliable.

DMS, which display travel time information in the region, use a DFE feed. A DFE feed generally consists of travel time information for a single trip, which may fuse information from the various sources. This assures the agencies that information displayed across jurisdictional boundaries is consistent. Design of DMS systems may require coordination with TRANSCOM to verify that the travel time information feeds to DMS will be available. As part of this process the various types of travel time information sources for the trips being displayed should be reviewed to ensure the accuracy of the data being provided to the public is acceptable to the PA.

6.6.1.2. Travel Time Estimation

TTS reader's primary function is to estimate vehicle travel times. When a vehicle is detected at a TTS site, the reader stores its *E-ZPass™* identification number, along with the date and detection time. The data is transmitted from the TTS reader sites back to TRANSCOM's servers, where the *E-ZPass™* ID numbers are scrambled by the system and compared to information collected at other TTS sites. As a vehicle passes through other TTS sites, travel time information is obtained.

6.6.1.3. Incident Detection

Incidents can be detected using the DFE through the use of 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/CommDesk. 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/CommDesk 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 (O/D) data is an important source for the development and update of travel demand forecasting. O/D data provides insight into when and where people are traveling. The Travel Time system is capable of providing O/D 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 Travel Time 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 Travel Time system.

Design of DMS systems that display travel time to the public requires verification that the accuracy of the information being provided is acceptable to the PA.

The criteria and guidelines in this chapter should be followed when designing new or modifying any 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 installations.

Table 6-7: Travel Time System 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 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 the TTS system 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 Radio-Frequency Identification Transponder-based Vehicle Detection components include:

- Reader Antennae (1 per 2 lanes in same direction – generally over lane lines)
- Tag Reader Assembly (in cabinet)
- Software hosted at TRANSCOM

Due to the 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 Travel Time System design may consist of the following elements:

- *E-ZPass*™ reader antennae
- *E-ZPass*™ detector reader assembly (in field enclosure)
- Communications cable/conduit
- Electrical cable/conduit
- Additional links in the TRANSCOM travel time software
- Modifications to the DMS software/hardware (only if DMS is used to display TTS information)

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

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

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

As TTS uses DMS for display, the location(s) and capabilities of existing DMS must be considered during design. If new TTS 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: Travel Time System Site Selection Considerations

Travel Time System 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.
Operations	• Install in urban areas, along major commuter routes and in other areas with frequent recurring congestion
Maintenance	• 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 TTS 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 TTS 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 and WiFi Readers*

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. WiFi readers are also available from many system vendors, and some have readers that use both forms of communications.

Bluetooth and WiFi detectors read the MAC (Media Access Control) addresses of Bluetooth-and WiFi-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. Devices that have both Bluetooth and WiFi will have two separate MAC addresses.

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, although this may vary by manufacturer. Typically, the detector operates with at least a 150-foot radius of detection. Some manufactures may have larger detection zones and any design should evaluate the current manufactures of these devices. Concerns that these areas of detection may be too large and would be able to pick up multiple parallel trips must be evaluated in each design. For example, at the GWB, a detector on the lower level approach with a 150 ft radius will pick up the local parallel road as well as the upper level approach, making the deployment impracticable. This is also the case at many of the airports where there are multiple parallel routes for arrivals, and departures, as well as parking, and service roadways. These types of 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), and only if there are not multiple parallel routes that can be detected.

These types of detectors 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. Overheight Vehicle Detection Systems

7.1 System Purpose and Design Flow

Overheight detectors are used to monitor vehicle height to determine the presence of overheight vehicles. The goal of overheight 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/CommDesk when vehicles over the allowable height pass an overheight sensor.

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

Table 7-1: Overheight Vehicle Detection System Standards

Criteria	Relevant Standard
Sensor and warning signs	PA ITS Specifications – Overheight 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 overheight 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 overheight detection system.

The criteria and guidelines in this chapter should be followed when designing new overheight 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 Overheight Vehicle Detection System installations.

For a design checklist, see Section 14.5 Appendix A - Overheight / 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: Overheight 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 Overheight 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 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

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

7.3.1. Overheight Warning System

Applications of overheight 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/CommDesk when activated.

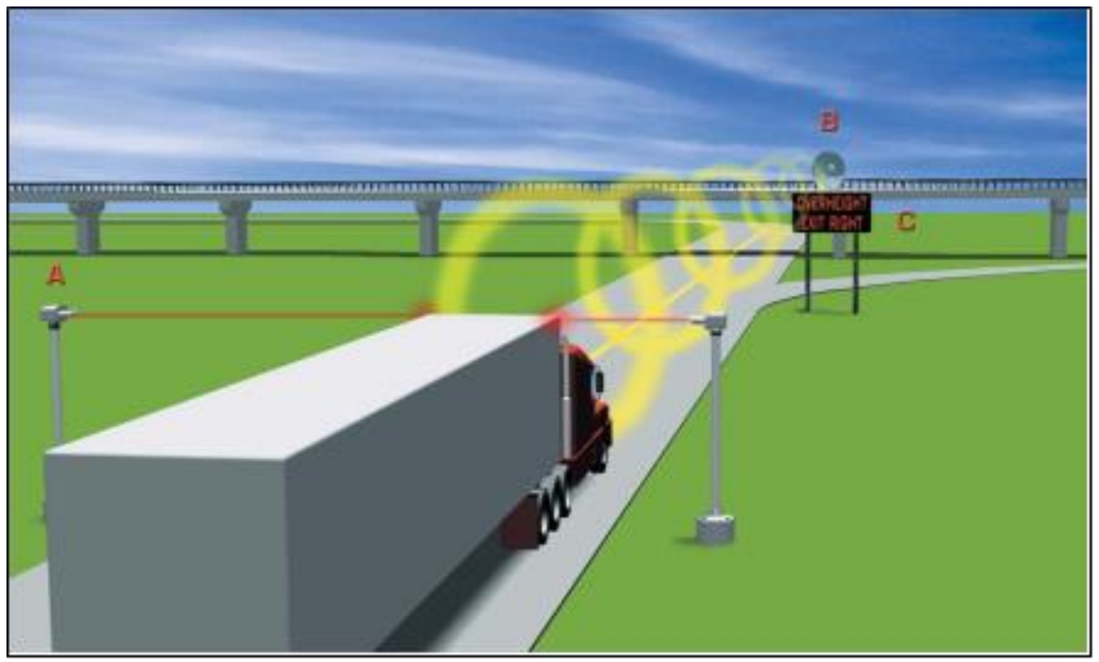


Figure 7-1: Overheight Warning System.
Photo Credit: Trigg Industries

7.3.2. Technology Choices

Overheight detection can be accomplished via visible red or infrared emitters. Video detection for the purposes of overheight 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:

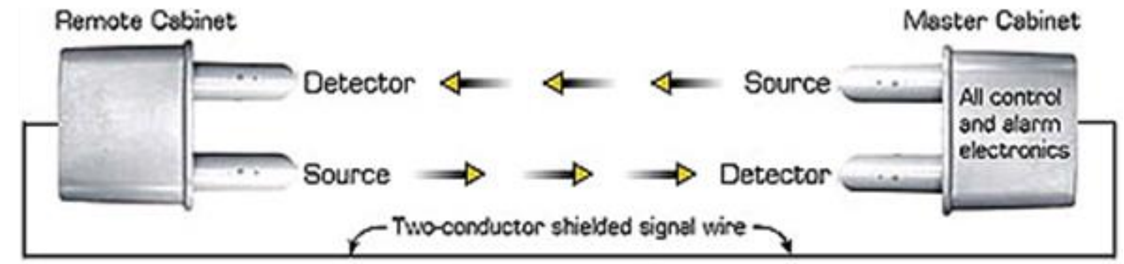


Figure 7-2: Z-Pattern® Concept.
Photo Credit: Trigg Industries

7.4 Deployment Guidelines

This section identifies deployment guidelines for overheight 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.

Overheight detectors consist of a sensor mounted on each side of the road. Overheight 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 overheight detector system includes transmitters and receivers, electronic warning sign and uninterruptible power supplies. When designing an overheight 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, overheight detectors can also be used to support WIM systems.

Table 7-3 lists items that the designer should consider when designing overheight 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 overheight 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.
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 overheight 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 overheight 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.

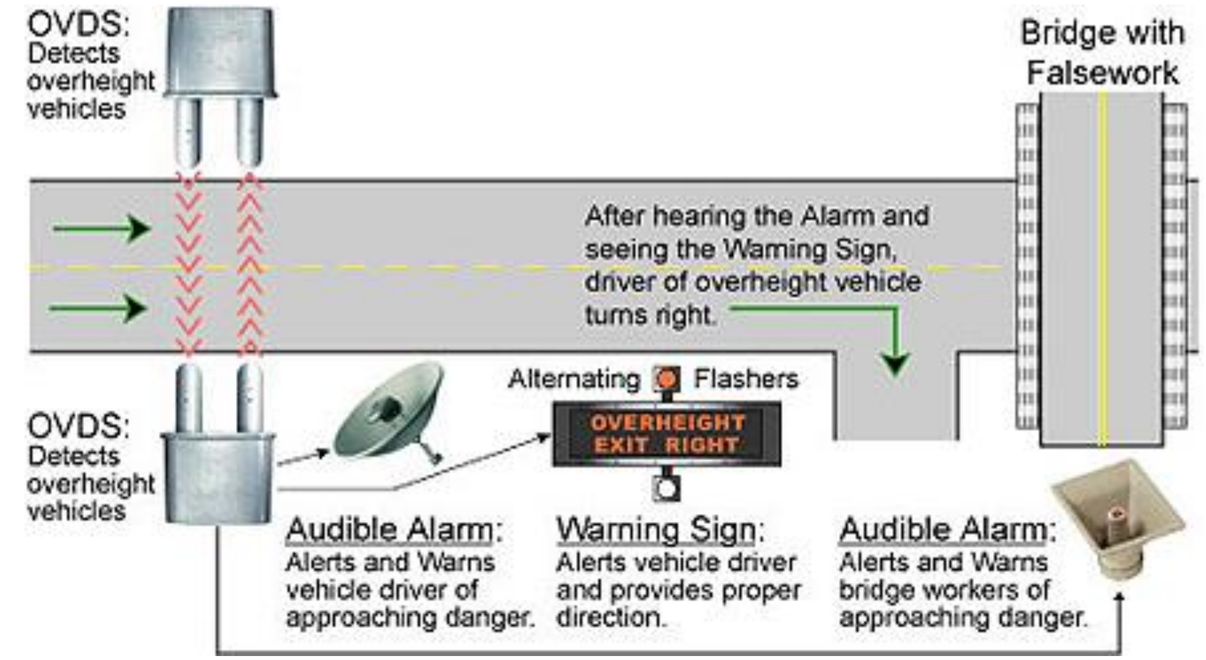


Figure 7-3: Typical Overheight Vehicle Detection System Installation.
Photo Credit: Trigg Industries

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

8.1 System Purpose and 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/CommDesk 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 section
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 14.5 Appendix A - Overheight / 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 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/CommDesk 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.

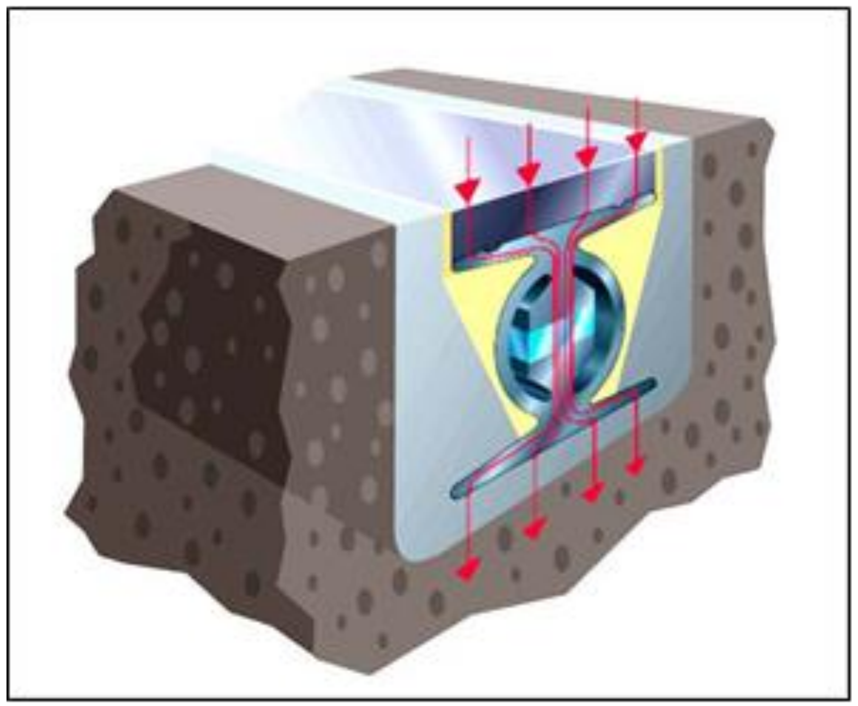


Figure 8-1: Cross Section of Piezoelectric WIM Sensor Installed in Asphalt.
Photo credit: KISTLER

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:

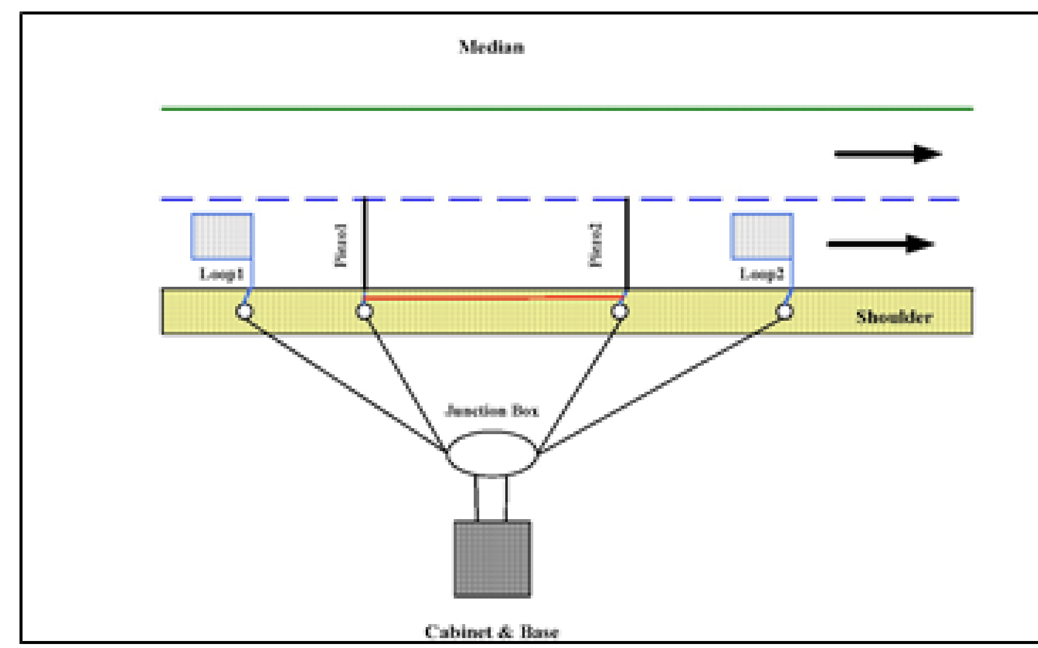


Figure 8-2: Piezoelectric WIM System Layout.
Photo credit: NJDOT

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

9.1 System Purpose and 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/CommDesk. 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 14.6 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 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.

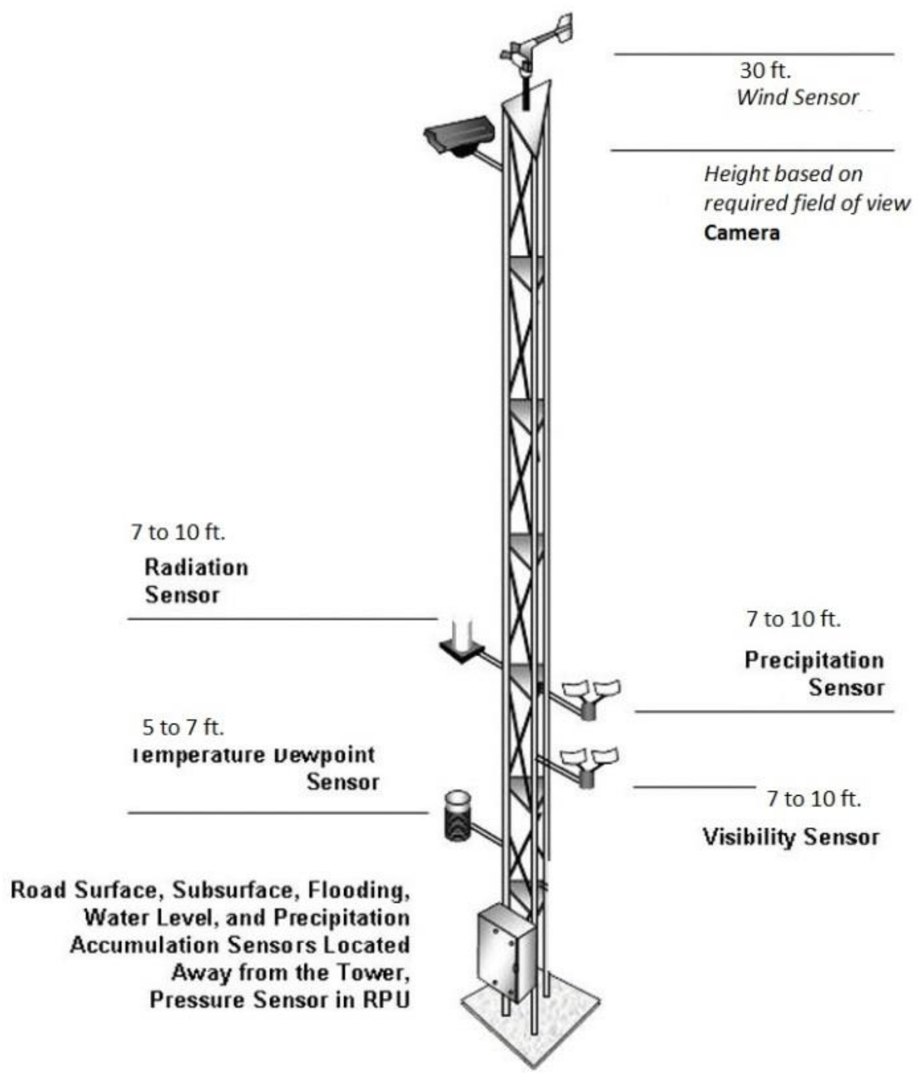


Figure 9-2: Typical Location of Pole-Based Sensors.
Photo Credit: FHWA

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 spider webs, 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.

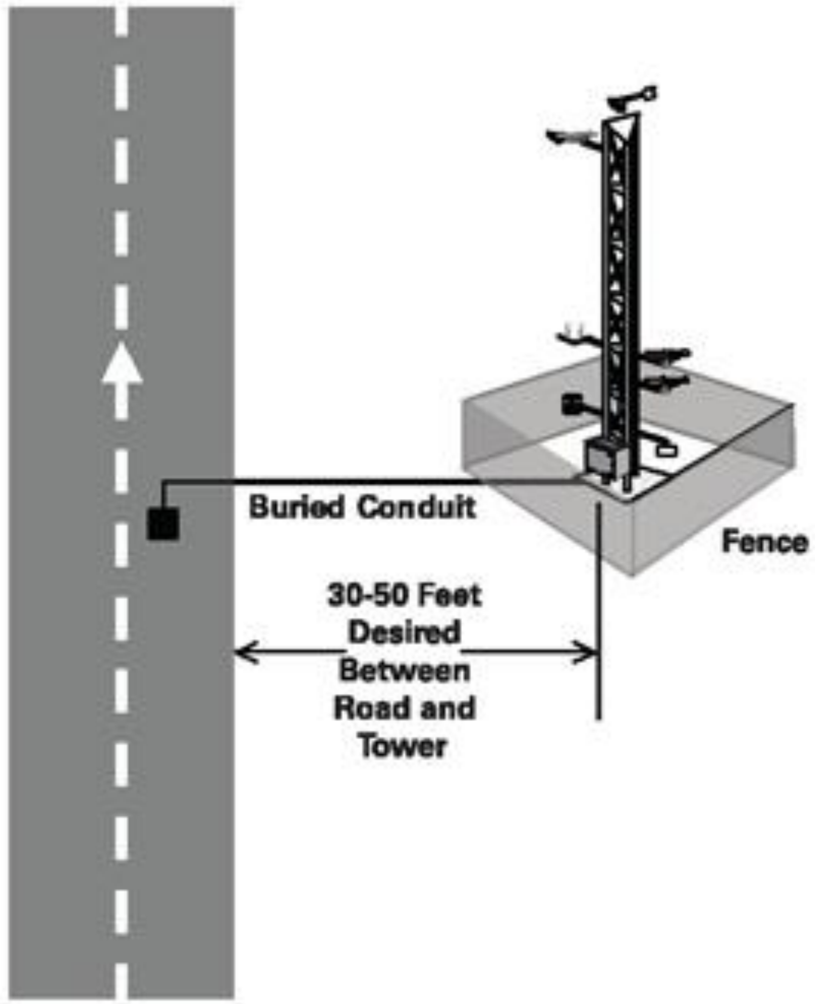


Figure 9-3: RWIS Pole Location.
Photo Credit: FHWA

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.

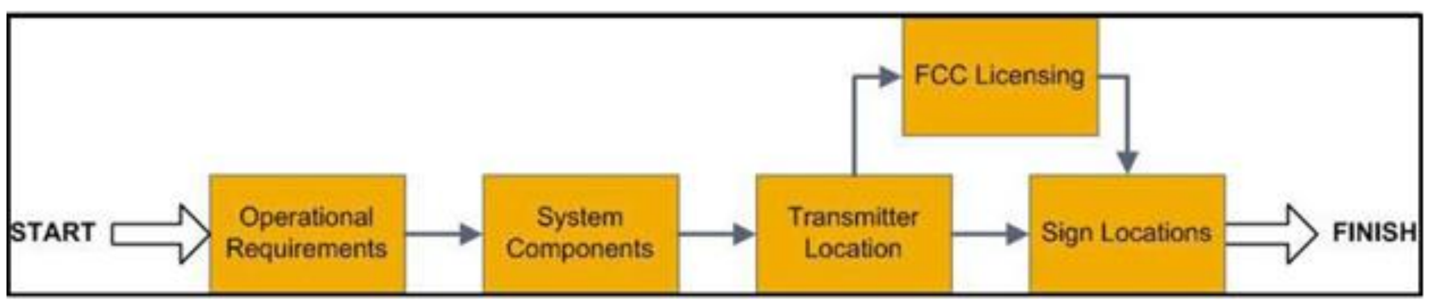


Figure 10-1: HAR Design Flow Chart

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 Control 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 Control 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 14.7 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/CommDesk 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 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/CommDesk)
- A transmitter and antenna assembly
- Roadside signs / beacons

When an operator at the Facility TMC/OCC/CommDesk 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.

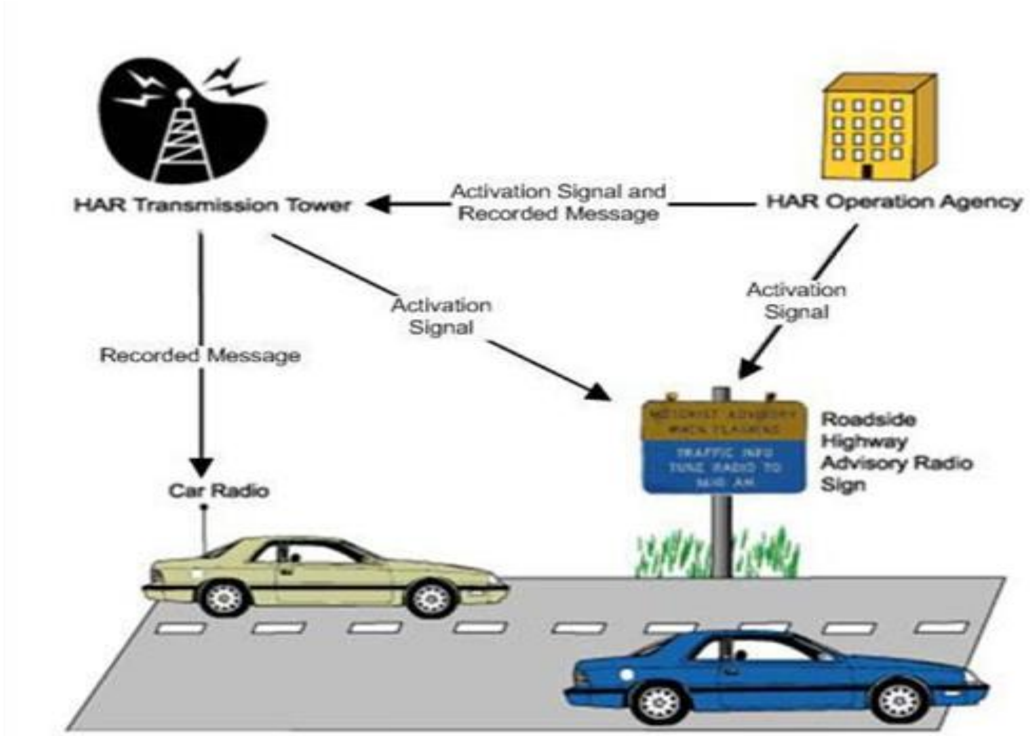


Figure 10-2: HAR System Model

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.
- **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/CommDesk. 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

remove sentence

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/CommDesk.

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	2,800 / 500 watts
Three 15-character lines, 30-degree view	3,600 / 700 watts
Three 18-character lines, 15-degree view	3,100 / 500 watts
Three 18-character lines, 30-degree view	4,400 / 700 watts
Three 21-character lines, 15-degree view	3,700 / 600 watts
Three 21-character lines, 30-degree view	4,800 / 800 watts
DMS (18" RGB LED characters) (Color)	Maximum / Typical
Three 15-character lines, 30-degree view	4,300 / 650 watts
Three 18-character lines, 30-degree view	5,200 / 900 watts
Three 21-character lines, 30-degree view	6,200 / 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
Travel Time	Typical
Travel Time Site	≈ 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.

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/CommDesk 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*.

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 Department (TEC) 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 TEC 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/CommDesk 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 communications bandwidth. A full T-1 (1.544 Mbps) service is typically used for video transmission to the Facility TMC/OCC/CommDesk, 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. *Travel Time System (TTS)*

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/CommDesk. However, the data collected by the TTS field equipment go directly to TRANSCOM's servers, located at TRANSCOM in Jersey City, NJ, where the TTS reader data is processed into travel times. TRANSCOM then sends processed data to PA Communications at a Facility TMC/OCC/CommDesk 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 traffic signals. All traffic signals should be integrated into this traffic signal management system, currently the Siemens TACTICS. See the PA 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 communications 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/CommDesk and the roadside devices that the TMC/OCC/CommDesk 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/CommDesk 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/CommDesk 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/CommDesk 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/CommDesk 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/CommDesk. NTCIP defines open, consensus-based communications protocols and data definitions for the traffic management industry. NTCIP allows a Facility TMC/OCC/CommDesk 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/CommDesk and the field device: Information, Application, Transport, Subnetwork and Plant.

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).

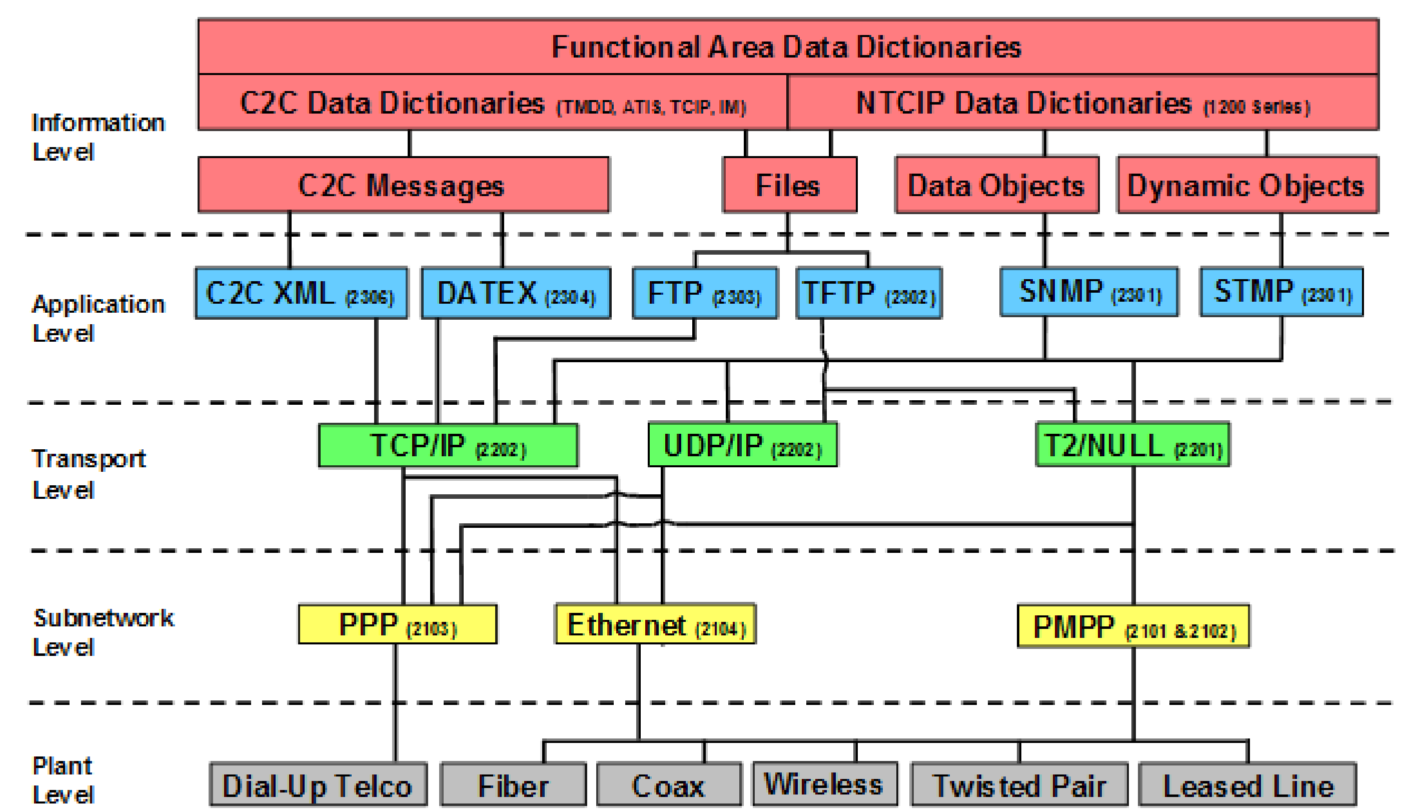


Figure 12-1: NTCIP Framework

- **Information Level.** The NTCIP Information Level defines the data to be used for exchanging information between the Facility TMC/OCC/CommDesk 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/CommDesk 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/CommDesk. 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/CommDesk 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/CommDesk 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/CommDesk 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/CommDesk 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 signal systems and the Facility TMC/OCC/CommDesk 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/CommDesk 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 Travel Time System (TTS)*

The communications interface between the TTS field devices and the Facility TMC/OCC/CommDesk 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 Overheight Detection Systems*

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

- **Configure the Overheight System Field Devices.** This feature allows an operator to determine the identity of each enforcement system device and configure the sensors.
- **Control the Overheight Detection System Field Devices.** This feature allows an operator to reset a field device and initiate diagnostics.
- **Monitor the Overheight 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/CommDesk 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/CommDesk 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. ITS Design and Drawing Guidelines

13.1 Identification of Device

Each Intelligent Transportation System Device requires a unique identifier. The identifier is comprised of a Facility code, Devices code and a unique Identification number. The identifier should be used on design drawings and labeled by contractor during installation, as indicated within the specifications.

Facility	Device	ID Num.
↓	↓	↓
XXXX –	XXXX –	XXXX
2-4 Digit	3-4 Digit	2-4 Digit

For Closed Circuit Television (CCTV) camera IDs, additional coordination with Traffic Engineering and Chief Security Office will be required.

13.1.1. Facility Abbreviation

The facility code shall be comprised of the facility's 2 to 4 digit abbreviation.

Aviation:

ACY-Atlantic City Airport

JFK- John F. Kennedy International Airport

LGA- LaGuardia Airport

EWR- Newark Liberty International Airport

SWF- Stewart International Airport

TEB- Teterboro Airport

Tunnels and Bridges:

BB- Bayonne Bridge

GB- Goethals Bridge

GWB- George Washington Bridge

HT- Holland Tunnel

LT- Lincoln Tunnel

OBX- Outerbridge Crossing

Bus Terminals:

PABT- Port Authority Bus Terminal

GWBBS- George Washington Bridge Bus Station

JSTC- Journal Square Transportation Center

Port Commerce:

PJN- Port Jersey North

PJS- Port Jersey South

BP- Brooklyn- Port Authority Marine Terminal (Brooklyn Piers)

EP- Elizabeth- Port Authority Marine Terminal

NYCT- New York Container Terminal (Howland Hook)

PN- Port Newark

PATH-Port Authority Trans-Hudson

WTC- World Trade Center

Facilities that are not included on above list should have abbreviations coordinated with Traffic Engineering to determine appropriate abbreviation.

13.1.2. Device Code

The device code references the type of ITS device; the code shall be 3 to 4 digits.

Acceptable device names include:

DMS- Dynamic Message Sign	LUCS- Lane Use Control Signal
VIDS- Video Imaging Detection System	TTS - Travel Time System
MVDS- Magnetometer Vehicle Detection System	PDMS-Portable Dynamic Message Sign
HAR- Highway Advisory Radio	OVDS- Overheight Vehicle Detection System
RWIS- Road Weather Information System	WIM- Weigh in Motion
VLS - Variable Speed Limit Sign	

As technology changes and other types of systems are used in design, coordination with Traffic Engineering shall be conducted to determine appropriate abbreviation.

13.1.3. Identification Number

The unique alphanumeric identification number is a 2 to 4 digit code coordinated with Traffic Engineering to obtain existing or new unique identification numbers for use in design documents.

13.2 ITS Drawings

ITS Drawings shall be designated with an alphabetic and numeric numbering starting from ITS001. The first sheet should have all Abbreviations, Legends, Notes, List of Manufacturers, etc. for only ITS Drawings. Efforts should be made to make use of any empty space on drawings.

ITS Drawings should call out all ITS Equipment including, but not limited to, the following

- Location of device
- Controller cabinets
- Reader locations
- Conduit and cables connections between the ITS device and control cabinet(s).
- Proposed mounting and installation location (plan and profile views)

Proposed/existing power and communications between field equipment and the ITS control cabinets should only be shown on the ITS drawings. All details and layout of power and communications beyond the ITS controller cabinet should be shown on Electrical (E) and Electronics (ES) drawings, respectively.

- ITS Details:
- Details that are available for design can be used as a starting point. However, these details shall not be considered standard. Designer shall modify and update them on each contract.

13.3 ITS Specifications

Engineering has developed a number of ITS Specifications. These specifications are updated regularly and many may not be standard sections. Traffic Engineering shall be contacted for any ITS design efforts to obtain the latest version of these Specifications. Any non-standard (C-Specification) section obtained should not be considered a standard section but instead should be modified based on the project needs.

14. Appendix A - Design Checklists

14.1 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 and 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 Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Department (TEC) 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?	☐	☐	

14.2 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 Department	YES	NO	Notes
Has the Authority's Technology Department (TEC) 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?	☐	☐	

14.3 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 Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Department (TEC) 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?	☐	☐	

14.4 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 Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Department (TEC) 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?	☐	☐	

14.5 Overheight / 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 Overheight 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 Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Department (TEC) 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?	☐	☐	

14.6 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 Department	**YES**	**NO**	**Notes**
Has the Authority's Technology Department (TEC) 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?	☐	☐	

14.7 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/CommDesk 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 Department	YES	NO	Notes
Has the Authority's Technology Department (TEC) 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?	☐	☐	

14.8 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?	☐	☐	

15. 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
CommDesk	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 Signal
M2M	Machine to Machine
MAC	Media Access Control
Mbps	Megabits per second
MDC	Major Desired Capability
MVDS	Magnetometer Vehicle 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
O/D	Origin / Destination
OVDS	Overheight 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
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

16. 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. 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 0.29of the PIRF is reproduced on the following pages. Of special importance is the 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.

remove entire section

Project Initiation Request Form (PIRF)

Version 0.29, USE CURRENT VERSION

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 and 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", ">=1and<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			

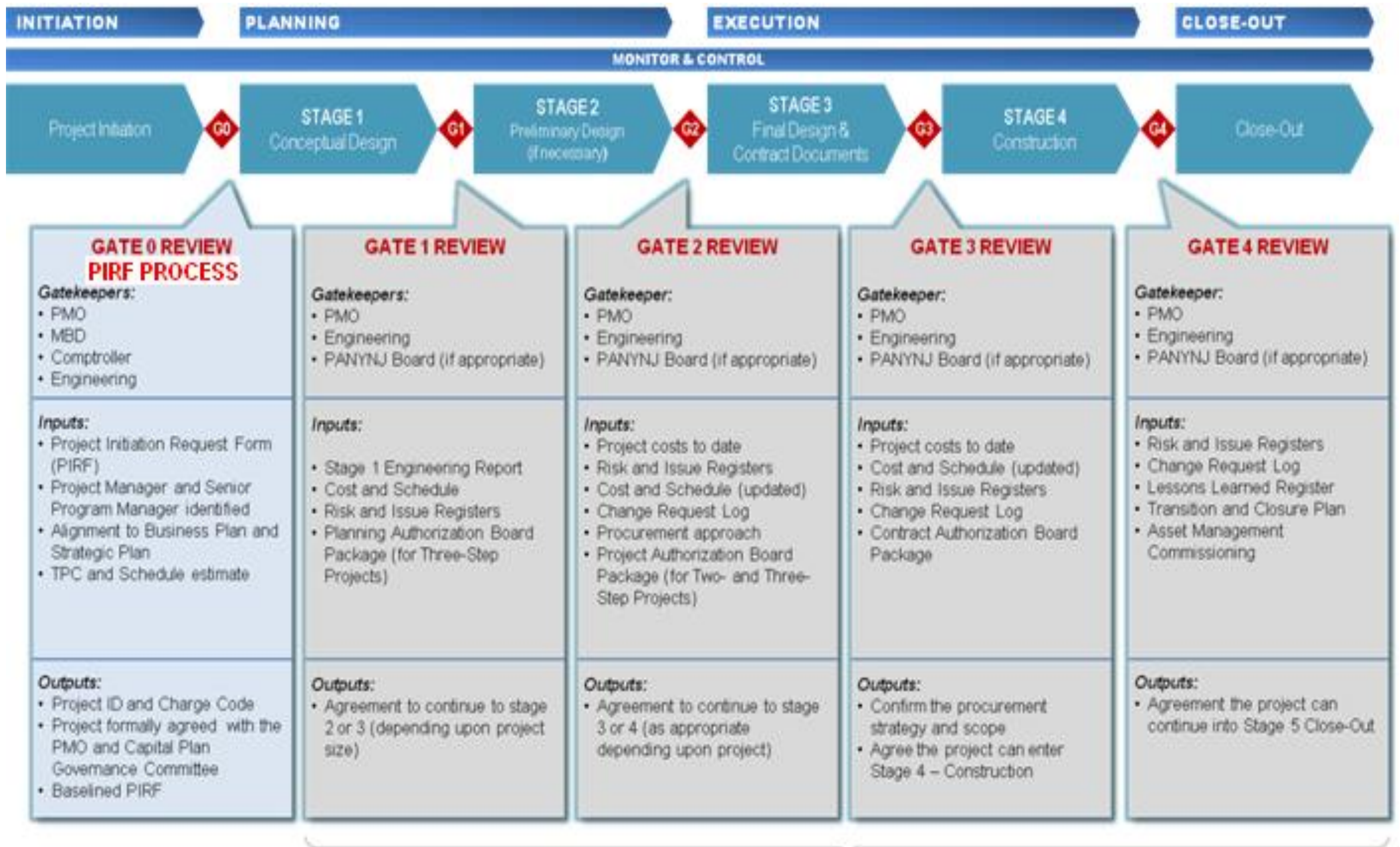
7. Other Comments

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.



Gates 1-4 are in development and not yet fully implemented

APPENDIX G

PA TRAFFIC SIGNAL DESIGN GUIDELINES

Traffic Signal Design Guidelines

THE PORT AUTHORITY OF NY & NJ

April 15, 2022

Prepared by: Traffic Engineering, Design Division, Engineering Department

For External Use

Traffic Signal Design Guidelines

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A. Traffic Signal Authorization Form

B. Signalized Intersection Pedestrian Crossing Guidelines

C. Standard Clearance Calculations Form

D. Traffic Signal Sample Drawings

E. Asset Commissioning Form

F. Signal Inspection Checklist

G. Procedure for the Re-Use of Existing Signal Pole Structures Memo and Flowchart

H. Installation and Approval of Traffic Signals

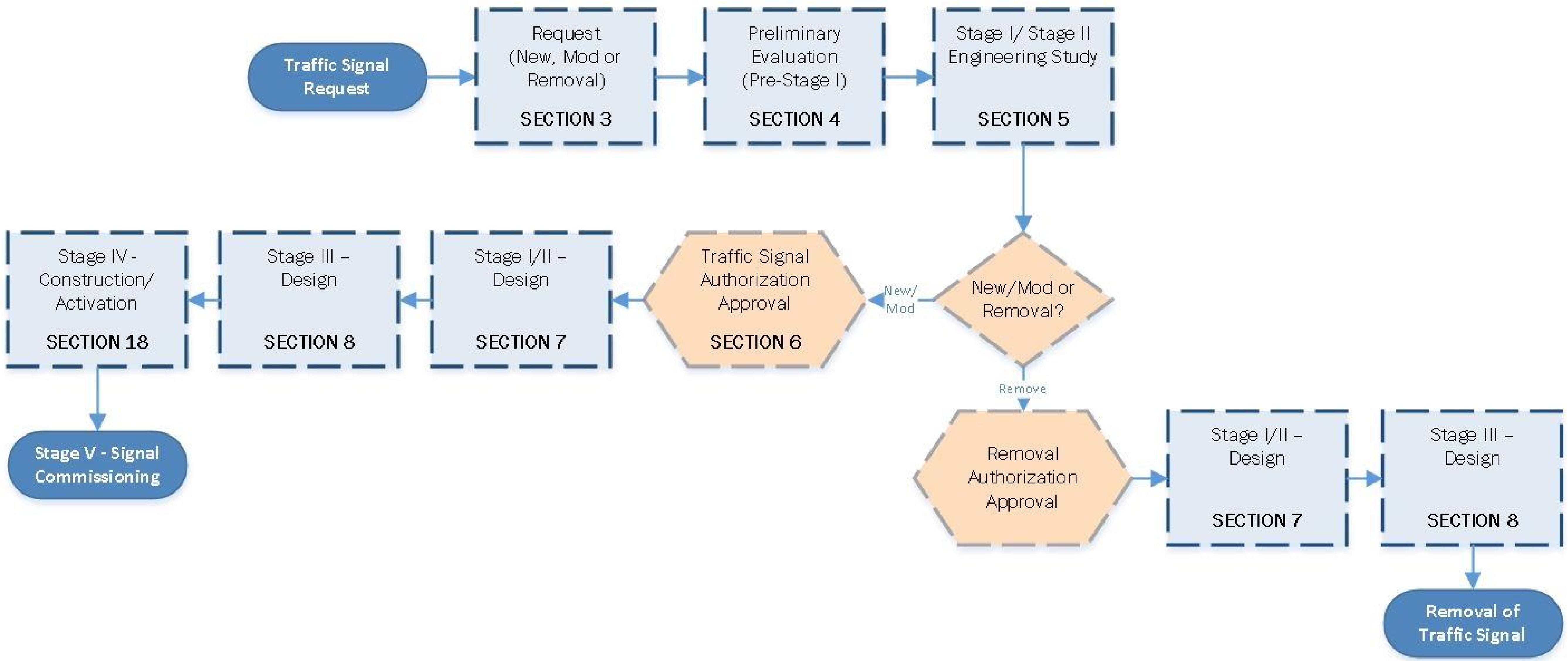
Reference Documents

- Design Guidelines – Traffic
    - Traffic Signal Specifications
    - Traffic Signal Standard Details
    - Traffic Signal Standard Notes

Section 1 - General Procedures

The following information is presented as a guideline for the development of typical traffic signal installation and is not intended to define all potential conditions that may be encountered. All traffic signal design and studies must be in compliance with the provisions and requirements of the current edition of the Manual on Uniform Traffic Control Devices (MUTCD). Any new traffic signal installation, modification to a traffic signal or removal of a traffic signal at a location under PA jurisdiction requires approval by the Chief Traffic Engineer.

The flow chart below illustrates the steps to be taken for the development of a typical traffic signal installation. The individual steps are explained in further detail in the following sections of the document.



Section 2 - Justification for Improvements

A request for any new traffic signal installation, modification to a traffic signal, or removal of a traffic signal may originate from various sources, including:

- Port Authority (PA) Engineering staff
- Facility managers
- Other agencies
- Government officials (City Manager, Supervisors, Commissioners)
- General public
- Media
- Facility tenants (Tenant Alteration Applications - TAA)
- Private developers

A modification or upgrade of a traffic signal includes adding/modifying an approach, signal phasing, detection, pedestrian signals, pushbuttons, pavement markings, and turn restrictions. Maintenance of equipment, such as replacing LEDs or replacing pedestrian signals (in kind) does not require prior approval by the Chief Traffic Engineer.

Replacement of existing equipment as part of normal maintenance operations does not require prior approval from the Chief Traffic Engineer. However, removal of an entire traffic signal requires prior approval from the Chief Traffic Engineer.

The procedures for signalization vary based upon the origin of the request and type of signalization work required. Any request for a new traffic signal or modification to an existing signal must be initiated by a written request. The form of written request depends on the entity making the request.

Section 3 - Request

A. PA Engineering Staff and Facility Managers

Submit letter, memo or e-mail to the Chief Traffic Engineer

B. Other Agencies, Government Officials, and the Media

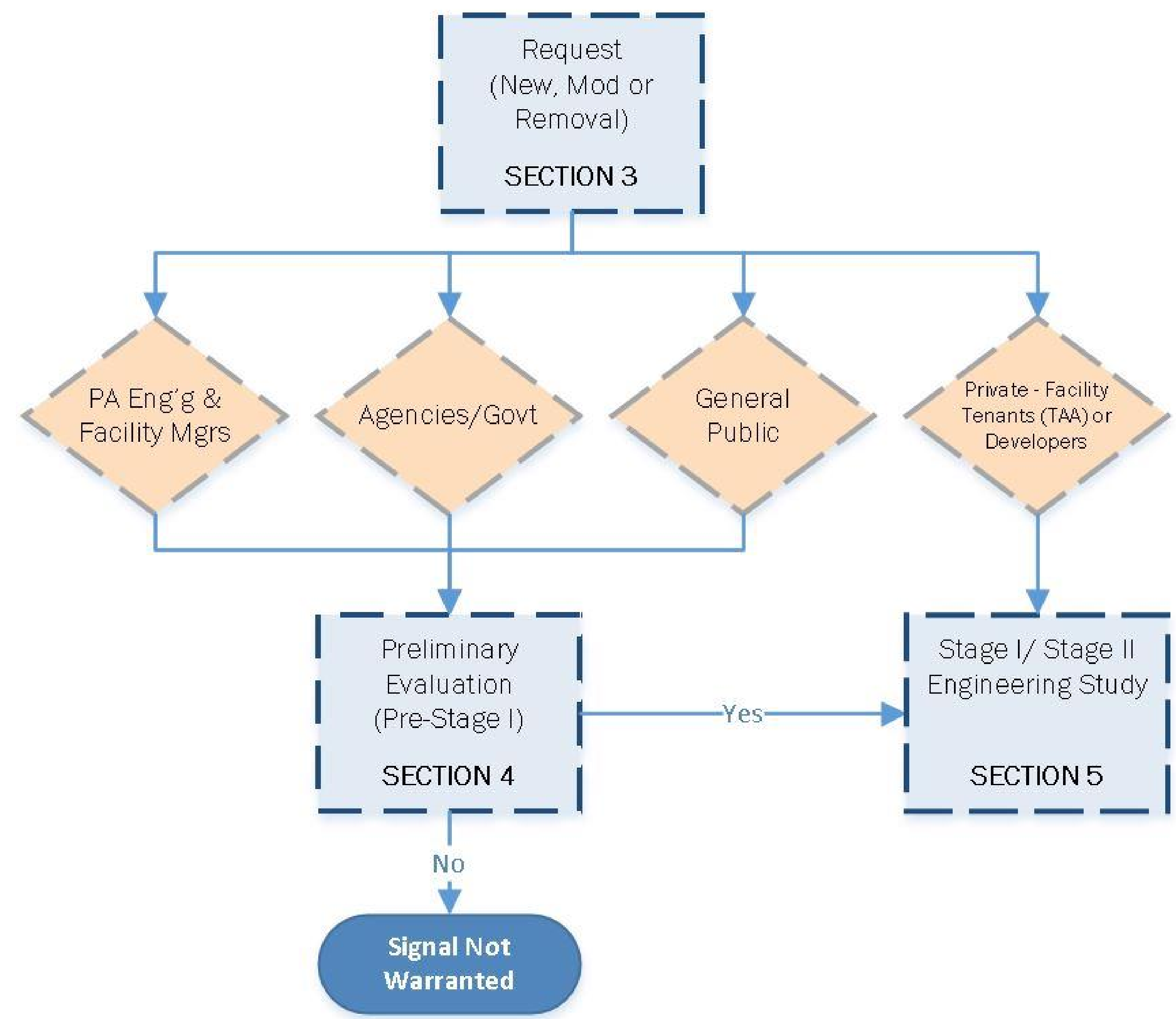
Submit letter, memo or e-mail to the Chief Traffic Engineer

C. General Public (private citizens, citizens groups)

Submit a letter with name, phone number, and return address through the Media Relations Department to the PA Chief Traffic Engineer. Requests received by informal communication (i.e., electronic mail) will not be accepted.

D. Tenant Representative or Private Developer

Facility managers, on their behalf, shall submit a written request, in the form of a memo or e-mail, to the Chief Traffic Engineer through strict conformance to the TAA process. This request shall include an engineering study, which is outlined below.



Section 4 - Preliminary Evaluation

A preliminary evaluation may include the following items:

- Review of available traffic volume data and crash records
- Review of available mapping of the location
- Field investigation to observe existing conditions and intersection geometry
- Preparation of a simple sketch plan showing the basic geometry of the intersection, existing traffic control devices, and adjacent land use
- Summary of preliminary findings with a recommendation for advanced study or rejection

In some cases, it will be apparent that the location is not a viable candidate for signalization. In these instances, the rationale for not pursuing further studies will be documented and a response will be sent to the appropriate parties. If problems do exist that may be resolved by less restrictive control measures or other minor improvements, this will be noted and recommended. At those locations where further study appears justified, the next step is to schedule and plan the engineering studies appropriate for the particular location.

A. Request from PA Engineering Staff, Facility Managers, Other Agencies, Government Officials, the Media or the General Public

Traffic Engineering will conduct a preliminary evaluation to determine if the request has sufficient validity to merit further investigation.

remove

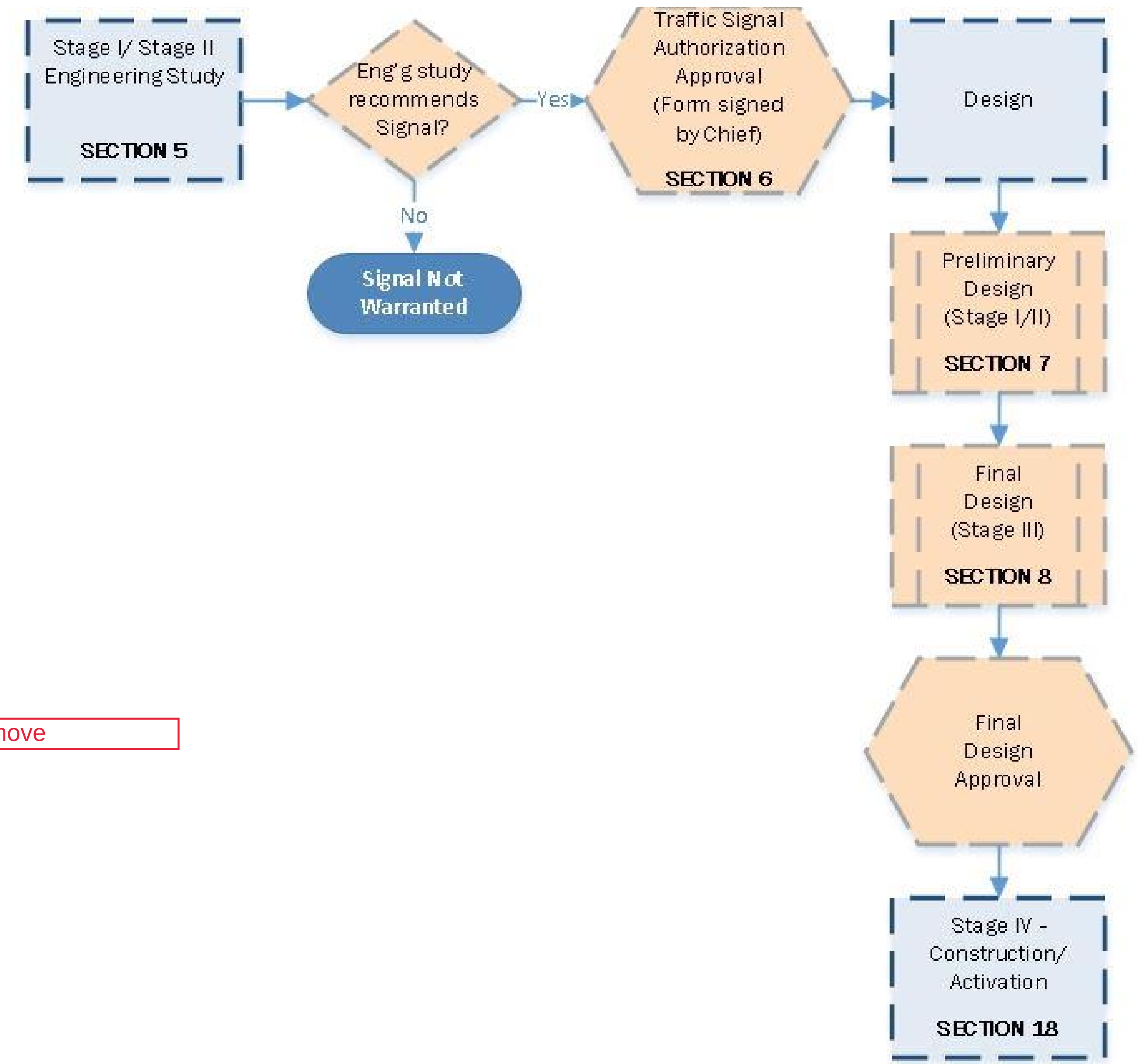
B. TAA Application

The preliminary evaluation will be performed by the applicant and shall be a part of the Engineering Study described below.

Section 5 - Engineering Study (Stage I/Stage II):

Before commencing the traffic signal design process, it must be determined whether signalization is truly needed. To avoid the operational and safety issues that can result from unnecessary or improperly used signals, a competent engineering study will be completed, based on the principles of the FHWA *Manual on Uniform Traffic Control Devices* (MUTCD), and the criteria included herein. This study will include a comprehensive Traffic Signal Warrant Analysis and a final decision will be made based on sound engineering judgment.

The MUTCD specifies nine different warrants that may be used to justify the installation of a traffic signal. The MUTCD requires, however, that a comprehensive engineering study of traffic conditions, crash history, pedestrian characteristics, and physical characteristics of the location be performed to determine whether installation of a traffic signal is justified at a particular location.



The investigation of the need for a traffic signal shall include an analysis of the applicable factors contained in the following signal warrants and other factors related to existing operation and safety at the study location:

- Warrant 1: Eight-Hour Vehicular Volume
- Warrant 2: Four-Hour Vehicular Volume
- Warrant 3: Peak Hour
- Warrant 4: Pedestrian Volume
- Warrant 5: School Crossing
- Warrant 6: Coordinated Signal System
- Warrant 7: Crash Experience
- Warrant 8: Roadway Network
- Warrant 9: Intersection near a Grade Crossing

The satisfaction of one or more traffic signal warrants shall not in itself require the installation of a traffic signal. A traffic signal shall not be installed unless an engineering study indicates that installing a traffic signal will improve the overall safety and/or operation of the intersection. A traffic signal shall not be installed if it will seriously disrupt progressive traffic flow. The engineering study may also include alternatives to installing a traffic signal.

Final approval of the traffic signal installation shall be issued upon acceptance by the Chief Traffic Engineer.

The *Traffic Signal Authorization Form* (Appendix A) shall be included in an engineering study to determine a need for a traffic signal.

Section 6 - Traffic Signal Authorization

Authorization to design a traffic signal will be issued by the Chief Traffic Engineer if an engineering study indicates that installing a traffic signal is warranted and will improve the overall safety and/or operation of the intersection.

Section 7 - Stage I/Stage II Design

All traffic signal design work shall comply with the provisions and requirements of the current editions of the MUTCD, *Port Authority Traffic Signal Design Guidelines*, Port Authority *Traffic Signal Standard Details*, Port Authority *Traffic Signal Specifications*, and other applicable Port Authority standards.

Preliminary Design (Stage I and II) work will include the following:

- Traffic Signal Layout Plan (SG Drawing)
- Capacity analysis
- Traffic signal timing
- Preliminary construction cost estimate

Stage I & Stage II – Preliminary Design Drawings

A Stage I & Stage II Design Level Traffic Signal Drawing is to be prepared in coordination with Traffic Engineering prior to developing the final contract documents. This plan will present the above-ground features, and should include the following:

- Vehicular and pedestrian traffic signal layout with pushbuttons (if applicable) and signal head numbering
- Traffic signal legend
- Traffic signal mast arm lengths
- Areas of vehicle detection
- Final striping and lane usage with dimensions (for traffic signal operations only)
- Signal phasing diagram
- Additional features as required
- Complete Designer's Checklist denoting that all items have been verified (separate sheet)

See *Traffic Signal Sample Drawings* (Appendix D) sheets SG001 and SG002 for sample traffic signal drawing formats.

Section 8 - Stage III Design

Final Design (Stage III) work will include the following:

- Contract drawings and documents listed below
- List of specifications
- Construction details
- Final construction cost estimate

Traffic Engineering will prepare the design documents. Final approval will be issued by the Chief Traffic Engineer.

Stage III Contract Documents ("SG") Design Level Traffic Signal Drawings are to be prepared following the guidelines set forth in *Drawing Preparation,* of this document.

Section 9 - Drawing Preparation

A. Sheet size for traffic signal drawings shall conform to the contract drawing size, which is usually 22"x34". Drawings will be prepared using a scale of 1" = 20' (1" = 40' for 11"x 17" drawings). All drawings shall be prepared using the latest PANYNJ AutoCAD standards.

B. Intersections shall be orientated on the drawings with the northerly direction pointing either up or to the right. The major road must always run horizontal on the plan sheet.

C. The contract set of drawings for traffic signals shall include:

1. General Notes – "SG" drawing
2. Legends and Abbreviations – "SG" drawing
3. Sign Text Data – "T" drawing
4. Signing and Pavement Markings – "T" drawing
5. Traffic Signal Wiring Plans – "SG" drawing
6. Traffic Signal Sequence, Timing and Phasing Diagram – "SG" drawing
7. Detector Table – "SG" drawing
8. Load Switch Table – "SG" drawing
9. Standard PANYNJ details – "SG" drawing
10. Standard details from other agencies and/or jurisdictions (if applicable) – "SG" drawing
11. Details developed specifically for the project (if applicable) – "SG" drawing

D. Contract ("SG") drawings for traffic signals shall be prepared in accordance with the most current PA traffic signal details and specifications, using the latest PANYNJ AutoCAD standards, and show the following:

1. Basemapping:
   a. North arrow and bar scale
   b. Street and/or ramp names
   c. Curblines, handicap ramps, drop curbs and driveways
   d. Sidewalks and grass buffer strips
   e. Trees, shrubs and other foliage
   f. Underground and overhead utility information, including pole numbers
   g. Right-of-way and building lines where applicable (excluding side property lines)
   h. Railroad tracks and track side features (e.g., gates, huts, etc.)
   i. Bus shelters and benches
   j. All existing ground-mounted and overhead signing
   k. Existing traffic signals, junction boxes, controller and meter cabinets
   l. Existing electrical service drop location for existing traffic signals
   m. Traffic signal interconnect and communication link
   n. Roadway lighting and load center
   o. Striping; overall roadway width; lane widths and designations
   p. Additional features as required

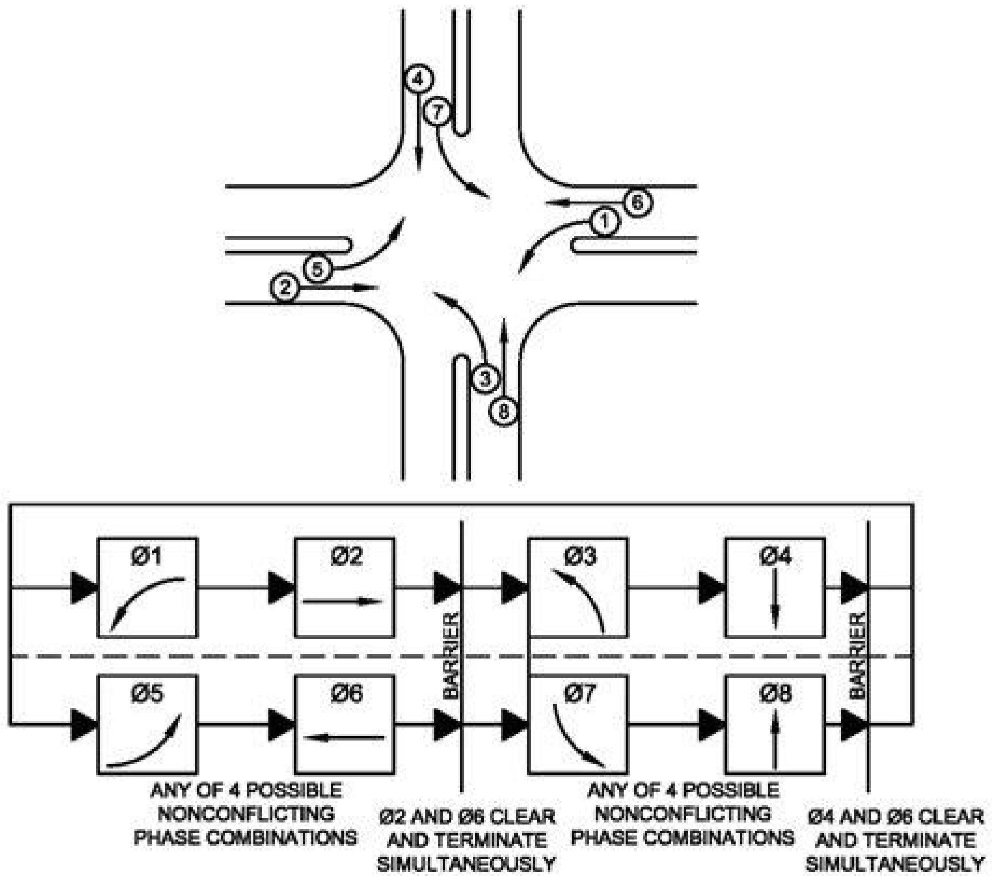
2. Traffic Signal Wiring Plan:
   a. Vehicular and pedestrian traffic signal layout with pushbuttons (if applicable) and signal head numbering
   b. Traffic signal legend
   c. Foundations for signal poles, controller and meter cabinet
   d. Block wiring diagram
   e. Vehicle detector layout with spacing and/or zone coverage (e.g., inductance loops or video) and designation
   f. Signs mounted on mast arms or span wire
   g. Lateral spacing of vehicular traffic signal heads on mast arms and span wire
   h. Mounting height of clamp or post-mounted traffic signals
   i. Traffic signal controller and meter cabinet with electrical service drop location
   j. Conduit runs, pullboxes and splice boxes
   k. Location of uninterruptible power system (UPS)
   l. Traffic signal interconnect and communication link
   m. Striping (for traffic signal operations only)
   n. Underground and overhead utilities
   o. Roadway lighting
   p. Additional features as required

   Traffic signal wiring plans shall be designated as "SG" drawings in the contract set. See *Traffic Signal Sample Drawings* (Appendix D) sheets SG010 – SG021 for sample traffic signal wiring plan and contract drawing formats.

Section 10 - Design Criteria

A. Phase Numbering Convention

Traffic movements shall follow NEMA phasing designation and convention as shown below.



See *Traffic Signal Sample Drawings* (Appendix D) sheets SG001, SG002, and SG010 – SG021 for the typical utilization of the phase numbering convention shown above.

B. Traffic Signal Poles and Foundations

1. Verify proper lateral and vertical overhead utility clearances with all proposed traffic signal poles, mast arms, and span wire, per the *National Electrical Safety Code (NESC)* and other State requirements.

2. Structural loading calculations shall be prepared for traffic signal poles, foundations, and span wires to be reviewed by PANYNJ Structures and PANYNJ Geotech. Design criteria is outlined in the *Traffic Signal Standard Details*.

   a. Steel Traffic Signal Structures

   Structures shall be designed in accordance with the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* (2013 Edition, with 2015 Interim Revisions).

   The PANYNJ utilizes two steel pole types (Type “S-A” or Type “S-B”) and specific design criteria is outlined in the *Traffic Signal Standard Details*.

   i. A Type “S-A” steel pole supports any steel mast arm from 30’ to 50’ long. All Type “S-A” steel poles and connections should be designed and fabricated for the a 50’ mast arm with the design loading shown in the Traffic Signal Standard Details unless the contract drawings show a loading greater than these details. In this case, the designer must design for this larger load.

   A steel mast arm from 30’ to 50’ long should be designed in accordance with the design loading shown in the Traffic Signal Standard Details for that specific arm length.

   ii. A Type “S-B” steel pole supports any steel mast arm from 55’ to 65’ long. At a minimum, all Type “S-B” steel poles and connections should be designed and fabricated for the a 65’ mast arm with the design loading shown in the Traffic Signal Standard Details unless the contract drawings show a loading greater than these details. In this case, the designer must design for this larger load.

   A steel mast arm from 55’ to 65’ long should be designed in accordance with the design loading shown in the Traffic Signal Standard Details for that specific arm length.

   This design approach is intended to allow for flexibility for future traffic signal revisions to these structures.

   b. Aluminum Traffic Signal Structures

   Structures shall be designed in accordance with the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* (2013 Edition, with 2015 Interim Revisions).

   The Consultant shall analyze the aluminum signal structure with the proposed attachments and shall compute and verify the top of foundation (i.e. bottom of structure) loads against the loads provided in the standard drawings. The Consultant shall use the computed loads or the loads shown in the standard drawing (whichever controls) for designing the foundations and anchor bolts and show them in the contract plans.

   c. Re-use of Existing Traffic Signal Structures

   The consultant shall follow the procedures outlined in the *PANYNJ Procedure for Re-Using Existing Traffic Signal Structures* (Appendix G).

3. For designs using poles and mast arms, both types of materials (i.e., steel and aluminum) are acceptable within the same installation.

a. Mast arm lengths shall range from a minimum of 15 feet up to a maximum of 65 feet, measured in five-foot increments. Aluminum mast arms and poles may be used for mast arm lengths between 15 and 25 feet. Steel mast arms and poles must be used for mast arm lengths between 30 and 65 feet.

b. Steel and aluminum cantilevered traffic signal structures shall be designed and manufactured in accordance with the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals*, 6th Edition, with 2015 interim revisions. The Fatigue criteria for the design of aluminum cantilevered structures as presented in these AASHTO specifications is waived.

4. For traffic signal installations that will use traffic signal poles and mast arms, the following information is furnished to provide guidance in the selection of traffic signal poles and foundations at PANYNJ intersections.

   a. Traffic signal pole, type "T" shall be used with foundation type "SFT".

   b. Traffic signal pole, type "K" shall be used with foundation type "SFK".

   c. Traffic signal pole, type "S" shall be used with foundation type, "STF".

   d. Traffic signal pedestal poles shall be used with foundation type, "SPF." Standard pole height for post top mounted traffic signal heads is 12 feet. The standard pole height for pedestrian signal heads is 8 feet.

5. Vertical clearance to vehicular traffic signal heads installed over roadways shall typically range from 16'-6" to 17'-0", as measured from the highest point of the roadway surface to the bottom of the signal head housing. Vertical clearances less than 16'-6" may be necessary due to site conditions (i.e., flight path restrictions, overhead structures, etc.); however, a minimum clearance of 15'-6" must be provided. At facilities where overheight vehicles are anticipated (such as Port Newark/Elizabeth PA Marine Terminals), all vehicular signal heads shall be mounted to provide a vertical clearance between 17'-6" and 18'-0". The vertical clearance shall be specified on the design details. The height at which the 15' and 20' arms are attached to the T-pole and the 25' arm is attached to the K-pole limits the maximum vertical clearance to 16'-6" and 17'-6" respectively when the pole is set 2'-8" from the curb. At this offset the low chord of the arm may control the vertical clearance if a greater clearance to the signal head is desired.

6. Foundations for all traffic signal poles shall be located as far as practical from the edge of the traveled way without adversely affecting the visibility of the signal indications or obstructing the passage of persons either on the sidewalk or within the access from the sidewalk to the crosswalk. At a minimum, the center for all aluminum traffic supports shall be offset 2'-8" (32") from the curb face. Where practical, all steel poles shall be located out of the clear zone (refer to the *American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide*). The use of traffic barriers may be considered based on field conditions, where poles cannot be located outside of the clear zone. All steel traffic signal supports shall be offset a minimum of 10' from the curb face. In addition, reference should be made to the *Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)* and *Public Rights-of-Way Accessibility Guidelines (PROWAG)* to ensure that the proper clearance is met for all passage areas around any signal pole base.

7. Soils testing and structural calculations are required for all foundations installed in accordance with the PANYNJ Geotech procedure, and must be signed by a structural engineer and reviewed by PA Structures and PA Geotech.

8. Pole and mast arm finishes will be dictated by the facility on a case-by-case basis.

9. Spare equipment including poles, mast arms and hardware will be dictated by the facility on a case-by-case basis.

10. For traffic signal installation applications that will use poles and span wire, the following information is furnished to provide guidance for the selection and design at PANYNJ intersections.

    a. In order to provide reserve capacity to support the installation of additional signal equipment in the future, all span poles and foundations shall be designed to support 125% of the signal loads that are shown on the plans.

    b. Span pole height shall be calculated utilizing the following criteria:

       (i) Minimum vertical clearance shall be as stated in Design Criteria Section B.4.e.

       (ii) Height of signal heads being installed.

       (iii) One-foot allowance for a signal hanger bracket.

       (iv) Span wire sag equal to 5% of span length shall be provided.

       (v) 18-inch allowance for the distance between the top of the span pole and the span wire attachment point.

       (vi) Existing intersection grades must be evaluated prior to selection of span pole height.

       (vii) The pole height shall be specified in even two-foot increments, and shall be the sum of the above values rounded up to the next two-foot increment to provide for future signal requirements.

       (viii) The designer shall specify the height of pole, design load capacity of the poles, footing capacity, and footing width on the design details.

C. Traffic Signal Controllers

The Port Authority standard controller is the Siemens Advanced Traffic Controller (ATC) Series NEMA TS-2/Type 2, in compliance with NTCIP standards, or approved equal. The controller shall be capable of transmitting and receiving all of the NTCIP functions to and from the PA Centralized Traffic Signal Management System (Siemens TACTICS).

The location of the traffic signal controller should be based on the following criteria:

- Offset the controller as far away from the travelled way as practical.
- Location should reduce vulnerability to vehicular crashes.
- Location should not restrict sidewalk accessibility.
- Door on cabinet should open away from traffic to provide the controller maintenance personnel optimal visibility of the signal indications.
- Consider elevating the critical electrical components above the flood elevation.

D. Signal Displays

Polycarbonate signal heads are preferred except where aluminum signals are required, such as for post top-mounted signals and end-mount free-swinging signals. The material type for all sections shall be specified on the contract drawings. Upper tether wires are required for all span wire installations. The minimum requirements set forth in the *MUTCD* shall be met.

1. *Vehicular Signals*:

   a. 12-inch signal sections are required for all vehicular signals, in accordance with the *MUTCD*.

   b. All signal sections shall be LED-type.

   c. It is recommended that two vehicular traffic signal faces be provided for the primary far-side indication for each intersection approach. A near-side vehicular traffic signal face should be provided for stop bar definition, unless geometric or other site constraints exist that precludes its installation. Mast arm traffic signals should have a "near left" / "far right" orientation where practical.

   d. The use of supplemental signal faces should be considered to improve signal visibility where geometric conditions limit visibility. If required, supplemental signal faces should be clamp or post-top-mounted 12 feet above finished roadway grade, unless site conditions dictate a different mounting height. Post top-mounted signals shall not have more than 3 signal sections. Signal faces with 4 signal sections and above shall be clamp mounted on the appropriate traffic signal support.

   e. Span wire signals shall utilize a separate yellow and green arrow signal section arranged in a "doghouse" configuration next to the yellow and green ball when the phasing dictates protected/permissive turning movements. For overhead mast arm installations, the preference is a "doghouse" signal; however, a 4-section bi-modal arrow signal may be used.

   f. In areas with overhead sign structures, the signal faces should be designed such that they are not obstructed from the view of approaching vehicles by the structure.

   g. Backplates shall be installed on signal faces to improve signal visibility where conditions present visual distractions (due to sun glare, lighting, signs, buildings, etc.).

2. *Pedestrian Signals and Pushbuttons*:

   a. Treatment of pedestrian crossings, including pedestrian signals and pushbuttons, shall be in accordance with the Port Authority *Signalized Intersection Pedestrian Crossing Guidelines* (Appendix B) document.

   b. The use of pedestrian signal heads shall be determined on a site by site basis, according to guidance provided in the *MUTCD.*

   c. Pedestrian signal faces shall be LED units that display a solid Walking Person and Upraised Hand symbols in accordance with the symbol designs that are set forth in the *Standard Highway Signs and Markings Book* and the *MUTCD*. Symbol height shall be 11 inches.

   d. The use of pedestrian interval countdown displays shall be standard for all traffic signal designs. Any accessible pedestrian signals and detectors (e.g., audible tones, tactile arrows, vibrotactile devices, speech messages, etc.) may be considered if appropriate. If used, the requirements of *MUTCD* Chapter 4E shall apply.

   e. Pedestrian signal faces should be mounted eight feet above the sidewalk elevation. If site conditions warrant, pedestrian signals may be mounted to a maximum of 10 feet above the sidewalk elevation to improve visibility.

   f. Pedestrian pushbuttons shall be utilized based upon the following signal operational criteria:

      (i) Semi-Actuated Traffic Signals

      (a) Pushbuttons should be provided to actuate the pedestrian phases associated with minor street approaches equipped with vehicle detectors.
      (b) Pushbuttons are not required on the major street. The major street will operate with pedestrian recall.

      (ii) Fully-Actuated Traffic Signals

      (a) Pushbuttons should be provided on all approaches.

      (b) Pedestrian recall will not be provided in the signal operation.

      (iii)Fixed Time (Pre-Timed) Traffic Signals

      (a) No pushbuttons are needed.

      (b) Pedestrian recall should be provided for the major and minor streets.

   g. Where pedestrian signals are provided, pedestrian pushbuttons shall include signs (R10-3) with appropriate arrow indication [L or R] for crossing path mounted above the pedestrian pushbuttons. Other signs may be used if found to be more appropriate for the specific location.

   h. Where pedestrian signals are not provided, but pedestrian pushbuttons are used, signs (R10-4) shall be provided. The pushbuttons shall provide the minimum green time for a pedestrian crossing, in accordance with the current *MUTCD*.

i. Pushbuttons must be of the LED latching type.

j. Pedestrian pushbuttons should be capable of easy activation and conveniently located near each end of the crosswalk (per the *MUTCD*). Pushbuttons shall be placed between 1.5 feet and 6 feet from the curb face and should be no further than 10 feet from the curb face where physical constraints exist. As the pushbuttons must be accessible and installed in accordance with the *ADAAG/ PROWAG* reach ranges, extension of the sidewalk may be necessary to accommodate these requirements.

3. *Visors and Louvers*

a. Vehicular signal sections should be installed with open tunnel visors.

b. Where limiting of the horizontal visibility of a signal indication is required (adjacent approaches to an intersection join at an angle of 60 degrees or less), the use of straight vane louvers, geometrically programmed louvers, angle visors, electronic steerable beam traffic signal heads or other visibility limiting techniques should be considered. To avoid swinging, which may affect visibility, these signal heads shall be fix-mounted. Viewing angles for geometrically programmed louvers shall be shown on the contract drawings.

c. Where limiting of the visibility of a signal indication along a roadway (e.g. for closely spaced intersections), the use of straight vane louvers, geometrically programmed louvers, angle visors, electronic steerable beam traffic signal heads or other visibility limiting techniques should be considered. The designer shall specify the limit lines of visibility beyond which select indications shall not be visible.

E. Signal Phasing and Timing

1. When determining the number of signal phases and the use of protected versus protected/permitted left turn phases, the designer shall consider safety, capacity, geometric and traffic conditions. The use of protected and protected/permitted left turns shall be evaluated on a case-by-case basis. Traffic Engineering shall make the final determination.

2. Signal timing values shall be developed based on an operational analysis of the intersection.

3. Yellow and All–Red times shall be calculated based on the PANYNJ *Standard Clearance Calculation Forms* (Appendix C).

4. Pedestrian "Walk" and flashing "Don't Walk" times shall be calculated in accordance with the latest edition of the PA Pedestrian Intervals Worksheet.

5. The criteria for coordinated signals shall consider:

a. Improving throughput capacity along a roadway corridor.

b. Controlling queues at closely spaced intersections.

6. The phasing of the intersection should be such that any potential of a yellow-trap situation is eliminated.

7. The following information is to be provided as part of the signal timing:

a. Minimum Green time (initial): seven seconds minimum for turn slots and side street through movements; 15 seconds minimum for main street through movement.

b. Maximum Green time.

c. Yellow time.

d. All Red time.

e. Vehicle Extension (typically 2 sec.) for actuated phases.

f. Pedestrian "Walk" and flashing "Don't Walk" time for each pedestrian phase.

g. Timing plan number.

h. Cycle.

i. System offsets and reference point (for coordinated traffic signal systems only).

j. Time of day schedule.

k. When designing a traffic signal within the vicinity of an at-grade railroad (RR) crossing, it must be investigated whether RR pre-emption will be incorporated into the signal operation. Intersection and queuing analyses must be performed to determine if vehicles stopped at a red signal will queue onto the RR tracks. A pre-signal shall be utilized to prevent vehicles from queuing on RR tracks.

8. The new controller shall be compatible with the PA Centralized Traffic Signal Management System.

See *Traffic Signal Sample Drawings* (Appendix D) sheets SG011, SG014, SG017, SG020, and FAC-INT for sample signal timing formats.

F. Vehicle Detection

Detection shall be designed in accordance with the latest edition of the Institute of Transportation Engineers publication, *Traffic Detector Handbook.* Video detection is preferred if the following criteria can be met. Inductance loops or another technology may be considered based on existing or proposed conditions and deemed acceptable by Traffic Engineering.

1. Video Detection:

The following guidelines shall apply:

a. The video detection zone shall be centered in the respective lane(s) or approach to a multilane roadway.

b. See *Traffic Signal Sample Drawings* (Appendix D) sheets SG003, SG004 and SG005 for video detection sample layouts, spacing, offsets and numbering convention.

c. The designer shall complete the intersection actuation table; see *Traffic Signal Sample Drawings* (Appendix D) sheets SG012, SG015, and SG021 for sample format.

d. The placement of the video sensor for the respective areas of detection should be such that there is a clear and unobstructed view of the area so that any false calls are avoided. Installation must be in accordance with PA details.

e. The video sensor cable (VSC) for video detection shall run continuously from the camera to the detector card in the controller without splicing.

f. For any installation that will utilize video detection, a fully functional video detection system shall be provided and installed in the controller cabinet, including a mouse and a video monitor unit.

2. Inductance Loops:

The following guidelines shall apply:

a. Inductance loop detectors shall be designed using the following offsets:

(i) For lanes that are 12 feet or greater: 3 feet from face of curb or edge of roadway and 3 feet from adjacent lane.

(ii) For lanes that are 11 feet: 3 feet from face of curb or edge of roadway and 3 feet from adjacent lane.

(iii) For thorough / right lanes less than 10 feet: 2 feet from face of curb or edge of roadway and 3 feet from adjacent lane. For left turn lanes less than 10 feet: 2 feet from adjacent lane and 3 feet from opposing travel lane.

b. Inductance loops operating in presence mode shall be placed no more than 10 feet nor less than 2 feet behind the extended curbline of the intersecting roadway closest to the approach where detection is being placed.

c. If possible, do not design loops that are within one foot of any manhole, water valve or other appurtenance.

d. Calculate the appropriate inductance based on the number of turns for each loop detector as shown in *Traffic Signal Sample Drawings* (Appendix D) sheets SG012 and SG015.

e. A separate shielded lead–in cable (with drain wire) shall be specified for each loop that is installed. Lead-in cable shall be installed as a "home run" cable (i.e., no splices) from the splice box to the control cabinet.

f. See *Traffic Signal Sample Drawings* (Appendix D) sheets SG003, SG004 and SG005 for sample loop detector layouts, spacing, offsets and numbering convention.

g. The designer shall complete the intersection actuation table; see *Traffic Signal Sample Drawings* (Appendix D) sheets SG012 and SG015 for sample format.

h. Only one loop should be wired to each channel of the loop amplifier.

3. Emerging Technologies:

a. Alternate technologies may be considered after video detection and inductance loops have been evaluated and deemed ineffective for the site conditions.

G. Traffic Signal Pullbox and Splice Box Installations

1. Pullboxes shall be designed to accommodate traffic signal cables, conduit, and cables for interconnect communication.

2. Splice boxes shall be utilized for splicing inductance loop detectors to loop detector leads.

3. Pullboxes and splice boxes should be designed so that entering conduit runs are as straight as possible.

4. Pullboxes shall be used whenever there is a change in direction of the conduit runs.

5. For long conduit runs (e.g., communication and/or interconnect cable), pullboxes should be installed every 500 feet.

6. Pullboxes shall be designed and located to accommodate up to 6 conduit run terminations.

7. Pullboxes and splice boxes shall be designed using the following conditions to facilitate signal cable or loop detector installation and future signal modification:

a. Pullboxes shall be installed adjacent to signal poles and controller cabinets to provide access to these facilities.

b. Pullboxes shall be installed on each end of conduits installed under paved roadways.

c. Splice boxes shall be installed on intersection approaches that include multiple inductance loop detector installations to provide a suitable location for splicing roadway loop wires to loop lead-in cables.

H. Conduit Type, Size and Installation

1. Conduits shall be either concrete encased PVC (RNMC-C), rigid galvanized steel (RGS) or flexible steel (FSC) and designed using the following criteria:

a. Traffic signal conduit installed underground between pullboxes shall have a minimum of two – 3" diameter PVC conduits encased in concrete. For locations where conduit fill or excessive conduit terminations is an issue, 4" diameter conduits may be used.

b. Traffic signal conduits installed between signal foundations and pullboxes shall confirm to the following:

   (i) One – 4" diameter PVC conduit encased in concrete for steel and aluminum mast arm poles.

   (ii) One – 3" diameter PVC conduit encased in concrete for pedestal poles.

   (iii)Two – 3" diameter PVC conduit encased in concrete for span wire poles.

c. A minimum of three and a maximum of four conduits shall be installed between controller cabinets and adjacent pullboxes. Can use 3" or 4" diameter PVC conduit as required.

d. Traffic signal conduit installed above ground shall be rigid galvanized steel (RGS) to match the size of the underground conduit.

e. Interconnect and/or communication conduit shall be a minimum of 3" diameter PVC.

f. Detector conduit at curb shall be a minimum of one – 1.5" diameter FSC, installed thru-curb, and accommodate up to 3 inductance loop detectors. If more than 3 inductance loop detectors need accommodation, two – 1.5" conduits shall be installed through the curb.

g. Detector conduit between loop splice boxes and signal pull boxes shall be 1.5" diameter RGS.

h. A separate conduit shall be installed for service power. Conduit for electrical service shall be in accordance with the utility supplying electricity to the intersection and should be coordinated with PA Electrical Engineering.

i. All conduit runs crossing a road shall contain an empty conduit.

2. Conduit sizes shall be determined based on a maximum percent fill of 40%, in accordance with the *National Electrical Code (NEC)*.

3. Grounding of the underground conduit system shall be in accordance with the *National Electrical Code (NEC)*. All grounding shall terminate at the traffic control cabinet's grounding bus. Conduit for loop detector lead does not need grounding.

4. Ground wire is to be installed continuous throughout the traffic signal system and secured to all ground rods, cabinets, pull boxes and traffic signal bases as noted.

5. Conduit runs should be designed to avoid field bends to the greatest extent possible.

6. A conduit run separate from those carrying voltage conductors is required for communication and/or interconnect.

See *Traffic Signal Sample Drawings* (Appendix D) sheets SG010, SG013, SG016, and SG019 for sample formats.

I. Traffic Signal Cable Types and Usage

1. The standard conductor size for traffic signal cable applications shall be #14 AWG. Voltage drop calculations shall be performed for the longest cable runs. In cases where the voltage drop exceeds five percent, the conductor size for traffic signal cable shall be #12 AWG. The cable shall be continuous from the base of the traffic signal support to the controller without any splices.

2. Traffic signal conductors shall be assigned in accordance with the wire color codes shown in the Master PA Specification List.

3. Cable assignments shall be shown in the block wiring diagram on the Traffic Signal Wiring drawing. The block wiring diagram shall indicate the cable letter for each cable extending from the controller to the traffic signal pole. The letters shall be assigned sequentially to cables terminating at the signal pole farthest from the control cabinet first, then the second farthest, etc. See *Traffic Signal Sample Drawings* (Appendix D) sheets SG010, SG013, SG016, and SG019 for sample formats.

4. All wires connected to the controller shall be shown in a block wiring diagram, as depicted on *Traffic Signal Sample Drawings* (Appendix D) sheets SG010, SG013, SG016, and SG019.

5. Vehicular and pedestrian traffic signal heads and pushbuttons shall not be wired together.

6. A separate neutral shall be provided for each phase and overlap of the vehicular signals.

7. The designer shall calculate the wire fill of all conduits to ensure conformance to the *National Electrical Code (NEC)*. A Conduit Fill Calculation form must be completed and submitted with the design. The following cable areas shall be used:

Cable	Cross Sectional Area	
	#14 AWG	#12 AWG
10/C	0.322 sq. in.	0.383 sq. in.
5/C	0.166 sq. in.	0.198 sq. in.
2/C	0.105 sq. in.	0.124 sq. in.
Ground Wire # 8 AWG (Insulated)	0.056 sq. in.	
Loop Detector Lead (LDL) #14 AWG	0.091 sq. in.	
Video Sensor Cable (VSC)	0.200 sq. in.	

8. The designer shall observe the following criteria:

   a. For mast arm installations, all signal indications should be wired individually on a 10/C cable.

   b. For span wire installations, all signal indications should be wired individually on a 10/C cable or a 5/C cable as required. One spare 10/C cable shall be run across the entire span.

   c. All pedestrian indications shall be individually wired on 5/C cable.

d. All pushbuttons shall be individually wired on a 2/C cable.

e. If the above criteria cannot be met due to existing or proposed constraints, the following may be considered:

(i) 3-Section signal heads that would never be considered in the future to be changed to 4 or 5 section heads can be wired on a 5/C cable.

(ii) Signal indications on the same phase can utilize the same cable. Signal indications for opposing phases should not be wired on the same cable.

(iii) Neutrals can be shared on signal heads of the same phase.

J. Uninterruptable Power Supply (UPS)

UPS requirements vary per facility. The designer shall contact the facility electrical maintenance shop for UPS requirements for every project.

Section 11 - Temporary/Portable Traffic Signals

A temporary traffic control signal is generally installed to help control conditions that are a result of construction activities and they typically use methods that minimize the costs of installation, relocation, and/or removal. Temporary traffic control signals may be portable or temporarily mounted on fixed supports. Portable Traffic Signals are temporary traffic control signals mounted on a moveable trailer and can be used for short or long term temporary traffic control situations. Temporary traffic control signals are subject to all the same requirements as permanent traffic signals and must be in conformance with the current MUTCD, as well as this document. Any required temporary traffic control signal equipment outside of the Port Authority's jurisdiction must be reviewed and approved by the respective jurisdictional agency prior to implementation.

1. Any installation of a Temporary or Portable Traffic Control Signal will require that an engineering study (Section 5) be prepared and the PANYNJ's *Traffic Signal Authorization Form* (Appendix A) be completed, noting any design exceptions. This form must be completed, approved and signed by the appropriate parties prior to installation. For signalization of an intersection, a Warrant Analysis must also be prepared in accordance with the MUTCD and the guidelines contained herein.

2. The designer is expected to develop temporary traffic control signal designs utilizing these guidelines and the other publications referenced herein. Temporary and Portable Traffic Signal plans shall be prepared showing the temporary traffic control signal layout, striping, signing, phasing, timing, vehicle detection, controller cabinet, and any necessary wiring, pullboxes, and conduits. The signal phasing and timing shall be prepared based upon capacity analysis. Any associated foundations and structures shall be designed in accordance with the *Traffic Signal Standard Details*.

3. Portable Traffic Signals are temporary traffic signals mounted on a moveable trailer. They are subject to all the same requirements as permanent traffic signals and must be in conformance with the current MUTCD (see Section 4D.32), and the following guidelines:

a. A temporary and/or portable traffic signal will be utilized under the following conditions:

(i) When roadway construction or other work requires the temporary disconnection or removal of any existing signal equipment such as vehicular signal heads, detectors, pedestrian signal heads and pushbuttons, poles, and controller cabinets, which is necessary to provide for a safe operation at the particular location;

(ii) When existing signal equipment is removed from a location, but the required permanent replacement signal equipment is not yet operational;

(iii) When signal operation is necessary for a location, but the related permanent signal equipment is not yet operational; or

(iv) Where engineering judgment indicates that installing the signal will improve the overall safety and/or operation of the location in direct relation to the construction activities being performed.

b. Portable traffic signals are not intended for permanent use. Any installations that remain in operation beyond six (6) months need to be re-evaluated and the Chief Traffic Engineer must approve their extended use.

c. Typically, portable traffic signals are deployed in the following two conditions:

(i) Knock-down of existing traffic signal

(ii) Temporary Traffic Control

(a) Intersections

(b) Flagger/Lane Closures

4. A temporary and/or portable traffic signal shall meet the following:

a. Meet the physical display and operational requirements of a conventional traffic signal;

b. Be removed when no longer needed;

c. Be placed in the flashing mode when not being used if it will be operated in the steady mode within 5 working days, otherwise it shall be removed;

d. Be placed in the flashing mode during the period when it is not desirable to operate the signal, or the signal heads shall be covered, turned, or taken down to indicate that the signal is not in operation.

5. Prior to installing any portable traffic signal, the following shall be evaluated:

   (i) Field inventory to determine the most appropriate location for the portable signal trailer, including adequate visibility for approaching motorists, level and clear area on stable ground for the trailer, and proximity to adjacent intersections and driveways.

   (ii) Traffic observations, including traffic volumes and speed of vehicles.

6. Visual confirmation of the state of the portable signals and a fault alarm indicator capable of sending an email and text alert must be provided for each portable traffic signal unit.

Section 12 - Traffic Signal Equipment Numbering Convention

Traffic Signal displays shall be numbered in accordance with the following convention for vehicular and pedestrian signal faces. Intersections shall be orientated on the drawings with the northerly direction pointing either up or to the right. The major road must always run horizontal on the plan sheet.

A. For main line arterials with an east-west orientation, vehicular signals shall be numbered using the priorities indicated below (as shown in Figure 1 and Figure 2). Signal faces shall be numbered from left to right on all approaches:

   Priority 1: Signal indications for eastbound traffic

   Priority 2: Signal indications for westbound traffic

   Priority 3: Signal indications for northbound traffic

   Priority 4: Signal indications for southbound traffic

Pedestrian signal displays shall be numbered using the priorities indicated below and shall have a "P" prefix to identify them as pedestrian signals. Pedestrian Pushbuttons shall be numbered utilizing the above convention with a "PB" prefix. The face numbers shall be assigned with the same priorities as vehicle signals, and shall be numbered from left to right (from an approaching vehicle perspective) concurrent with the respective vehicle signal priorities:

   Priority 1: Southerly Crosswalk

   Priority 2: Northerly Crosswalk

   Priority 3: Easterly Crosswalk

   Priority 4: Westerly Crosswalk

MAJOR STREET
EAST-WEST ORIENTATION

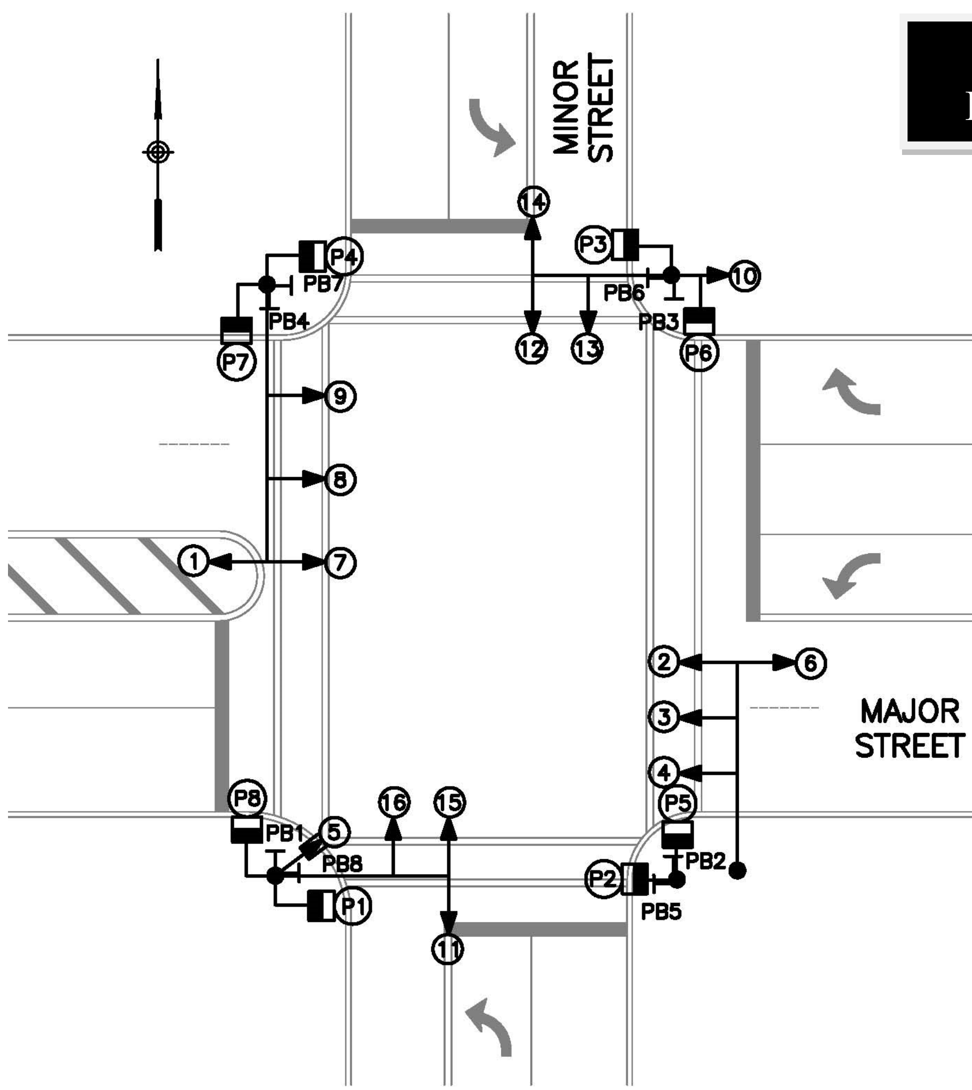


Figure 1: Traffic Signal Numbering Convention - Mast Arm Installation

NOTE:
Pedestrian pushbuttons shall be visible to pedestrians waiting to cross. The pedestrian signs shall show the arrow pointing to the crosswalk actuated by the respective pushbutton.

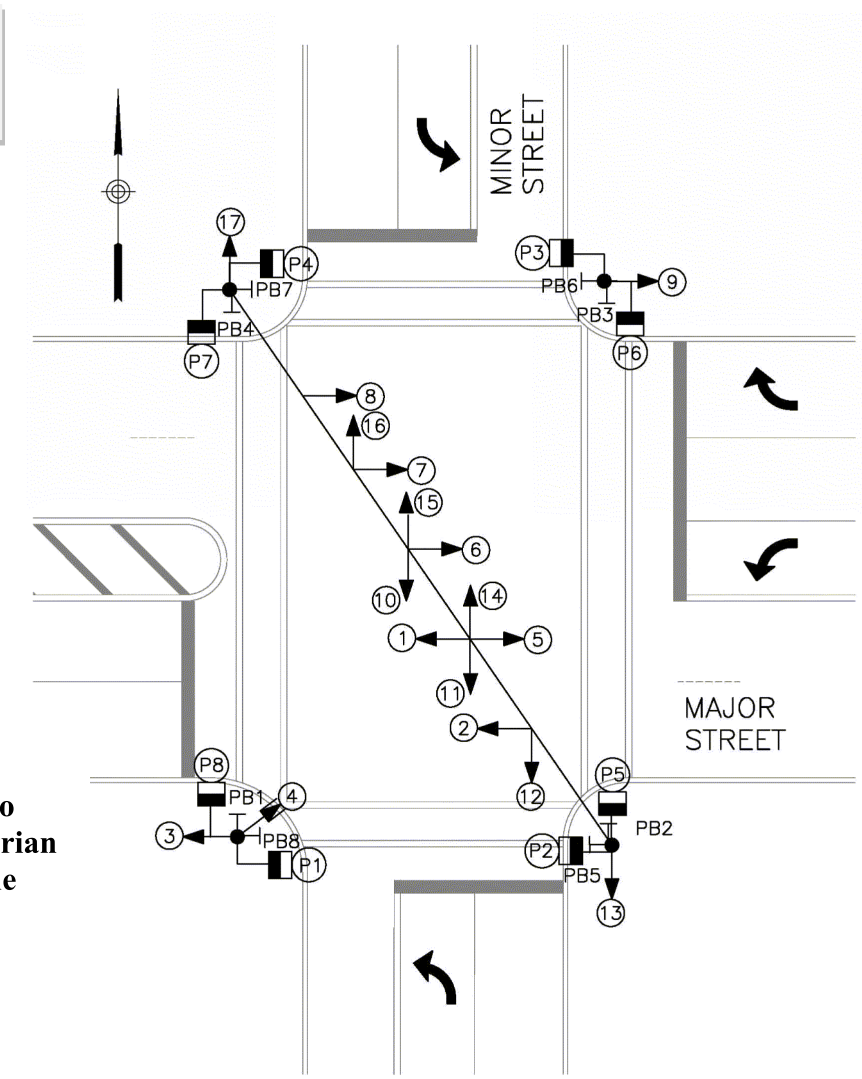


Figure 2: Traffic Signal Numbering Convention – Span Wire Installation

B. For main line arterials with a north-south orientation, vehicular signals shall be numbered using the priorities indicated below (as shown in Figure 3 and Figure 4). Signal faces shall be numbered from left to right on all approaches:

Priority 1: Signal indications for northbound traffic

Priority 2: Signal indications for southbound traffic

Priority 3: Signal indications for westbound traffic

Priority 4: Signal indications for eastbound traffic

Pedestrian signal displays shall be numbered using the priorities indicated below and shall have a "P" prefix to identify them as pedestrian signals. Pedestrian Pushbuttons shall be numbered utilizing the above convention with a "PB" prefix. The face numbers shall be assigned with the same priorities as vehicle signals, and shall be numbered from left to right (from an approaching vehicle perspective) concurrent with the respective vehicle signal priorities:

Priority 1: Easterly Crosswalk

Priority 2: Westerly Crosswalk

Priority 3: Northerly Crosswalk

Priority 4: Southerly Crosswalk

MAJOR STREET
NORTH-SOUTH ORIENTATION

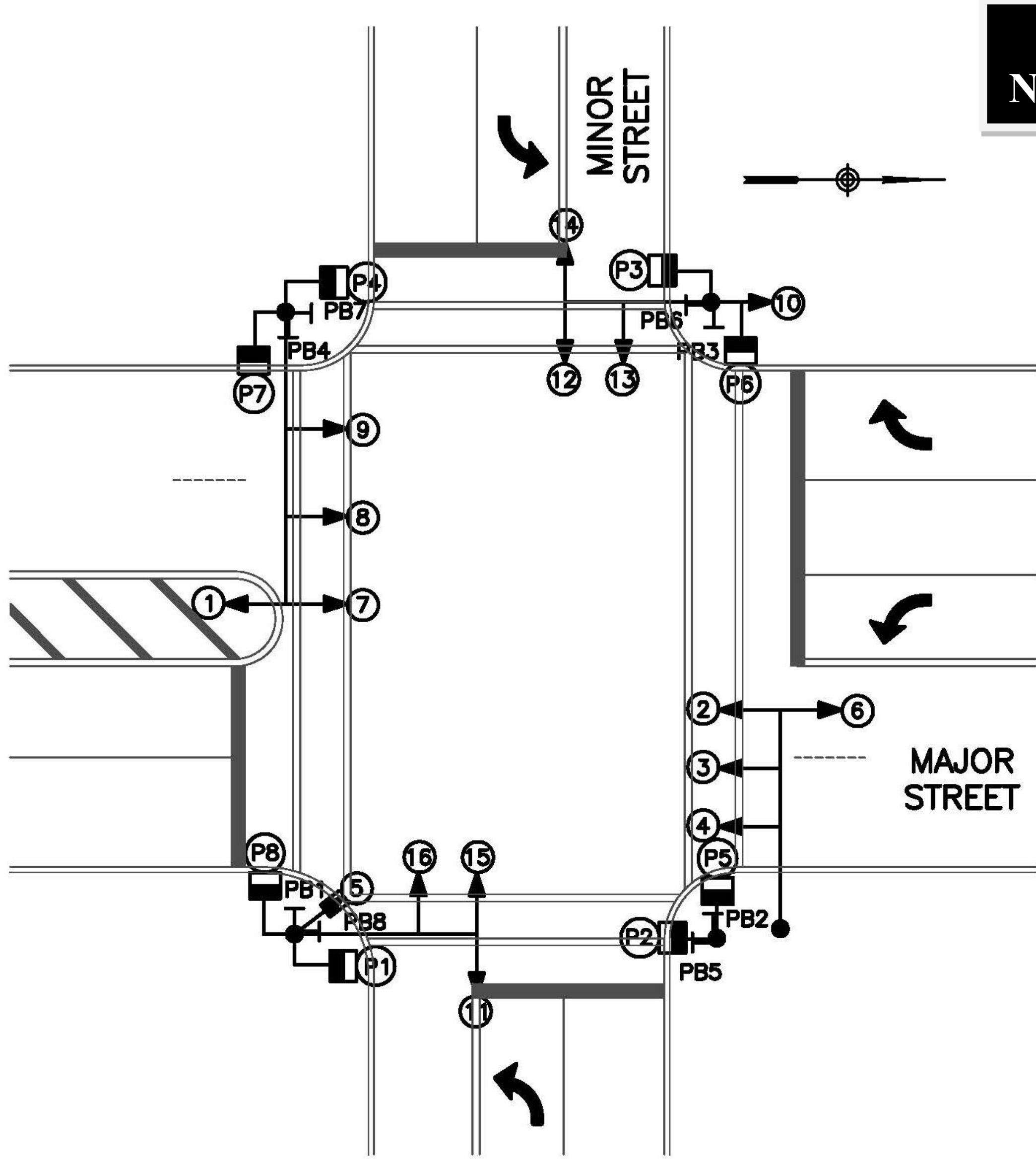


Figure 3: Traffic Signal Numbering Convention - Mast Arm Installation

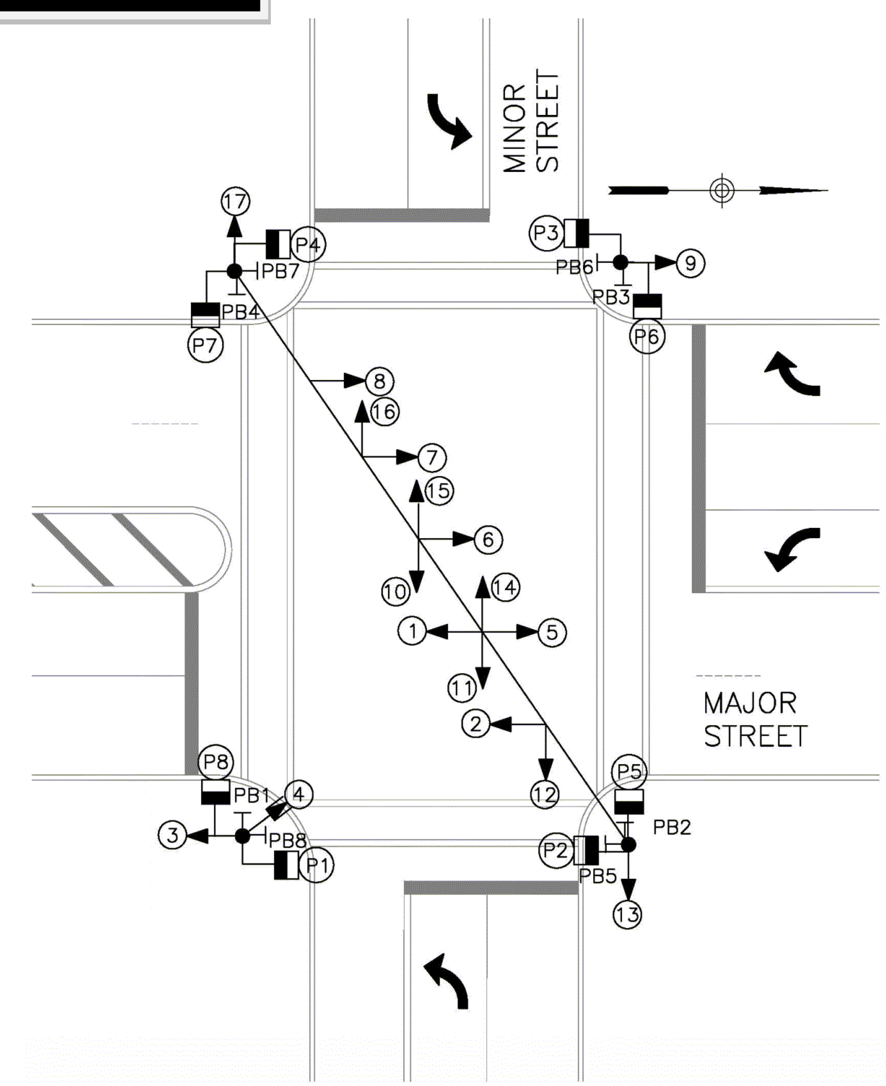
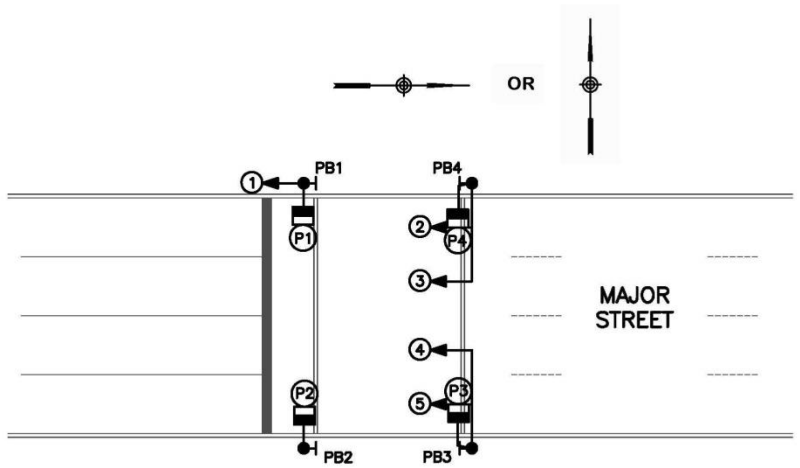


Figure 4: Traffic Signal Numbering Convention – Span Wire Installation

C. For mid-block crossings, the numbering convention for vehicle and pedestrian signals shall follow the above priorities based on the orientation of the arterial (see Figure 5).



Section 13 - Traffic Signal Detection Numbering Convention

The number assigned to each intersection area of detection or detector shall be formatted as follows:

A. Video

First Digit: (V) for video detector

Second Digit: (X) for NEMA phase

Third Digit: (N) for camera number (which should follow the vehicular priority convention)

Fourth Digit: (Y) for detection zone

B. Inductance Loop

First Digit: (D) for detector.

Second Digit: (X) represents the NEMA phase number associated with the detector.

Third Digit: (N) represents the detector unit number associated with each phase (one, two, three, etc.).

Fourth Digit: (Z) represents the detector unit channel assigned to the detector (one or two).

Section 14 - Traffic Signal Details

All Traffic Signal Design Contracts should have a complete set of construction details. The Traffic Signal Standard Details, as included in *Design Guidelines - Traffic* should be used as a baseline and should be modified accordingly to meet the requirements of the design.

Section 15 - Sample Notes

All Traffic Signal Design Contracts should include General Notes on the first page. The Traffic Signal Standard General Notes, as included in *Design Guidelines - Traffic* should be used and should be modified accordingly to meet the requirements of the design.

Section 16 - Sample Plans

Reference the Traffic Signal Sample Drawings, as included in *Design Guidelines - Traffic* for guidance on how Traffic Signal Plans should be prepared.

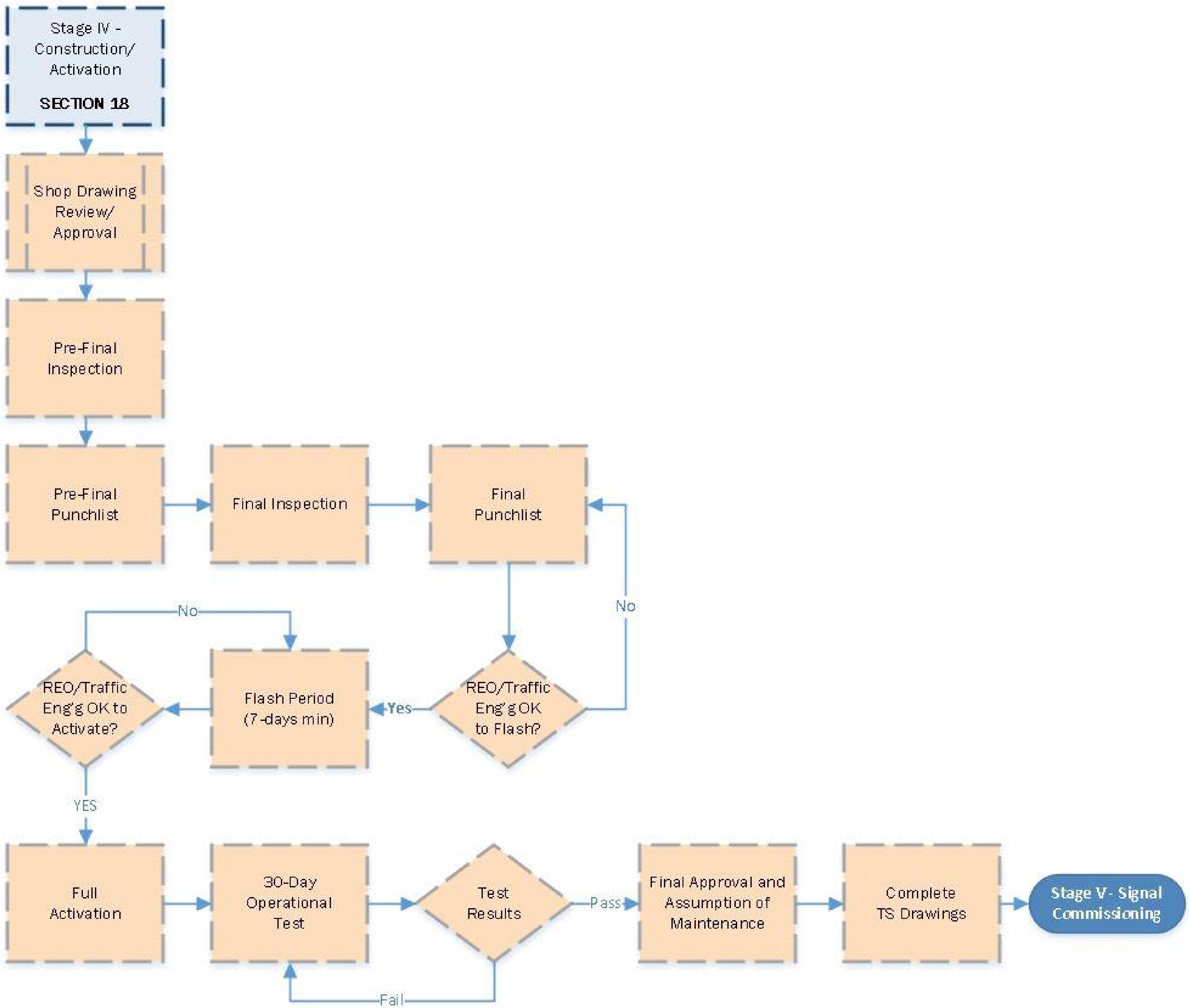
Section 17 - Specifications

Based on the Master PA Specification List, the designer shall select all appropriate specifications for each project, which will include all traffic signal items for all disciplines (i.e. specifications for traffic, civil, structural, and electrical). If required for non-standard items, a custom "C Spec." must be prepared.

Reference the Traffic Signal Specifications, as included in *Design Guidelines - Traffic* for the most recent specifications.

Section 18 - Construction (Stage IV)

It is the responsibility of the designer to provide the Installation and Approval of Traffic Signals spreadsheet (Appendix H) to the REO prior to the start of the project. Note #1 of the Traffic Signal Standard Notes, included in the Design Guidelines- Traffic, must be reviewed by the REO and the contractor prior to the start of the project.



A. Shop Drawing Review and Approval

Traffic Engineering will review, comment on, and provide approval or rejection of shop drawings during construction (Stage IV). Submittal and review of shop drawings will conform to the contract requirements established by the PA Project Manager.

B. Preparing a Traffic Signal for Full Activation:

As construction of the new traffic signal is nearing completion, and before activation of permanent operation, the following procedures and limitations shall be followed:

I. Traffic signal heads shall not be installed more than four weeks in advance of the scheduled traffic signal activation.

II. All traffic control signal heads shall remain covered until activation of permanent operation.

III. The activation of new traffic control signals shall not occur:

   a. On Fridays, on or the day before a public holiday;

   b. During peak hours of traffic flow;

   c. During serious inclement weather (snow, heavy rain, or fog); or

   d. Other times when follow-up troubleshooting could be difficult to schedule.

IV. Traffic control signal timing data, including coordination-timing plans, where applicable, shall be prepared by Traffic Engineering. The timing shall be entered into the controller and tested before being implemented in the field.

V. "SIGNAL AHEAD" warning signs shall be installed on all high volume, major and minor roadway approaches to warn drivers of the new traffic signal. These signs shall remain covered until the traffic signal is activated.

C. Pre-Final/Turn-On Inspection:

The Resident Engineer's Office (REO), with the help of Traffic Engineering, will conduct the Signal Pre-Final/Turn-On inspection. Notification must be given to all involved parties at least two weeks in advance of the inspection date.

The REO will notify the PA Police of the scheduled Signal Pre-Final/Turn-On Inspection. The inspection will be performed using the *Signal Inspection Checklist* (Appendix F). A Pre-Final Punch List will be generated from the inspection, which will list all the items that must be corrected by the contractor before the final inspection. The REO requires that the engineer-of-record, controller representative, and the contractor attend the Pre-Final/Turn-On Inspection.

D. Final Inspection:

The Resident Engineer's Office (REO), with the help of Traffic Engineering, will conduct the Signal Final/Turn-On inspection. Notification must be given to all involved parties at least two weeks in advance of the inspection date. The purpose of this inspection is to verify that the Pre-Final Punch list items have been addressed and to determine if any additional items need to be addressed.

The REO will notify the PA Police of the scheduled Signal Final Inspection. The inspection will be performed using the *Signal Inspection Checklist* (Appendix F). If required, a Final Punch list will be generated from the inspection, which will list all the items that must be corrected by the contractor before the signal can be placed in flashing operation. The REO requires that the engineer-of-record, controller representative, and the contractor attend the Final Inspection.

E. Flashing Operation:

After the Signal Final Inspection, REO/Traffic Engineering will determine if the signal can be placed on flash (yellow-red) prior to starting the permanent operation. A flashing phase will be required for a period of seven (7) days. For a period of two weeks, portable VMS shall be used on all approaches to the intersection to warn motorists of the new traffic pattern.

F. Full Activation:

After successful completion of the flashing period, Traffic Engineering will recommend to REO when the traffic signal should be activated into permanent operation. REO requires that the engineer-of-record, controller representative, and contractor attend the activation of the signal into permanent operation. The following procedures shall be used to activate the traffic signal:

I. If used, "SIGNAL AHEAD" warning signs shall be uncovered as the traffic signal is activated.

II. Once the traffic signal is in permanent operation, it shall be coordinated with adjacent traffic control signals immediately, if applicable and where feasible.

G. 30-Day Operational Test:

Upon completion of the punch list items to the satisfaction of the REO with input from Traffic Engineering, the 30-day operational test period will begin. If the signal does not pass the operational test, modifications to the signal must be made as appropriate. Upon completion of the modifications, the 30-day operational test period will restart. This will be repeated until the signal passes the operational test.

H. Final Approval and Assumption of Maintenance:

Upon successful completion of the 30-day operational test, the Chief Traffic Engineer will issue written acceptance approval. The PA will assume responsibility of the maintenance and operation of the Traffic Signal once all involved parties have given their approvals.

I. Complete TS Drawings

Upon Final Approval and Assumption of Maintenance, a Stage IV Final Record Traffic Signal (TS) Drawing and signal timing are to be prepared and shall reflect the final field conditions to be approved by Traffic Engineering. See Intersection Number FAC-INT drawing for Sample Final Record TS drawing and Traffic Signal Timing

J. Final Asset Commissioning:

Upon final acceptance of the traffic signal installation, the *Asset Commissioning Form* (Appendix E) is to be completed.

Appendix A – Traffic Signal Authorization Form

REQUEST FOR THE INSTALLATION, MODIFICATION, OR REMOVAL OF TRAFFIC CONTROL SIGNALS

THE PORT AUTHORITY OF NY & NJ

Facility ____________ Location ______________________________

☐ New Signal ☒ Intersection
☐ Modification ☒ Mid-block
☒ Remove Signal ☐ Other

Reason for this request.

As per the standard set forth in the Manual on Uniform Traffic Control Devices (MUTCD), an engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location to determine whether removal or installation of a traffic control signal is justified was performed. This study included an analysis of the traffic signal warrants, which describes the minimum conditions under which installing a traffic control signal might be justified. The results of the traffic signal warrant analysis are attached and is summarized below:

Warrant 1: Eight-Hour Vehicular Volume	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 2: Four-Hour Vehicular Volume	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 3: Peak Hour	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 4: Pedestrian Volume	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 5: School Crossing	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 6: Coordinated Signal System	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 7: Crash Experience	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 8: Roadway Network	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable
Warrant 9: Intersection Near Grade Crossing	☐ Satisfied	☐ Not Satisfied	☒ Not Applicable

Other conditions under which decommissioning traffic control signals might be justified based on engineering judgment.

Required attachments.
- ☐ A – Location Map
- ☐ B – Detailed Layout of Intersection (30 Scale)
- ☐ C – Photos of all approaches
- ☐ D – Traffic Signal Warrant Analysis
- ☐ E – 24-Hour ATR Counts for all approaches
- ☐ F – Peak Hour Manual Turning Movement Counts by classification

Other attachments (if applicable).
- ☐ G – Peak Hour Pedestrian Counts
- ☐ H – Delay Calculations
- ☐ I – Crash Data Summary
- ☐ J – Collision Diagram
- ☐ K – Projected Traffic Data for New Intersection
- ☐ L – Analysis supporting engineering judgment

Recommendation:

Requested by: ______________ Principal Traffic Engineer ______
Title Date

Reviewed by: ______________ Principal Traffic Engineer ______
Title Date

Approved by: ______________ Chief Traffic Engineer ______
Rizwan Baig, P.E., PTOE Title Date

Att.
Copy To: Michael Diculescu, (TE Facility Ops Representative)

Appendix B – Signalized Intersection Pedestrian Crossing Guidelines

THE PORT AUTHORITY OF NY & NJ

SIGNALIZED INTERSECTION PEDESTRIAN CROSSING GUIDELINES

APRIL 2016

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INTRODUCTION

There are approximately 140 signalized intersections under the jurisdiction of The Port Authority of New York & New Jersey (PANYNJ). These intersections are owned, operated and maintained by the PANYNJ and are located in some of the most heavily traveled facilities in the country. These facilities include diverse land uses such as airports, tunnels and ports. Each facility experiences its own unique mix of tourist, commuter and heavy truck traffic.

To maintain consistency along PANYNJ roadways across all types of facilities, PANYNJ Traffic Engineering has prepared these guidelines to assist in navigating general design parameters and requirements for the installation of pedestrian treatments at PANYNJ signalized intersections. These guidelines are an update to the strategy previously developed by PANYNJ and combines the practices found in an earlier national survey of other agencies, industry guidance documents, peer-reviewed research and local knowledge of PANYNJ facilities. The content of these guidelines are not intended to conflict with or contradict any Federal, State, or City code or regulation, but rather serves as the outline for PANYNJ procedures to aid in the design of PANYNJ facility projects.

Installation of new traffic signals or modification to existing traffic signals requires prior approval from the Chief Traffic Engineer. This includes installation or modification of pedestrian treatments. In accordance with the requirements set forth in the ***Port Authority Intersection Signalization Procedures***, prior to any installation or modification to a traffic signal, including pedestrian treatments, a written request shall be submitted to the Chief Traffic Engineer. For PA Engineering staff and Facility Managers, this can be in the form of a letter, memo or e-mail. For other agencies, government officials or the media, the request shall be submitted on official agency letterhead. Any requests by the general public shall be in the form of a letter that contains the name, phone number and return address of the requestor.

A. BACKGROUND

The following section describes the PANYNJ facility characteristics and provides an overview of industry guidelines/best practices and definitions pertaining to pedestrian facilities, signal operations, pedestrian operations and behaviors that will help define the process for PANYNJ crosswalk and pedestrian actuation treatment selection described in Section B of this guideline.

1. PA FACILITY CHARACTERISTICS

The PANYNJ operates and maintains various facilities throughout the NY/NJ metropolitan area, which each have a unique set of roadway and usage characteristics. The following is a summary of each unique roadway type:

AIRPORT FRONTAGE ROADWAYS

Roadways that pass along the terminals (arrival and departure) of an airport facility are referred to as Airport Frontage Roadways. These roadways experience large traffic volumes made up of passenger vehicles, taxis/limousines, shuttle buses and transit buses. These vehicles are often times traveling along these roadways to drop off or pick up passengers using the airport departure or arrival gates. As such, there is typically a heavy volume of pedestrians along these roadways and in many instances, many pedestrians are crossing these roadways to access parking garages, bus/shuttle stops or other pedestrian generators.

AIRPORT CENTRAL TERMINAL AREA ROADWAYS

Roadways that circulate around airport terminals are referred to as Central Terminal Area Roadways. These roadways experience large traffic volumes made up of generally the same passenger vehicles, taxis/limousines, shuttle buses and transit buses looking ultimately to access the Airport Frontage Roadways, the surrounding parking or rental car facilities or to exit the airport property. Mostly, these roadways are away from the large pedestrian generators and therefore experience low pedestrian activity.

AIRPORT CARGO AREAS

Roadways that surround the airport facility but are not directly utilized to access passenger terminals are referred to as Airport Cargo Roadways. These roadways are utilized to connect airports cargo facilities and other airport properties such as administrative buildings. These roadways experience normal vehicle volume peaks throughout a 24-hour period and sometimes have an above average percentage of heavy truck usage. The pedestrian activities in these areas vary greatly and are primarily tied to the generators in the area.

BRIDGE AND TUNNEL APPROACH/DEPARTURE ROADWAYS

Roadways that directly service the entrance and exit of bridge and tunnel facilities are referred to as Bridge or Tunnel Approach/Departure Roadways. The PANYNJ bridge and tunnel facilities experience very high vehicular volumes throughout the day, particularly during commuter business peaks and weekend recreational periods. Generally, pedestrians avoid these locations. However, the bridge and tunnel facilities are located near walkable, urban communities with high pedestrian volumes so it is important to focus on pedestrian safety at these facilities.

PORTS ROADWAYS

Roadways that are within port commerce facilities are referred to as Ports Roadways. These roadways are critical to the movement of goods from port terminals facilities to the regional highway and railroad system. These roadways experience high volumes with a large heavy vehicle percentage which are tied to the fluctuating shipping schedules. High speeds and aggressive driving are common on these roadways. While the pedestrian activities also vary greatly in these areas as many pedestrians do not utilize the roadways for circulation, bus stops and "lunch trucks" sometimes generate moderate pedestrian volumes.

2. PEDESTRIAN ACCOMMODATIONS

There are various pedestrian accommodations that can be used to increase mobility and safety of pedestrians along roadways and at intersections. The following section describes some of these features.

CROSSWALK STRIPING

Pedestrian crosswalks help alert road users of a designated pedestrian crossing location. When installed under appropriate conditions, they can improve safety for pedestrians crossing a roadway. There are many established guidelines regarding when, how, and in what situations to mark a crosswalk. Some of these guidelines include the following:

- FHWA – Manual on Uniform Traffic Control Devices (MUTCD)
- NYSDOT – Highway Design Manual: Chapter 18 – Pedestrian Facility Design
- National Association of City Transportation Officials (NACTO)
- Americans with Disabilities Act of 1990 (ADA)
- Public Rights-of-Way Accessibility Guidelines (PROWAG)
- Uniform Vehicle Code (UVC)

PEDESTRIAN PUSH BUTTONS

Pedestrian push buttons are electronic buttons, which when pressed by a pedestrian, send a signal to the traffic signal controller to change the traffic signal timing to accommodate pedestrian movements across the street. There are many different types of push buttons and placement of push buttons is generally controlled by the MUTCD and PROWAG. The use of pedestrian push buttons is a function of the desired traffic signal and pedestrian operation.

PASSIVE PEDESTRIAN DETECTION SYSTEM

Passive detection devices register the presence of a pedestrian in a position indicative of a desire to cross, without requiring the pedestrian to push a button. Some passive detection devices are even capable of tracking the progress of a pedestrian as the pedestrian crosses the roadway for the purpose of extending or shortening the duration of certain pedestrian timing intervals. Typically video, infrared, or microwave detection based technologies are used and some agencies have even successfully deployed pressurized mats for passive detection.

PEDESTRIAN SIGNAL HEADS

According to the MUTCD, "Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK), an UPRAISED HAND (symbolizing DONT WALK) and a COUNTDOWN indication (showing the remaining time to cross)." All use of pedestrian signal heads, and the associated traffic signal timing development, shall be in strict conformance to the MUTCD.

ACCESSIBLE PEDESTRIAN SIGNALS (APS)

APS provide pedestrians with information in non-visual formats such as audible tones and messages, vibrating surfaces and braille messages. APS is meant to provide the same message to all users and especially those with disabilities.

With the increased push for safety via the Americans with Disabilities Act (ADA), and adoptions of policy measures of Public Rights-of-Way Accessibility Guidelines (PROWAG) into the future Manual on Uniform Traffic Control Devices (MUTCD), accessible pedestrian signals (APS) are on the verge of becoming the industry standard throughout the United States.

CURB RAMPS

Curb ramps are depressions in the curb height to allow all roadway users, particularly those in wheelchairs, access between the roadway and sidewalk facilities. As mentioned above, with the increased focus on ADA and PROWAG, all curb ramps shall be designed with strict conformance to these documents.

SIGNING

Signing specific to the pedestrian facilities can be found in Chapter 2 of the MUTCD. These pedestrian regulatory and warning signs should be used wherever feasible to increase pedestrian safety and visibility.

3. VEHICULAR SIGNAL OPERATION

Traffic Signals can operate in a variety of ways and it is important to consider the traffic signal operation and phasing when determining the appropriate pedestrian treatment.

FIXED TIME OPERATION

Traffic Signals that are in a "fixed time" operation do not have vehicular detection. In many cases, these signals utilize a background cycle length and can be coordinated with other intersections along a corridor. Pedestrian indications can be utilized to assist pedestrians in crossing the intersection but push buttons are not needed to activate the pedestrian crossing phase since it is automatically provided during each cycle of the signal. Fixed time operation is the least efficient operation as it is not responsive to vehicular demand.

SEMI-ACTUATED OPERATION

Traffic Signals that are in a "semi-actuated" operation usually have vehicular detection on side streets and/or turning lanes. This actuation allows the traffic signal to operate more efficiently by limiting green time to "detected" approaches and reallocating time to the main line.

FULLY-ACTUATED OPERATION

Traffic Signals that are in a "fully-actuated" operation have vehicular detection on all approaches. By detecting all approaches, the traffic signal operates more efficiently by allocating the appropriate green time to the approaches based on current vehicular demand.

ADAPTIVE OPERATION

Traffic Signals that are in an "adaptive" operation typically have additional technology that allows it to assess traffic demand and generate real time timing directive and/or phasing modifications to most efficiently deal with traffic conditions. Typically, adaptive operation requires detection on all approaches and sometimes at mid-block locations.

4. PEDESTRIAN OPERATION

Traffic Signals can also operate in a variety of ways with respect to pedestrian actuation and it is important to consider the pedestrian operation during the signal design process.

PEDESTRIAN RECALL

Traffic Signals are in a "Pedestrian Recall" operation when the controller automatically places a pedestrian call during each cycle. During this condition, pedestrian indications are activated automatically. The corresponding green times are automatically extended to ensure that the appropriate "Walk" and "Pedestrian Clearance Intervals" are satisfied.

SEMI-ACTUATED PEDESTRIAN PHASE

Traffic Signals that are in a "Semi-Actuated Pedestrian" operation require actuation by the pedestrian to cross the unactuated approach (typically main line). Actuation provides a call to the controller which brings up and/or extends the side street green time to satisfy the necessary "Walk" and "Pedestrian Clearance Intervals." Side street pedestrian indications are automatically displayed with the non-actuated main line movement phasing. Green time on the main line is calculated such that it will accommodate the "Walk" and "Pedestrian Clearance Intervals" during each phase.

FULLY-ACTUATED PEDESTRIAN PHASE

Traffic Signals that are in a "Fully-Actuated Pedestrian" operation require actuation by pedestrians to cross every approach. Actuation provides a call to the controller which extends the approach's green time to satisfy the necessary "Walk" and "Pedestrian Clearance Intervals."

EXCLUSIVE PEDESTRIAN PHASE

Traffic Signals that have an "Exclusive Pedestrian Phase" provide a dedicated phase for pedestrians to cross while all vehicular indications are stopped with a red indication. This phase can be initiated by actuation of a push button or pedestrian recall mode. Exclusive pedestrian phases are utilized in the industry at locations requiring special treatment of pedestrian movements based on engineering judgment and need.

LEAD PEDESTRIAN PHASE

Traffic Signals that have a "Lead Pedestrian Phase" provide a head-start (lead phase) for pedestrians to cross prior to initiation of the vehicle phase. During this phase, which typically has a duration of 3-7 seconds, all vehicular indications are stopped with a red indication.

5. PEDESTRIAN CHARACTERISTICS AND BEHAVIORS

Traffic Signals can also operate in a variety of ways with respect to pedestrian actuation and it is important to consider the pedestrian operation during the signal design process. The following items describe the characteristics that must be understood and considered when choosing pedestrian accommodations.

WALKING PATTERNS

Pedestrians tend to utilize the most efficient feasible path, sometimes regardless of the provided pedestrian treatments. Therefore, it is important to understand pedestrian circulation patterns and generators in the area when developing design. Also, designers must be realistic when establishing facilities and should not propose new routes which are significantly longer. If changes to an established walking route are proposed, it may be necessary to provide additional signing or even some sort of educational campaign so pedestrians understand the additional safety benefits.

PUSHING BUTTONS

The FHWA "Pedestrian and Bicycle Information Center" website estimates that roughly one-half of pedestrians do not appropriately utilize the push buttons at traffic signals, especially in areas where there may be sufficient vehicle gaps. Many pedestrians feel the button is not functional when not provided feedback showing its actuation.

VISION/HEARING DISABILITIES

A large percentage of the population has some sort of visual or hearing disability and while some may not be legally blind and/or deaf, it is still important to design facilities to account for pedestrians with low vision or hearing capabilities. Pedestrian Signals and push buttons which are too far away, misaligned or obstructed may not be noticeable to a sizeable percentage of pedestrians.

WALKING SPEED

The MUTCD defines the normal adult walking speed as 3.5 feet per second. However, it also states that slower walking speeds should be considered where slower walking pedestrians or wheelchairs are anticipated.

B. DESIGN

The following section provides guidance for pedestrian crossing design at a new traffic signal or an existing traffic signal undergoing significant modification. The Key Design Steps are presented below.

KEY DESIGN STEPS

STEP 1. PEDESTRIAN NEEDS ASSESSMENT

a. Review pedestrian circulation studies, if any.
b. Determine generators/attractors in area.
c. Identify physical constraints.

STEP 2. CROSSWALKS

a. Provide access to all 4 corners, except if physically constrained.
   - 4-Leg Intersection – minimum of 3 crossings
   - 3-Leg (T) Intersection – minimum of 2 crossings
   - Choose crossing locations based on the following:
     - Minimum of one crossing across the mainline
     - Pedestrian Needs (per Step 1)
     - Physical Constraints
     - Traffic Signal Operations

b. Stripe all crossings.
c. Provide appropriate signing.

STEP 3. CURB RAMPS

Provide ADA compliant curb ramps at all crosswalks.

STEP 4. PEDESTRIAN SIGNAL EQUIPMENT

a. Pedestrian Countdown Signals shall be provided at all crosswalks.
b. Accessible Pedestrian Signals (APS) shall be installed at all new traffic signal installations and existing traffic signal installations as required by PA Traffic.
c. Pedestrian Push Buttons (PBs) shall be provided at all crossings.
d. Passive Pedestrian Detection may be considered.

STEP 5. PEDESTRIAN PHASE OPERATION

a. Select pedestrian phase operation based on the type of vehicle detection.
   - Fixed Time Signals – Pedestrian Recall
   - Semi-Actuated Signals – Semi-Actuated or Fully Actuated Pedestrian Operation
   - Fully Actuated Signals - Fully-Actuated Pedestrian Operation

b. Additional Design Considerations:
   - Provide Ped Recall at all Airport Terminal Frontage crossings.
   - Consider an Exclusive Pedestrian Phase at locations with high pedestrian volumes on all approaches.
   - Consider a Lead Pedestrian Phase for crossings where there is a high conflict between pedestrians and turning vehicles.

1. PEDESTRIAN CIRCULATION NEEDS ASSESSMENT

The first step should always be to obtain any available pedestrian circulation plans or pedestrian studies in the project vicinity. If such studies exist, it is likely that recommended pedestrian treatments have already been outlined for the area. These treatments should be reviewed based on the current site conditions and if no pedestrian circulation plan exists the following steps should be followed. Existing sidewalk installations should be reviewed to determine where there are established pedestrian access routes (PAR). When the PAR crosses through an intersection, ADA compliant crossings shall be considered, including location of curb ramps, pedestrian signal heads and pedestrian detection method.

If no pedestrian studies have been completed for the area, it is the designer's responsibility to investigate the site, collect the necessary count data, and ensure coordination with the facility to determine pedestrian demand. When assessing the demand all pedestrian generators shall be considered, such as:

a) Parking Facilities
b) Transit/Rail/Bus Stops
c) Food/Restaurant Facilities (sometimes in the form of food trucks)

If it has been determined that there is a pedestrian demand, the signalized intersection should be provided with pedestrian treatments as described below. If no pedestrian demand is determined, documentation shall be prepared and the appropriate pedestrian prohibition/restriction signing shall be installed (see Section 7 below).

2. CROSSWALKS

The first pedestrian treatment to be considered is the installation of crosswalks in accordance with the current version of the MUTCD. Crosswalks should be visible, in good repair, and installed at well-lit locations.

Regardless of pedestrian demand, access should be provided to all 4 corners of an intersection. At a 4-leg intersection, this requires a minimum of 3 crosswalks. At a 3-leg (T) intersection, this requires a minimum of 2 crosswalks. If crosswalks are not provided across each approach, first consideration should be to eliminate one crossing the mainline. The location of the crossings provided should be selected based on the pedestrian needs and demand assessment prepared in Step 1, any physical constraints, and the traffic signal operations. If physical constraints exist, pedestrian crossing shall be prohibited at that location by appropriate signing.

The designer shall evaluate each intersection independently to determine the appropriate usage of crosswalks. The following outlines some factors to consider:

a) Connectivity: It is important that the pedestrian access routes in a facility are connected. However, it is also counterproductive to cross pedestrians to corners that either do not have any pedestrian attractors/generators or do not have adequate refuge areas. Also, be sure to assess obstructions (i.e. Guiderail or Barrier) when determining the appropriate crosswalk connectivity.

b) Impacts to Signal Operations: Crosswalks that conflict with exclusive left turning phases can degrade the operation of the signalized intersection because a protected arrow cannot be provided while pedestrians are given the Walk/Flashing Don't Walk indications. In these situations, the designer should consider prohibiting the crossing which conflicts with these major left turn movements and providing a crosswalk traversing the opposite approach instead.

c) High Crash Locations: Review crash history. Alternate pedestrian routing and/or safety countermeasures may be needed at locations where the amount of crashes involving pedestrian and drivers not yielding to pedestrians is high. Such scenarios could occur at entrances to tunnels or bridges with heavy congestion.

d) Poor Lighting: Review existing lighting conditions. If crosswalks are necessary in areas with poor lighting, additional lighting should be installed.

e) Poor Sight Distance: Review the existing sight distance. Obstructions of sight distance include vegetation, high walls or fences, and parking. Crosswalks should only be installed at locations with poor sight distance if countermeasures such as additional warning/regulatory signing, tree trimming, curb extensions, refuge islands/medians, enhanced lighting, and traffic calming techniques are utilized.

f) Property Limitations: Sidewalk easements should be investigated where additional right-of-way is needed to install a required pedestrian facility. Should it be determined that there is a lack of availability of right of way or insufficient room for adequate facilities, alternate crosswalk locations should be considered.

g) Security Related Limitations: In some areas, particularly near guard posts, it is not recommended to cross pedestrians. The designer should always coordinate with PANYNJ Traffic and facility staff to determine if there are any areas which are sensitive from a security standpoint.

In addition to the various situations for crosswalk implementation, the designer should also consider the various crosswalk striping alternatives and make sure the design is consistent with other crossings in the facility. Vehicular and pedestrian volumes, traveling speed on roadway and gaps between vehicles should be reviewed in determining whether high visibility crosswalks should be considered. Engineering judgment should be used to determine the need for high visibility crosswalks. This includes locations where physical conditions are such that the location would benefit for increased crosswalk visibility. This includes locations where with low lighting levels, high vehicular speed or where the crosswalk may be unexpected.

3. CURB RAMPS

If crosswalks are utilized, ADA compliant curb ramps shall be included in the design. While PANYNJ Civil handles the design of curb ramps, Traffic designers should be proactive about proposing the design characteristics and/or constraints of the proposed curb ramps.

All curb ramps adjacent to a push button should provide a flat (less than 2% in all directions) 4’ by 4’ landing area immediately adjacent to the button. Traffic designers should coordinate with PANYNJ Civil to ensure the traffic needs of the ramp design are accommodated.

PROWAG requires that alterations to existing facilities shall comply with the requirements for new construction to the “maximum extent feasible.” This document further clarifies “that where elements, spaces, or facilities are altered, each altered element, space, or facility within the scope of the project shall comply with the applicable requirements for new construction.” For example, if a project includes adding APS to a traffic signal, and there are no detectable warning surfaces on the curb ramps at the intersection, the guidelines would only require installation of APS and pedestrian push buttons, but would not require that detectable warning surfaces be installed, since this is not in the scope of work. In addition, if the pedestrian access route (PAR) is not altered, then the PAR is not required to comply with the proposed regulations for new construction. See PROWAG for further information.

4. PEDESTRIAN SIGNAL EQUIPMENT

The next step is to determine what types of pedestrian signal equipment will be utilized as part of the design.

Pedestrian Signal Indications

When used, pedestrian traffic signal heads shall be in strict compliance with the MUTCD and be countdown type. The placement of the pedestrian traffic signal heads should provide the most visibility to crossing pedestrians and shall comply with all standards in the MUTCD and the PANYNJ Traffic Signal Design and Drawing Preparation Guidelines.

a) <u>Accessible Pedestrian Signals (APS)</u>: Install APS at all new signalized intersections. In the case of intersection alteration, APS should be provided in line with the extent of the project scope. Engineering judgment shall support the evaluation and implementation of APS on a case-by-case basis and shall require a decision by PA Traffic. The following provisions for APS usage at new and altered intersections shall apply, in accordance with the requirements of PROWAG:

   - Provide APS where the project scope includes the new installation or replacement of pedestrian or vehicular signals.
   - Provide APS where the project scope includes the alteration of the signal controller and software.
   - APS is not required for maintenance related alterations to traffic signals which currently do not have APS facilities.

- APS is not required for traffic signal timing directive modifications.
- APS is not required when the additional cost of APS equipment and installation exceeds 20% of the original design budget.

APS equipment, and the appropriate installation locations, shall be in strict compliance with the MUTCD Section 4E.09 and the PROWAG.

Pedestrian Detection

Pedestrian signal design requires the determination of the appropriate pedestrian detection.

a) Pedestrian Push Buttons: Regardless of signal and pedestrian operation, push buttons shall be provided at all crossings. The pedestrian push button shall include latching capabilities and provide the pedestrians with an indication that the call has been placed (audible tone, light, etc.). All push buttons should be oriented so the face of the button is parallel to the crosswalk. Figure 1 shows the appropriate orientation with reference to the crosswalk striping, per MUTCD Section 4E.10.

Figure 1: Proper Push Button Orientation

b) Passive Pedestrian Detection: The use of passive pedestrian detection should be considered on a case-by-case basis. The installation of passive pedestrian detection could be justified in the following situations:

- Areas with a documented history of pedestrians not pushing the buttons.
- Intersections that have geometric constraints that make the installation of push buttons impractical.
- Areas where it may be prudent to track pedestrian movements and extend green times.
- Areas with documented crashes between pedestrians and vehicles.

If passive pedestrian detection is utilized, push buttons shall also be provided. The type of passive pedestrian detection system provided, such as video or infrared, must be specifically designed for pedestrian detection, as they have more capabilities and better performance than standard vehicle detection methods. Also, audible and vibrotactile messages still need to be provided in these installations.

5. PEDESTRIAN PHASE OPERATION

Selection of pedestrian phase operation is based on the type of vehicle detection at the intersection.

a) Fixed Time Signals
   - Pedestrian Recall shall be provided on all approaches

b) Semi-Actuated Signals
   - Semi-Actuated Pedestrian Operation – actuation is required to cross with the actuated phase. "Walk" indication will automatically be displayed during the non-actuated phase. If no vehicle actuation occurs, the signal shall rest in "Walk" on the non-actuated crossing.
   - Fully Actuated Pedestrian Operation – actuation is provided to cross all approaches. "Walk" indication will only be displayed if actuated by a pedestrian.

c) Fully Actuated Signals
   - Fully Actuated Pedestrian Operations - actuation is provided to cross all approaches. "Walk" indication will only be displayed if actuated by a pedestrian.

The following describes the facility specific operational considerations for selecting pedestrian detection operation. The selection of the appropriate pedestrian detection will also depend on the traffic signal operation (fixed time, semi-actuated or fully-actuated). All new pedestrian push buttons shall include the APS unit. For alterations, selection of detection type shall require a decision by PA Traffic.

d) <u>Airport Terminal Frontage Roadways</u>
   - Push buttons shall be provided
   - Pedestrian Recall shall be activated

e) <u>All Other Facility Crossings</u>:
   - Push buttons shall be provided for all crossings
   - Operation shall be semi-actuated or full-actuated based on the traffic signal operation and pedestrian characteristics

An Exclusive Pedestrian Phase may be considered at locations with high pedestrian volumes on all approaches. Determination of "when and where" to utilize exclusive pedestrian phases shall be made on a case-by-case basis. Justification for using an exclusive pedestrian phase shall be provided.

A Lead Pedestrian Phase may be considered for crossings where there is a high conflict between pedestrians and turning vehicles. Determination of "when and where" to utilize lead pedestrian phases shall be made on a case-by-case basis. Justification for using a lead pedestrian phase shall be provided.

Closely spaced pedestrian crossings (i.e., where pedestrians are making a long crossing with island refuge between crossings) can create a “pull through” condition where a pedestrian can see the pedestrian signal heads for the downstream crossing and become confused. In these instances, all pedestrian heads should show the same indications (Walk, Flashing Don’t Walk and Don’t Walk). This is shown in Figure 2.

Figure 2: Pull Through Pedestrian Signal Head

6. TRAFFIC SIGNAL TIMING DEVELOPMENT

When developing the traffic signal timing, all “Walk,” “Flashing Don’t Walk,” and “Don’t Walk” intervals shall strictly conform to Section 4E.06 of the MUTCD. All pedestrian clearance intervals shall be calculated based on the most current PANYNJ Traffic Signals Pedestrian Intervals Worksheet.

7. SIGNING INSTALLATIONS

A critical aspect of pedestrian accommodation is the appropriate signing, both from a vehicular and pedestrian perspective. The following guidance should be used when signing pedestrian facilities:

a) Push Button Signs: All push buttons shall be accompanied by an R10-3 series sign mounted in a frame, in accordance with the PANYNJ Traffic Signal Design and Drawing Preparation Guidelines. These signs include an arrow pointing in the direction of the crosswalk. The finger on these signs should point in the same direction as the arrow. If using APS, braille features should also be used.

b) Pedestrian Crossing Prohibition Signs: Wherever pedestrians are prohibited from crossing at an intersection, “No Pedestrian Crossing” signs (R9-3 series) shall be used. Also, where feasible, “Use Crosswalk” signs (R9-2B series) should also be utilized to direct pedestrian to the appropriate route.

8. ENGINEERING JUDGMENT

The standard PANYNJ procedure is to consider pedestrian treatment at all signalized intersections throughout the various facilities. These guidelines are intended to provide the framework and decision making process for pedestrian treatment installations. In all circumstances, apply engineering judgment when determining the pedestrian treatment recommendation. There may be occasions when the installation of pedestrian facilities fall outside of these guidelines or require additional considerations. The approach used shall be documented.

Appendix C – Standard Clearance Calculation Forms

THE PORT AUTHORITY OF NY & NJ

TRAFFIC SIGNAL YELLOW CHANGE AND RED CLEARANCE INTERVALS

GENERAL GUIDANCE

Intersection Name:		**Calculated By:**	
Intersection ID:		**Checked By:**	

The designer shall adhere to the general parameters set forth in the instructions of the "Yellow, Red" and "Walk, Don't Walk" tabs.

A Traffic Signal Drawing shall accompany the vehicle and pedestrian interval calculations, showing typical parameters such as clearance distance, potential collision point based on ensuing vehicle phasing (where applicable), vehicle phases, crosswalk width, crosswalk length. For each phase of an intersection, evaluate the worst-case (i.e., longest clearance distance) scenario for clearance calculations.

Yellow, Red Clearance Intervals

Within the "Yellow, Red" tab, copy the required cells to provide the appropriate number of calculation sections. At least one calculation section is required for each phase. Shared phases shall use the worst-case scenario.

For the evaluation of left or right turns, a total of 3 calculations are required: one utilizing the regular speed limit to calculate the yellow clearance, another utilizing the turning speed to calculate the red clearance, and a third utilizing to show the combined (or total) clearance.
- The yellow and red clearance interval sections shall be modified and only show the calculated values. The "Yellow Change + Red Clearance" portion shall be empty, or dashed.
- The 'combination' clearance section shall have the yellow and red calculated values hard-inputted. The "Yellow Change + Red Clearance" value shall be calculated from the formula sheets, and rounded to the nearest 0.5 increment.
- Where there is protected-permitted phasing, clearance calculations shall be provided for the approach's protected left as well as those for the permitted movements.

Should the calculated red clearance interval be greater than 4.0 seconds, there may be opportunities to reduce its value based on evaluating main vehicle's travel with the conflicting movement's arrival time and space differential.
- Based on the drawing provided with the designated clearance distances listed, determine the conflict movement based on the phase sequence, and the associated distance.
- Calculate the travel time the conflicting movement will take to reach the conflict point.
- Determine if there is an opportunity to reduce the main vehicle's red clearance, based on the time the conflicting movement is anticipated to reach the same location.
- In evaluating the main movement's red clearance reduction, leave a 2.0 second headway (where possible) between potentially conflicting vehicles.
- This information can be summarized quickly with a statement such as "Proposed all-red clearance reduced to 4.0 seconds *(or 4.5, 5.0, etc.)* by removing X.X seconds from the conflict vehicle approach time, leaving Y.Y seconds of vehicle headway."

As a working example, consider the following:
- Calculated red clearance interval = 4.9 seconds
- Conflicting vehicle approach time (to conflict point) = 3.9 seconds
- Calculated red clearance interval may be reduced to 4.0 seconds (i.e., 4.9 - 0.9 = 4.0 sec)
- In so doing, the conflicting vehicle approach time also is reduced, to 3.0 seconds (i.e., 3.9 - 0.9 = 3.0 sec). That is, there remains a headway of 3.0 seconds, from the time the main/primary vehicle passed the collision point to when the conflicting vehicle reaches the same location.
- The summary statement may be written as: "Proposed all-red clearance reduced to 4.0 seconds by removing 0.9 seconds from the conflicting vehicle arrival time to the collision point, leaving 3.0 seconds of vehicle headway."

- The contents of the tab labeled "Reduction Calc" shall be completed for each clearance reduction to be issued for approval. It contains a more detailed version of the general procedure mentioned above. The tab itself shall be renamed to the direction of travel of the desired clearance reduction. Any additional clearance reductions proposed shall be separate tabs.

Walk, Don't Walk Clearance Intervals

Within the "Walk, Don't Walk" tab, copy the required cells to provide the appropriate number of calculation sections needed for the amount of crosswalks under investigation. One calculation section is required for each paired pedestrian phase (i.e, if there is a Phase 2 Ped and Phase 6 Ped, the calculations associated with the longest crosswalk distance is required. Central Terminal Area frontages and/or any areas heavily traveled by clusters of pedestrians shall utilize 3.0 ft/sec as the walking speed. All other areas shall use 3.5 ft/sec.

Approval Signature of Supervising Engineer:	____________________	**Date:**	_____/______/_____
Implemented in field by:	____________________	**Date:**	_____/______/_____

THE PORT AUTHORITY OF NY & NJ

TRAFFIC SIGNAL YELLOW CHANGE AND RED CLEARANCE INTERVALS

Intersection Name: ______ **Calculated By:** ______
Intersection ID: ______ **Checked By:** ______

Yellow Change: $y = t + \frac{v * 1.47}{(2a+2Gg)}$

Red Clearance: $r = \frac{(w+L)}{v * 1.47}$ * Used when there is no crosswalk on the approach departure.

$r = \frac{(P + L)}{v * 1.47}$ * Used when a crosswalk exists on the approach departure.

y = length of the yellow change interval (in sec), rounded up to the nearest 0.5 second
t = driver perception/reaction time (in sec), AASHTO recommends 1.5 sec
v = velocity of approaching vehicle (in mph), use posted speed limit unless 85^{th} percentile speed is available
a = average deceleration (in ft/sec^2), AASHTO recommends 11.2 ft/sec^2 (for facilities with predominantly truck volumes, use a value of 9.66 ft/sec^2)
g = acceleration due to gravity (32.2 ft/sec^2)
G = grade of approach (in percent divided by 100), downhill grade is negative

r = length of red clearance interval (in sec), rounded up to the nearest 0.5 second
w = width of the intersection (in ft) measured from the near-side stop line to the far edge of the conflicting traffic lane along the actual vehicle path
P = width of the intersection (in ft) measured from the near-side stop line to the **near** side of the farthest conflicting pedestrian crosswalk along the actual vehicle path. The width shall be measured to **far** side if intersection only consists of a midblock crosswalk
L = length of vehicle, use 20 ft (for facilities with predominantly truck volumes, use 73.5 ft)
v = speed of the vehicle through the intersection (in mph) use posted speed limit unless 85^{th} percentile speed is available

To avoid overestimating Red Clearance Time, the start up delay and travel time of the next vehicular or pedestrian phase may be considered when determining values for **w** and **P**.

Treatment of Right and Left Turns

For turning movements, approach velocity is typically the same as the through movement. As a result, Yellow Change should be same for all movements.

Protected turning movements shall be considered in the Red Clearance Interval for the overall phase and engineering judgement shall be used in their Red Clearance calculation and application, specifically, W and/or P may be calculated using the trajectory and length of vehicle path to the point no longer likely to be in conflict with the next vehicular or pedestrian phase. Use 15mph and 20mph for the velocity of protected right and left turns, respectively, unless engineering judgement or studies indicate otherwise.
As standard practice, to be conservative, these calculations are performed for turning movements for all phases.

** Yellow Change Intervals should be in the range of 3 and 6 seconds.

** All Red Clearance Intervals greater than 4 seconds shall receive approval from Chief Traffic Engineer.

Approach: ______
Movement: ______ **Signal Phase:** ______

Speed (mph):	25	t (sec):	1.5
w (feet):	0	a (ft/s^2):	11.2
P (feet)		g (ft/s^2):	32.2
G (%/100):	0		
L (feet)	20		

Yellow Change:
Calculated: 3.1 sec

Red Clearance:
Calculated: 0.5 sec

Yellow Change + Red Clearance:
Calculated: 3.6 sec
Rounded: **4.0** sec

Recommended Intervals: Yellow: 3.5 sec Red: 0.5 sec

Remarks:

Approval Signature of Supervising Engineer: ______________________ **Date:** ____/_____/____

Implemented in field by: ______________________ **Date:** ____/_____/____

THE PORT AUTHORITY OF NY & NJ

TRAFFIC SIGNAL PEDESTRIAN INTERVALS

Intersection Name:		**Calculated By:**	
Intersection ID:		**Checked By:**	

WALK Signal Indication

WALK signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder. The walk interval should be long enough to allow pedestrians adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins. MUTCD requires a minimum walk interval of 7 seconds. However, if pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used. There is no maximum Walk interval length.

W= minimum walk interval, typically 7 sec

If a large number of pedestrians cross at the crosswalk, the following equation may be used to calculate the minimum walk interval:

Walk Interval: $w < 10$ ft. $W = 3.2 + 0.27N_{ped}$

$w \geq 10$ ft. $W = 3.2 + \frac{2.7N_{ped}}{w}$

W= minimum walk interval (in sec)
N_{ped} = number of pedestrians crossing per cycle.
w= effective crosswalk width (in ft)
3.2 = Assumed Pedestrian Start-up time (in sec)

FLASHING DON'T WALK Signal Indication

$$FDW = \frac{L}{v}$$

FLASHING DON'T WALK signal indication is also known as the pedestrian clearance time. The pedestrian clearance time should be sufficient to allow a pedestrian (who left the curb or shoulder during the WALK) crossing in the crosswalk signal indication to travel at a walking speed of 3.5 ft/sec, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. If the crosswalk is utilized by pedestrians who routinely walk slower than 3.5 ft/sec (e.g. at Airport Terminal Frontage Areas, by people with baggage, by elderly people, etc), a walking speed of 3.0 ft/sec may be used.

FDW = pedestrian clearance interval (in sec)
L = crosswalk length or length of traveled way (in ft)
v = walking speed (in ft/sec), typically 3.5 ft/sec

Cross-Check Calculation

Cross-Check calculation for "Slower Ped Time" is calculated using a 3 ft/sec. walking speed to determine if there is sufficient crossing time provided for slower pedestrians to cross the street. In this calculation, the distance used is measured from the pedestrian push button (or, if none, measured 6 feet back from the face of curb or the edge of pavement) to the far side curb or to a median with sufficent width for pedestrians to wait. The WALK interval plus the calculated pedestrian clearance time using 3.5 ft/sec walking speed must be equal to or greater than the calculated "Slower Ped Time." However, if the calculated "Slower Ped Time" is greater than the walk plus pedestrian clearance time, then the difference in time should be added to the walk interval.

THE PORT AUTHORITY OF NY & NJ

TRAFFIC SIGNAL PEDESTRIAN INTERVALS

Intersection Name: ______ **Calculated By:** ______
Intersection ID: ______ **Checked By:** ______

Crosswalk: ______
Signal Phase: 1

		WALK Interval:			**FLASHING DON'T WALK Interval:**	
		Calculated:	7.0 sec		Calculated:	12.9 sec
N_{ped} (per cycle) = 0	L (feet) = 45	Rounded:	7.0 sec		Rounded:	13.0 sec
w (feet) =	v (ft/sec) = 3.5					

Walk: 7.0 sec Don't Walk: 13.0 sec

Walk + FDW : 20.0

Cross-Check Calculation:

L (feet) = 61 Calculated: 20.3 sec
v (ft/sec) = 3 Rounded: 21.0 sec

Calculated Slower Ped Time: 21.0 sec

Recommended Intervals: Walk: 8.0 sec Don't Walk: 13.0 sec

Remarks:

Approval Signature of Supervising Engineer: ______________________ **Date:** _____/______/_____

Implemented in field by: ______________________ **Date:** _____/______/_____

Methodology for Reduction of Red Vehicle Clearance Interval

Intersection Name and ID :	*Corbin Street and Tyler Street (PN-NS-509)*

Main Movement: 1. *PRIMARY*
Conflicting Movement: 2. *SECONDARY*

Calculated Red Clearance Interval is 9 seconds for PRIMARY movement.

A vehicle must travel approximately 999 feet from the SECONDARY approach stop bar to reach the potential collision point with PRIMARY traveling vehicles.

Based on the distance and uniform acceleration equation:

$s = ut + (1/2)at^2$

where,

s = distance from the SECONDARY stop bar to the conflicting point (from clearance distance drawing) = 999 feet
u = initial speed of the vehicle stopped at stop bar = 0 miles per hour (mph)
a = assumed acceleration of stopped heavy vehicle = 11.2 feet/second^2
t = time required to travel from the SECONDARY approach stop bar to the potential collision point.

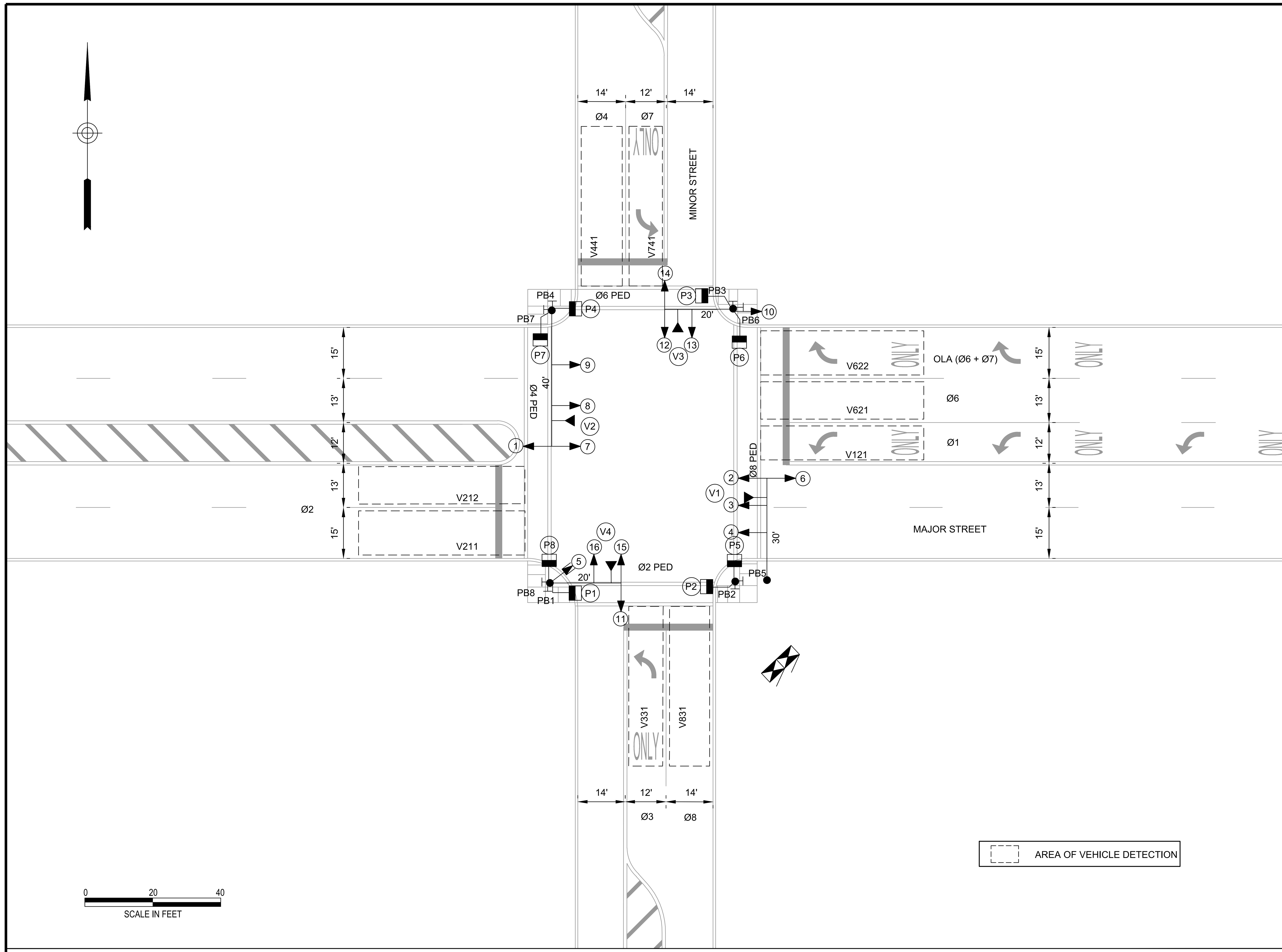
The time it would take a conflicting SECONDARY traveling vehicle to reach the potential collision point would be:

999 = 0(t) + 1/2(11.2)t^2

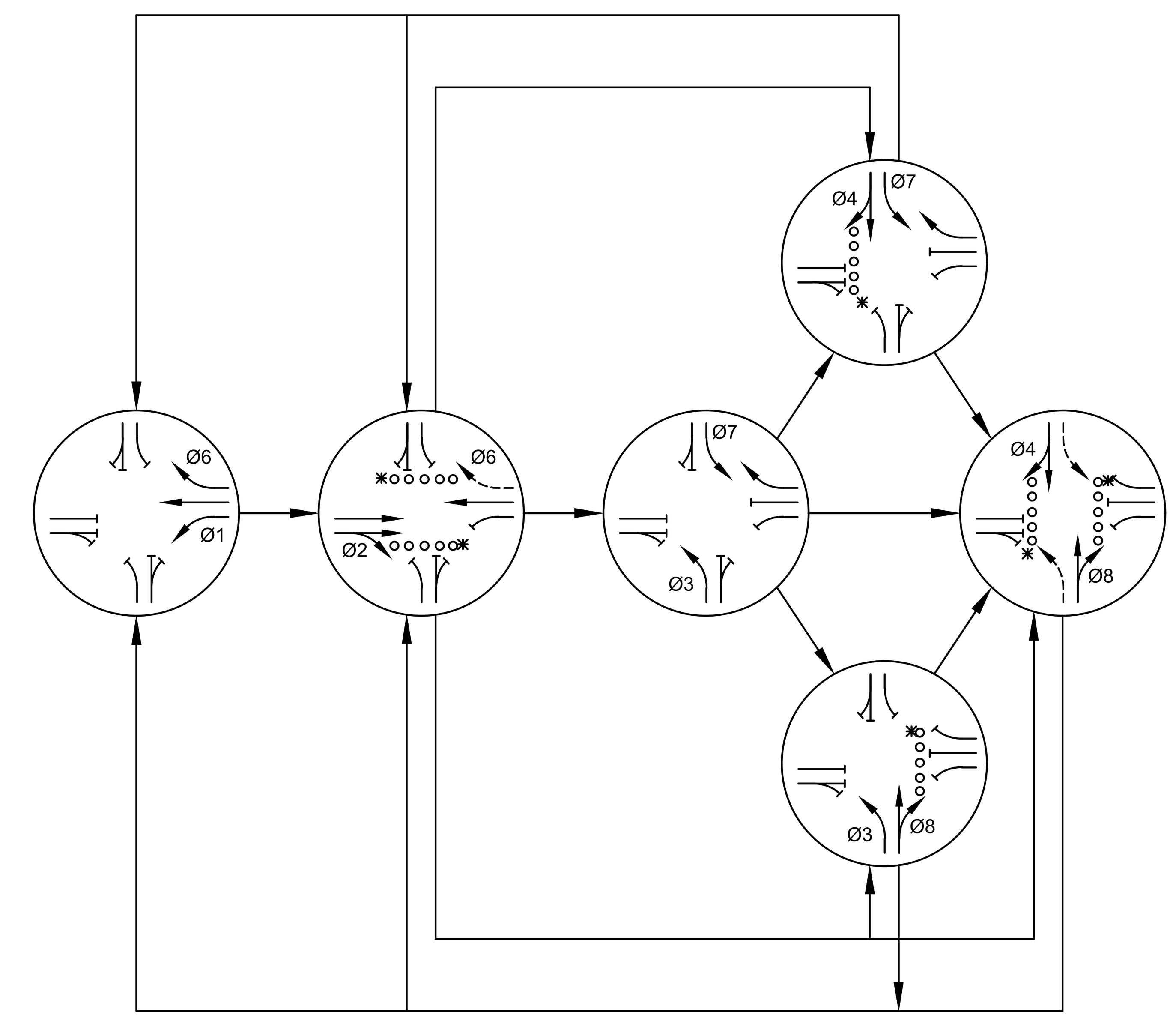
or,

t = 13.4 seconds

As a result, there is an opportunity to reduce PRIMARY red clearance interval. A reduction of 5 seconds is proposed, reducing the clearance interval from 9 seconds to 4 seconds.
The proposed All Red Clearance is reduced to 4 seconds by removing 5 seconds from the conflicting vehicle arrival time to the collision point, leaving 8.4 seconds (13.4 minus 5) of vehicle headway.

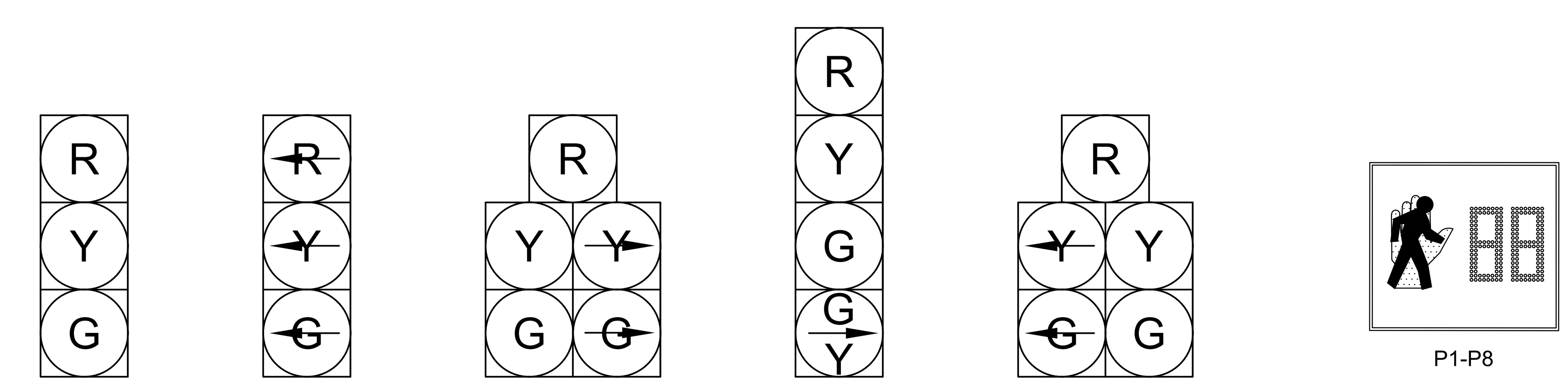


PHASING DIAGRAM



*ONLY OCCURS UNDER PEDESTRIAN ACTUATION

SIGNAL LEGEND



SAMPLE OF FULLY-ACTUATED OPERATION

Sheet XX of XX

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

(STAGE 1 AND STAGE 2) SAMPLE MAST ARM TRAFFIC SIGNAL LAYOUT PLAN

Designed by

Drawn by

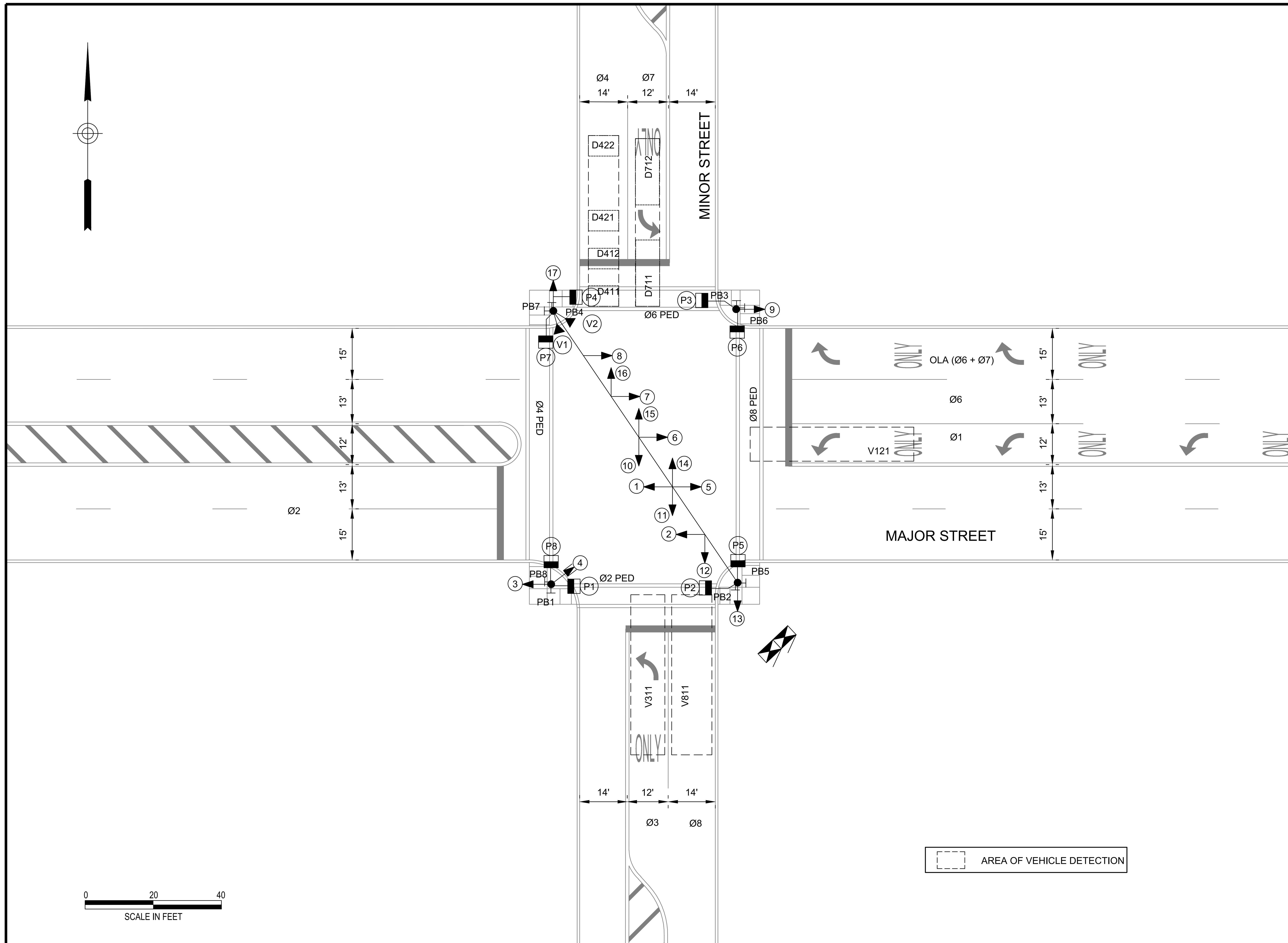
Checked by

Date DECEMBER 2018

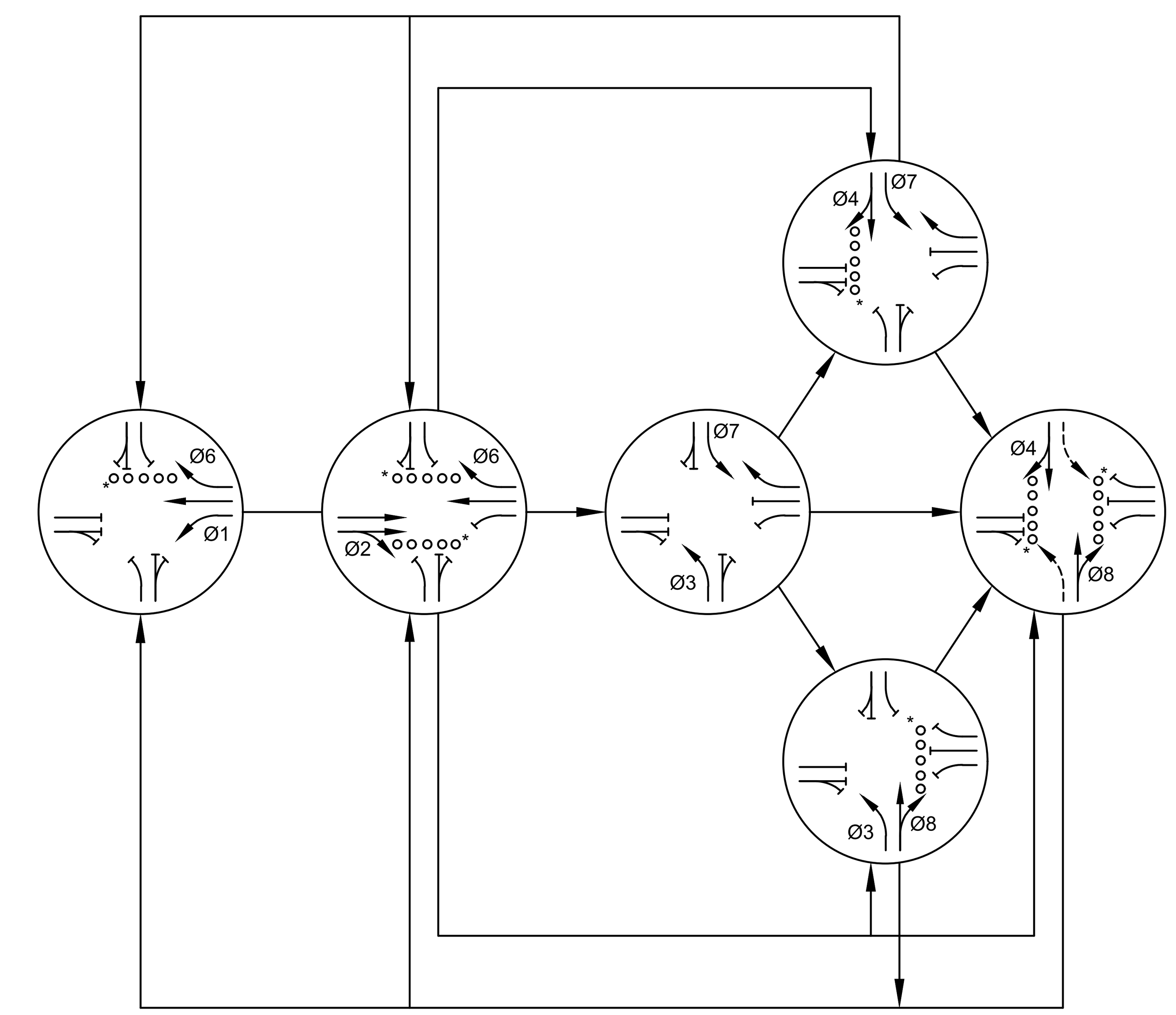
Contract Number

Drawing Number SG001

PID#

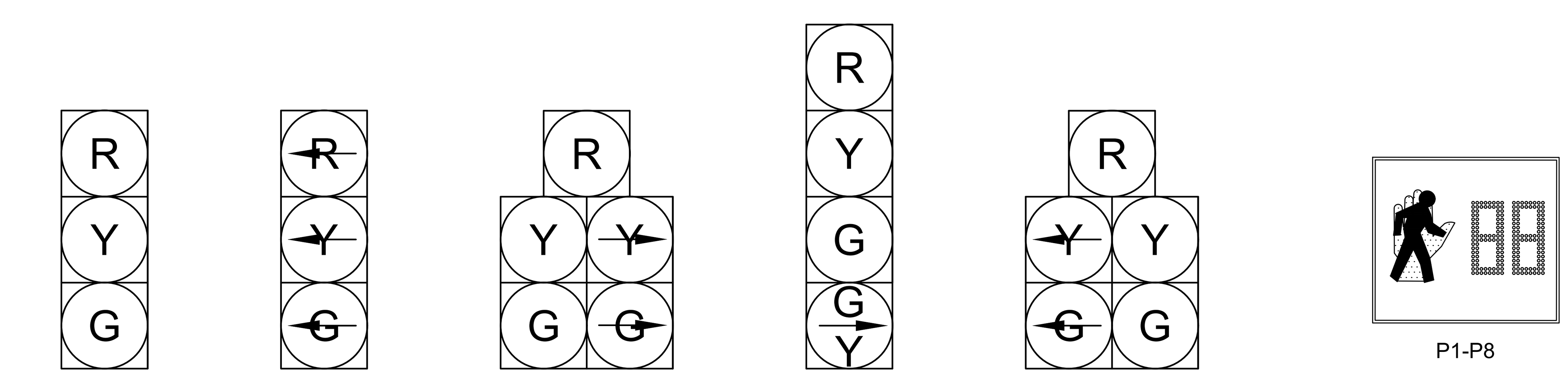


PHASING DIAGRAM



*ONLY OCCURS UNDER PEDESTRIAN ACTUATION

SIGNAL LEGEND



Sheet XX of XX

THE PORT AUTHORITY
OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

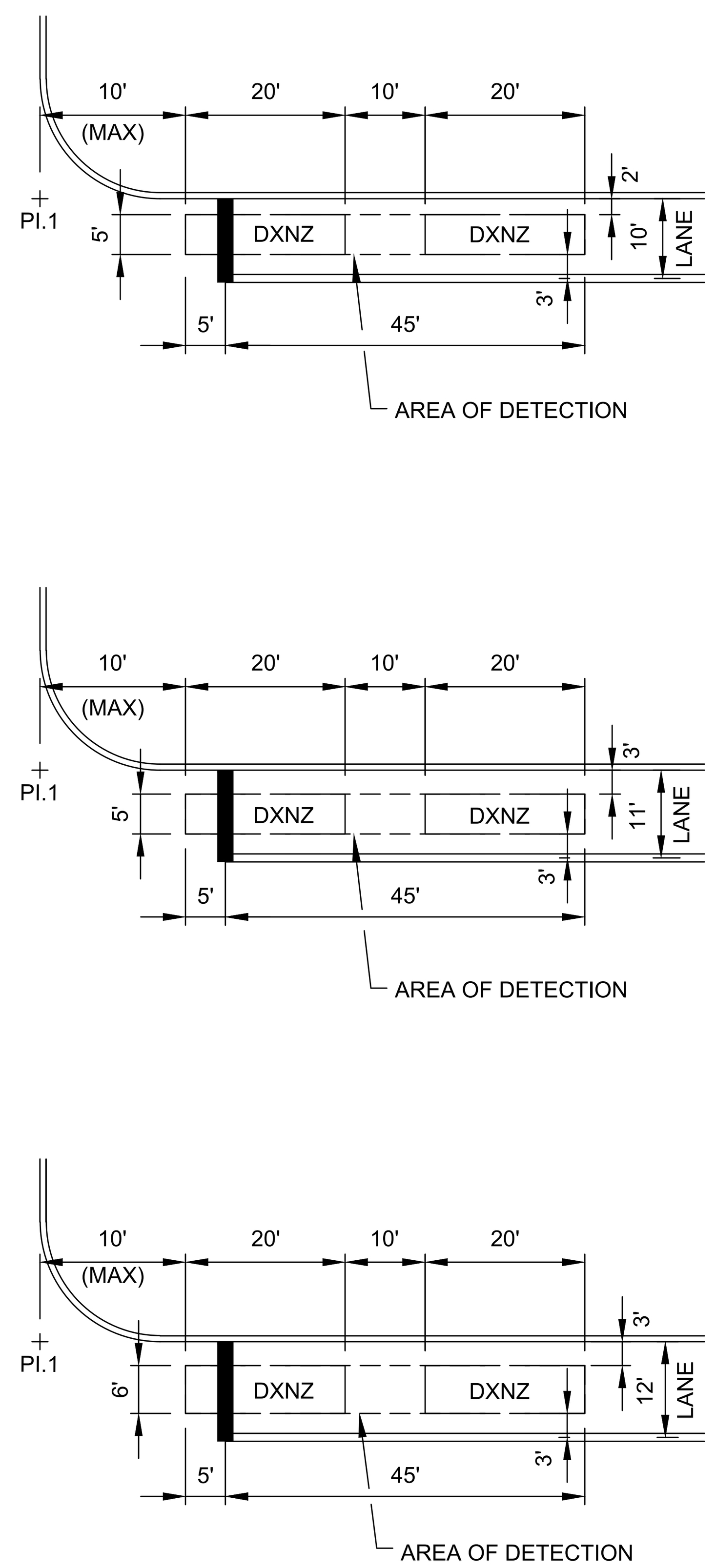
TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

(STAGE 1 AND STAGE 2)
SAMPLE SPAN WIRE
TRAFFIC SIGNAL
LAYOUT PLAN

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG002
PID#

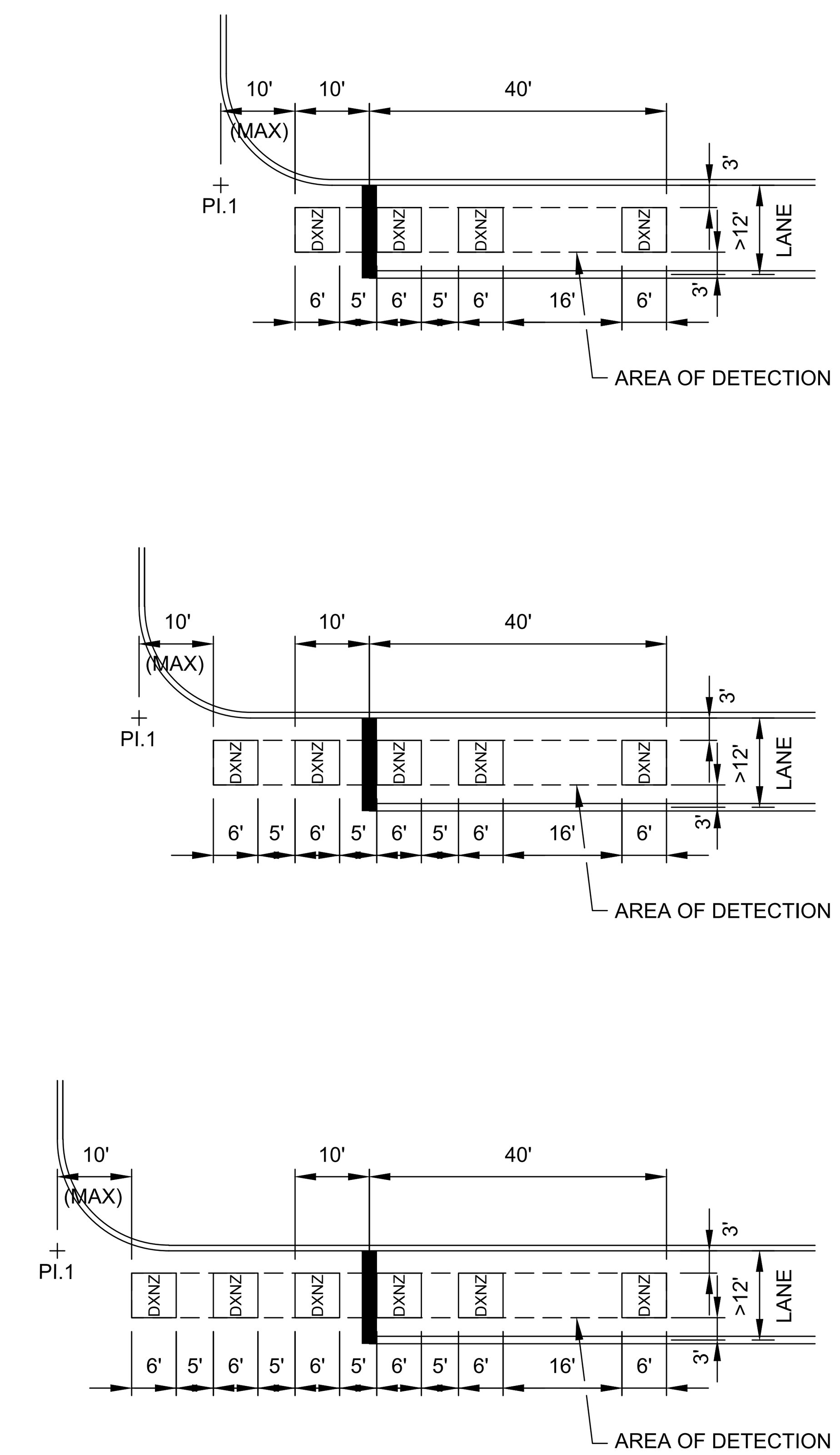
SAMPLE OF
SEMI-ACTUATED OPERATION

THE PORT AUTHORITY
OF NY & NJ



LOOP DETECTOR LAYOUT
SINGLE LANE 12 FEET OR LESS

N.T.S.



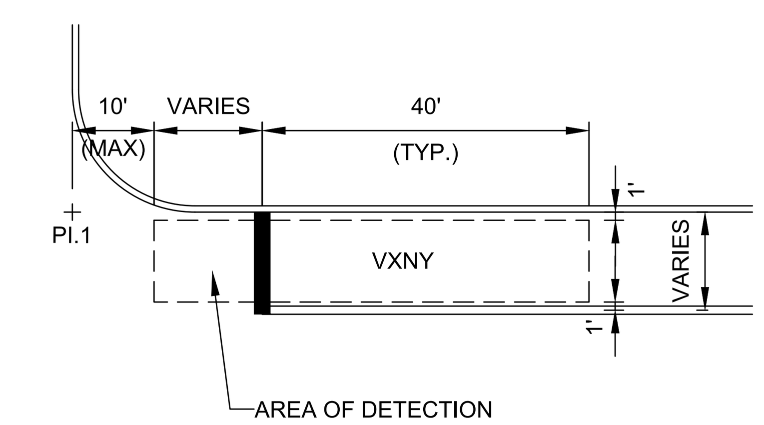
LOOP DETECTOR LAYOUT
SINGLE LANE GREATER THAN 12 FEET

N.T.S.

LOOP DETECTOR NOTES:

THE NUMBER ASSIGNED TO EACH INTERSECTION DETECTOR SHALL CORRESPOND TO A DETECTOR AMPLIFIER CHANNEL AND SHALL BE FORMATTED AS FOLLOWS:

FIRST DIGIT:	(D) FOR DETECTOR
SECOND DIGIT:	(X) WHERE X REPRESENTS THE NEMA PHASE NUMBER ASSOCIATED WITH THE DETECTOR
THIRD DIGIT:	(N) WHERE N REPRESENTS THE DETECTOR UNIT NUMBER ASSOCIATED WITH EACH PHASE (ONE, TWO, THREE, ETC.)
FOURTH DIGIT:	(Z) WHERE Z REPRESENTS THE CHANNEL NUMBER FOR EACH LOOP (ONE OR TWO)



AREA OF VIDEO DETECTION

N.T.S.

VIDEO DETECTION NOTES:

THE NUMBER ASSIGNED TO EACH INTERSECTION AREA OF VIDEO DETECTION SHALL CORRESPOND TO A VIDEO SENSOR SHALL BE FORMATTED AS FOLLOWS:

FIRST DIGIT:	(V) FOR VIDEO DETECTOR
SECOND DIGIT:	(X) WHERE X REPRESENTS THE NEMA PHASE NUMBER ASSOCIATED WITH THE AREA OF DETECTION
THIRD DIGIT:	(N) WHERE N REPRESENTS THE CAMERA NUMBER ASSOCIATED WITH THE AREA OF DETECTION
FOURTH DIGIT:	(Y) WHERE Y REPRESENTS THE DETECTION ZONE (ONE, TWO, THREE, ETC.)

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

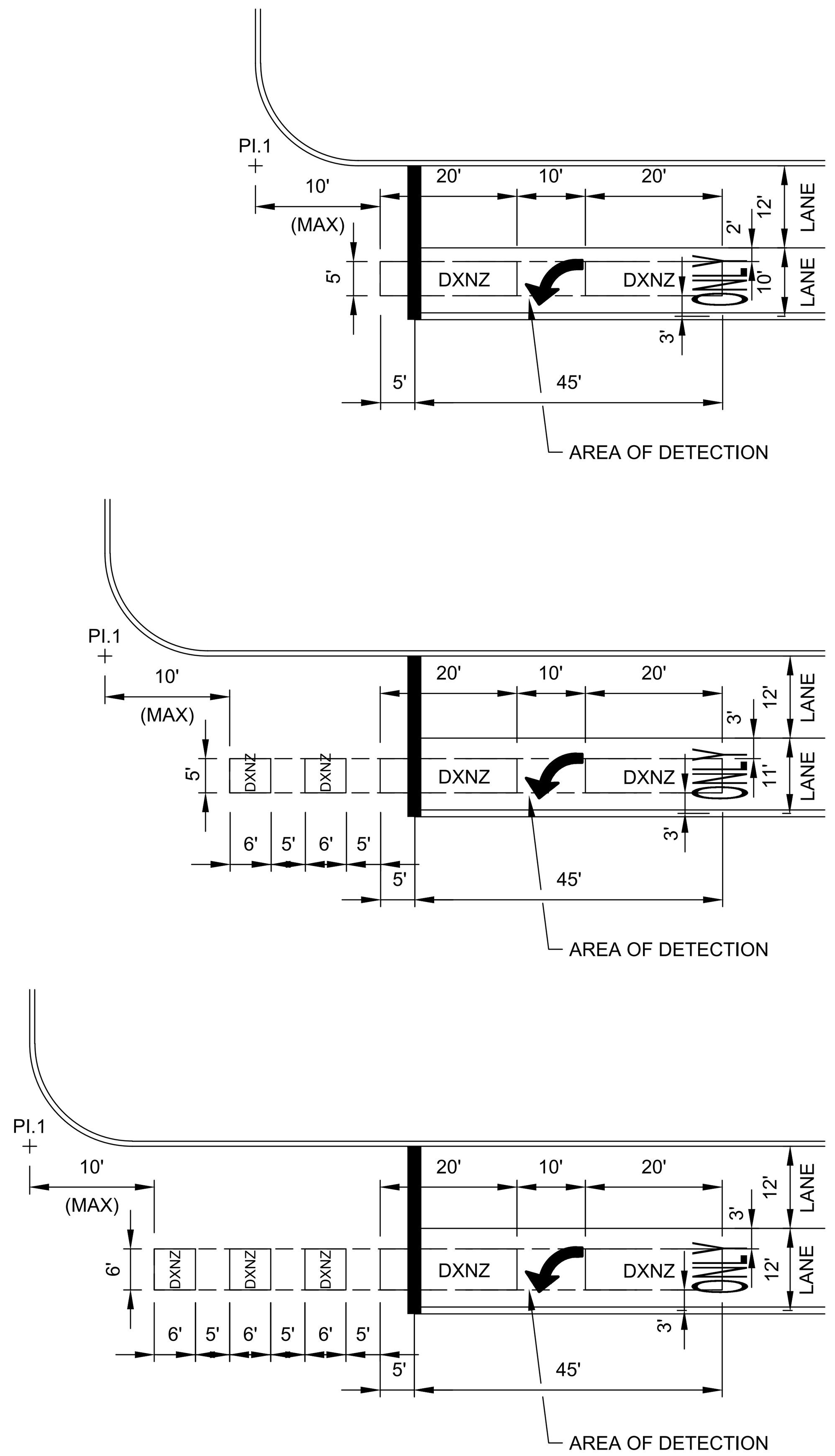
TRAFFIC

Title

TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

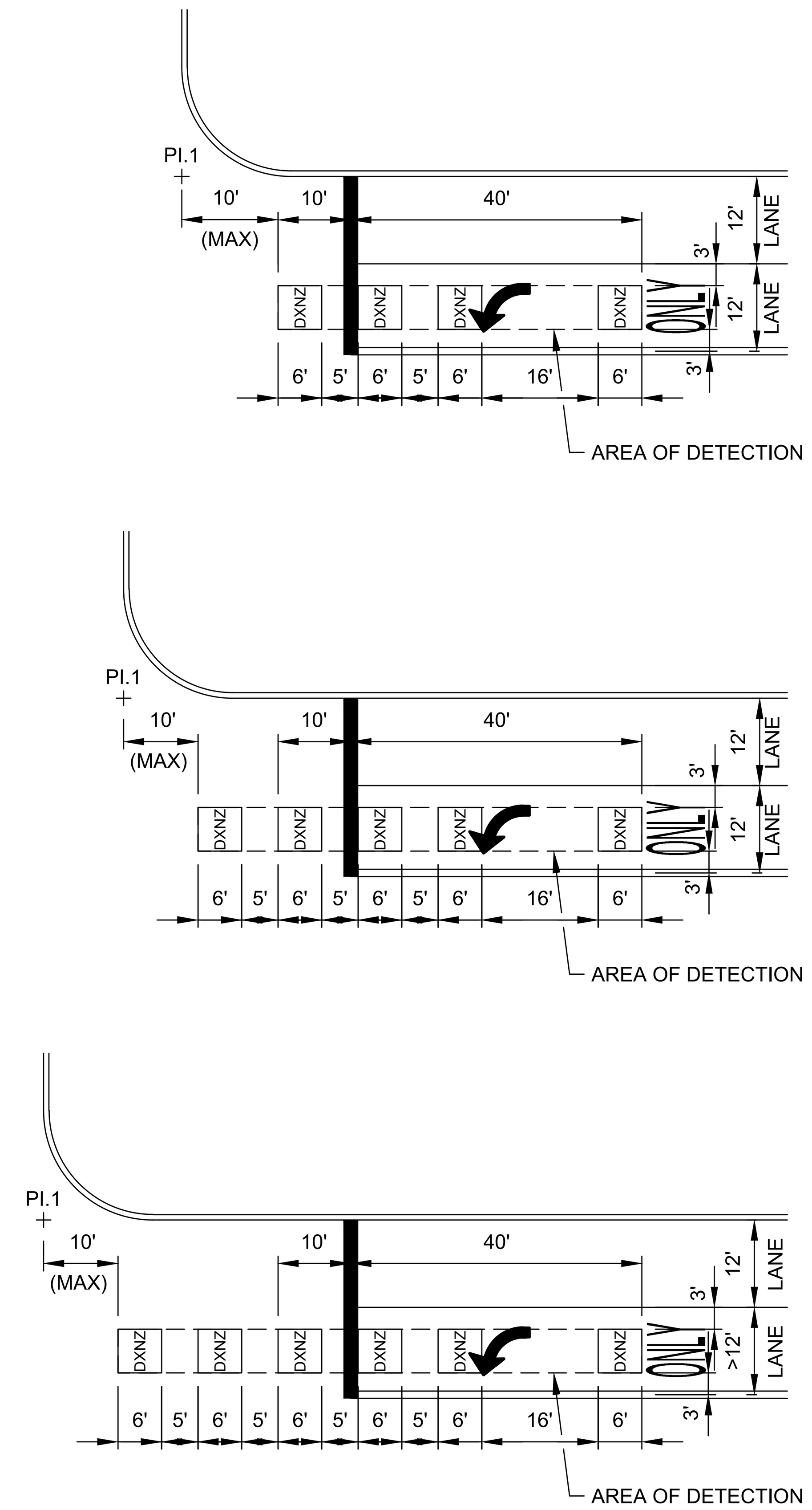
SAMPLE
SINGLE LANE
DETECTION LAYOUTS

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG003
PID#



LOOP DETECTOR LAYOUT
LEFT TURN LANE 12 FEET OR LESS

N.T.S.



LOOP DETECTOR LAYOUT
LEFT TURN LANE GREATER THAN 12 FEET

N.T.S.

LOOP DETECTOR NOTES:

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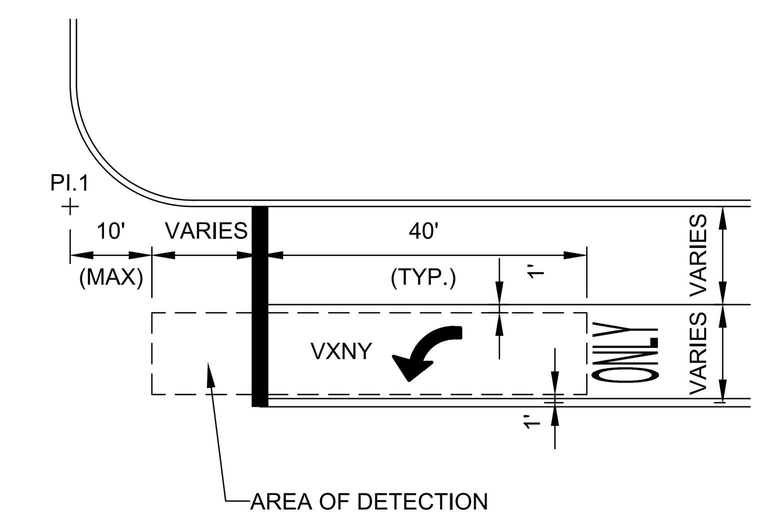
FOURTH DIGIT: (Z) WHERE Z REPRESENTS THE CHANNEL NUMBER FOR EACH LOOP (ONE OR TWO)



AREA OF VIDEO DETECTION
LEFT TURN LANE

N.T.S.

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FOURTH DIGIT: (Y) WHERE Y REPRESENTS THE DETECTION ZONE (ONE, TWO, THREE, ETC.)

THE PORT AUTHORITY
OF NY & NJ

No.	Date	Revision	Approved

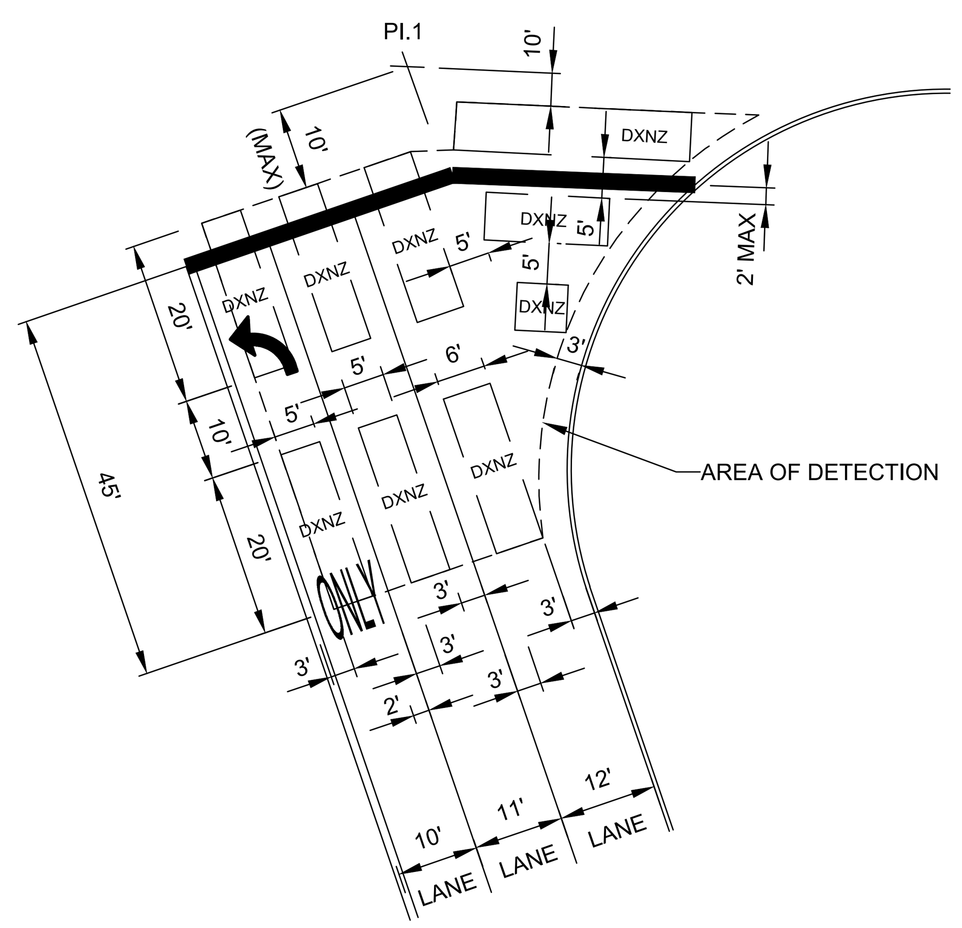
ENGINEERING DEPARTMENT

TRAFFIC

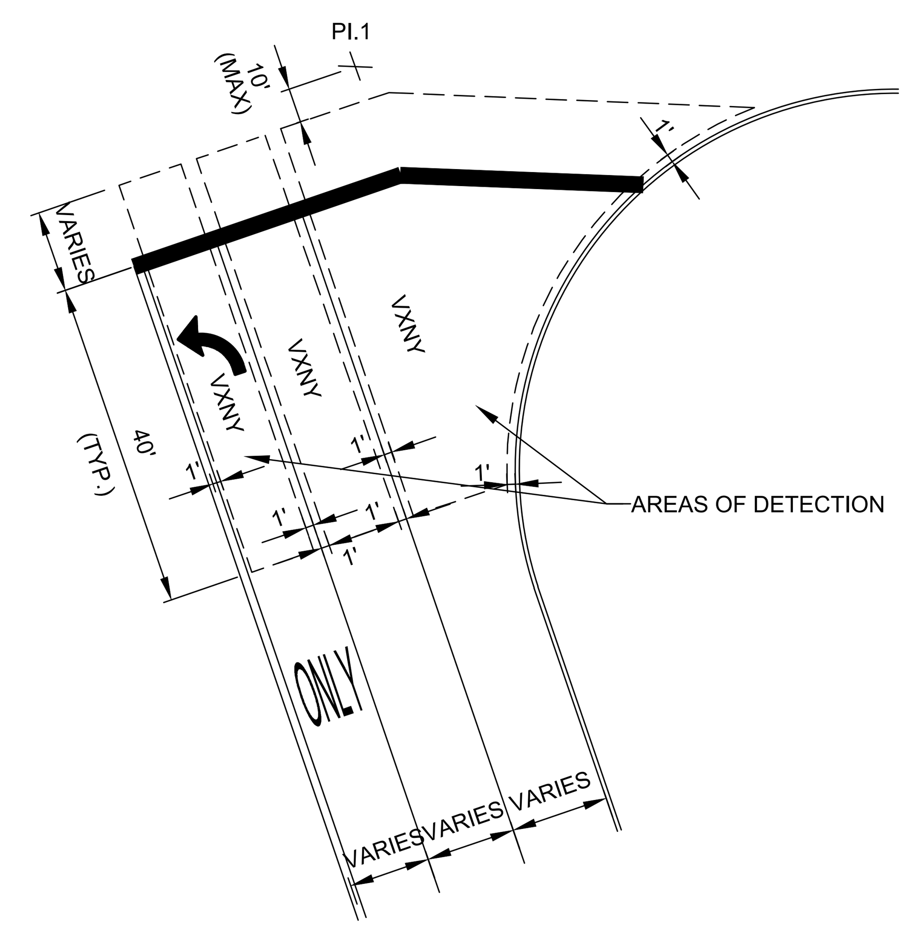
Title
TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

SAMPLE
LEFT TURN LANE
DETECTION LAYOUTS

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG004
PID#



LOOP DETECTOR LAYOUT
MULTI-LANE
N.T.S.



AREA OF VIDEO DETECTION
MULTI-LANE
N.T.S.

LOOP DETECTOR NOTES:

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VIDEO DETECTION NOTES:

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FOURTH DIGIT:	(Y) WHERE Y REPRESENTS THE DETECTION ZONE (ONE, TWO, THREE, ETC.)

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title
TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE
MULTI-LANE
DETECTION LAYOUTS

Designed by	
Drawn by	
Checked by	
Date	DECEMBER 2018
Contract Number	
Drawing Number	SG005

PID#

TRAFFIC SIGNAL NOTES (FOR SG DRAWINGS ONLY):

1. CONTRACTOR ASSUMES MAINTENANCE RESPONSIBILITY OF THE TRAFFIC SIGNAL SYSTEM AT THE START OF ANY WORK THAT IS PERFORMED. THE START DATE OF MAINTENANCE RESPONSIBILITY SHALL BE DOCUMENTED AND BE ON FILE IN THE ENGINEER'S OFFICE. THE CONTRACTOR SHALL BE REQUIRED TO VERIFY THIS DATE IN WRITING. THE CONTRACTOR SHALL BE RESPONSIBLE FOR MAINTENANCE UNTIL SUCH TIME AS FINAL APPROVAL AND ASSUMPTION OF MAINTENANCE BY THE AUTHORITY.

   A. AT LEAST 20 DAYS PRIOR TO START OF WORK, THE CONTRACTOR SHALL SET UP A MEETING WITH THE AUTHORITY ENGINEER'S OFFICE (EO) TO VERIFY THE OPERATIONAL STATUS AND MAINTENANCE RESPONSIBILITY OF THE TRAFFIC SIGNAL SYSTEM. THE CONTRACTOR SHALL SUBMIT A MAINTENANCE PLAN TO THE EO PRIOR TO THIS MEETING.

   B. MAINTAIN FULL FUNCTIONALITY AND OPERATION OF EXISTING TRAFFIC SIGNALS DURING CONSTRUCTION. CHANGES TO THE EXISTING TRAFFIC SIGNAL OPERATION WILL ONLY BE PERMITTED WITH APPROVAL OF THE ENGINEER.

   C. IF TRAFFIC SIGNAL SYSTEM FAILS OR BECOMES DAMAGED PRIOR TO ACCEPTANCE OF THE INSTALLATION, THE CONTRACTOR SHALL REPAIR AND RESTORE THE TRAFFIC SIGNAL SYSTEM TO NORMAL OPERATION.

   IF THE CONTRACTOR FAILS TO PROVIDE ON-SITE FORCES TO INITIATE THE REPAIR WITHIN 2 HOURS, THE AUTHORITY WILL RESPOND WITH THEIR OWN FORCES. IF THIS HAPPENS, THE CONTRACTOR IS ASSESSED THE COSTS OF MOBILIZING THE AUTHORITY'S FORCES AND EQUIPMENT, AND THE ACTUAL COSTS OF THE REPAIRS.

2. TEMPORARY TRAFFIC SIGNALS WILL ONLY BE PERMITTED WITH APPROVAL OF THE ENGINEER AT NO ADDITIONAL COST TO THE AUTHORITY. SUBMIT SHOP DRAWING SIGNED BY A NEW JERSEY OR NEW YORK PROFESSIONAL ENGINEER FOR TEMPORARY TRAFFIC SIGNALS THAT INCLUDE SIGNAL LAYOUT, EQUIPMENT, AND PHASING AND TIMING PLANS TO THE ENGINEER FOR APPROVAL.
   [DESIGNER NOTE: SHOW DRAWING IS TO BE SIGNED BY A LICENSED ENGINEER IN THE STATE THAT THE SIGNAL RESIDES IN. IT IS THE DESIGNER'S RESPONSIBILITY TO REVIEW THE EXISTING TRAFFIC SIGNAL OPERATIONS AND ENSURE THAT IT CAN BE MAINTAINED DURING CONSTRUCTION. IF MODIFICATIONS AND/OR A TEMPORARY SIGNAL IS REQUIRED, THEY ARE REQUIRED TO BE DESIGNED AS PART OF THE CONTRACT SET. THIS NOTE SHALL ONLY BE USED IN SITUATIONS WHERE A TEMPORARY OR INTERIM SIGNAL IS NECESSARY.]

3. COVER ALL TRAFFIC SIGNAL HEADS THAT ARE NOT IN OPERATION WITH AN OPAQUE MATERIAL AND DISCONNECT POWER. ADEQUATELY FASTEN THE MATERIAL TO THE SIGNAL HEADS IN A NEAT, SECURE, AND WEATHER PROOF MANNER.

4. THE VIDEO DETECTION SYSTEM SHALL BE VANTAGE NEXT, MANUFACTURED BY ITERIS, INC., INCLUDING MOUSE AND MONITOR IN EACH CONTROLLER CABINET, NO SUBSTITUTIONS PERMITTED. ALL VIDEO DETECTION EQUIPMENT SHALL BE FURNISHED BY MARBELITE CO. INC. ALONG WITH INSTALLATION, PROGRAMMING, AND TESTING OF VIDEO EQUIPMENT INSIDE CONTROLLER CABINET. NO SUBSTITUTION PERMITTED.
   [DESIGNER NOTE: PLEASE RECOGNIZE THAT CURRENTLY VIDEO DETECTION IS A SOLE SOURCE ITEM, AND PROPER DOCUMENTATION SHOULD BE PROVIDED.]
   [WHEN APPLICABLE INCLUDING THE FOLLOWING:]
   PROGRAM VIDEO SENSORS TO COMMUNICATE WITH THE EXISTING TRAFFIC CONTROL CENTERS THROUGH PAWANET AT BOTH THE FACILITY OFFICE LOCATED AT (*SPECIFY LOCATION*) AT AND THE AUTHORITY TRAFFIC ENGINEERING OFFICE LOCATED AT 4 WTC VIA (*SPECIFY COMMUNICATION TYPE*).

5. THE UNINTERRUPTIBLE POWER SOURCE (UPS) SHALL BE NOVUS FXM UPS SERIES, AS MANUFACTURED BY ALPHA TECHNOLOGIES, OR APPROVED EQUAL. UPS UNIT SHALL HAVE A BASELINE (NORMAL) OPERATION RUNTIME OF (*SPECIFY NUMBER OF HOURS*) SUPPORTING THE LOAD FOR THE EQUIPMENT SHOWN. BATTERIES SHALL BE HOUSED IN A CABINET SEPARATE FROM THE CONTROLLER CABINET.
   [DESIGNER NOTE: TYPICAL RUNTIMES: PN-PERMIT - 8 HRS; ALL OTHER FACILITIES - 4 HRS]

6. PEDESTRIAN PUSHBUTTONS SHALL BE EZ COMMUNICATOR NAVIGATOR ACCESSIBLE PEDESTRIAN SYSTEM (APS), AS MANUFACTURED BY POLARA ENGINEERING, INC., OR APPROVED EQUAL, WITH LATCHING LED. THESE PUSHBUTTONS SHALL BE COMPLIANT WITH THE ADA, PROWAG, AND MUTCD AND INCLUDE THE FOLLOWING ACCESSIBLE PEDESTRIAN SYSTEM (APS) FEATURES:

   A. PUSH BUTTON LOCATOR TONE;

   B. A VIBRO-TACTILE BUTTON WITH RAISED ARROW;

   C. A SPEECH WALK MESSAGE FOR THE WALKING PERSON INDICATION;

   D. A SPEECH COUNTDOWN CORRESPONDING TO THE FLASHING DON'T WALK TIMING;

   E. A SPEECH PUSH BUTTON INFORMATION MESSAGE. SEE CONTRACT DRAWINGS FOR SPECIFIC INFORMATION MESSAGES;

   F. PUSH BUTTON SIGN, AS SHOWN ON CONTRACT DRAWINGS, WITH FRAME AND BRAILLE FEATURES; AND

   G. EXTENSION BRACKET TO ACCOMMODATE AN UNOBSTRUCTED HORIZONTAL REACH OF 10 INCHES OR LESS.

   [OR]

   PEDESTRIAN PUSHBUTTONS SHALL BE BULLDOG MODEL BDLL2 (LATCHING LED MODEL) AS MANUFACTURED BY POLARA ENGINEERING, INC., OR APPROVED EQUAL. PUSHBUTTON ASSEMBLIES SHALL BE EQUIPPED WITH FRAME FOR "R10 SERIES" PEDESTRIAN CROSSING SIGN. MOUNTING FRAME SHALL BE VANDAL RESISTANT.
   [DESIGNER NOTE: COORDINATE WITH TRAFFIC ENGINEERING ON TYPE OF PUSHBUTTONS TO BE USED.]

7. CONTROLLERS SHALL BE SIEMENS M62 SERIES ATC NEMA TS-2/TYPE 2 IN COMPLIANCE WITH NTCIP STANDARDS. NO SUBSTITUTIONS PERMITTED. THE TRAFFIC SIGNAL CONTROLLER SHALL ALSO BE EQUIPPED WITH THE FOLLOWING FEATURES:

   A. DATA KEY READER

   B. DATA KEY 2RS-232 PORTS

   C. LATEST SEPAC AND NTCIP SOFTWARE

   FURNISH AND INSTALL GPS CLOCK COMPATIBLE WITH THE ABOVE CONTROLLER.
   [DESIGNER NOTE: PLEASE RECOGNIZE THAT CURRENTLY A CONTROLLER IS A SOLE SOURCE ITEM, AND PROPER DOCUMENTATION SHOULD BE PROVIDED.]

8. EMPLOY A REPRESENTATIVE OF THE CONTROLLER MANUFACTURER TO PERFORM THE PROGRAMMING OF THE CONTROLLER TO PERFORM THE SIGNAL OPERATION AS SHOWN ON THE CONTRACT DRAWINGS.

9. THE CONFLICT MONITOR SHALL BE A MALFUNCTION MANAGEMENT UNIT TYPE MMU2-16LE(IP) SMARTMONITOR AS MANUFACTURED BY EDI AND PROVIDED BY MARBELITE CO., INC. NO SUBSTITUTIONS PERMITTED.
   [DESIGNER NOTE: PLEASE RECOGNIZE THAT CURRENTLY CONFLICT MONITORS ARE A SOLE SOURCE ITEM, AND PROPER DOCUMENTATION SHOULD BE PROVIDED.]

10. CONDUCT A TRAFFIC SIGNAL PRE-FINAL/TURN-ON INSPECTION FOR EACH INTERSECTION IN THE PRESENCE OF THE ENGINEER PRIOR TO TESTING THE NEW TRAFFIC SIGNAL OPERATION. UPON COMPLETION OF THE PUNCHLIST ITEMS FROM THE PRE-FINAL/TURN-ON INSPECTION, CONDUCT A FINAL INSPECTION IN THE PRESENCE OF THE ENGINEER. NOTIFY THE ENGINEER AT LEAST TWO WEEKS PRIOR TO THE REQUESTED DATES OF BOTH INSPECTIONS. THE NEW TRAFFIC SIGNAL OPERATION SHALL UNDERGO A 30-DAY ACCEPTANCE TEST PERIOD AFTER ALL FINAL INSPECTION AND PUNCHLIST ITEMS ARE ADDRESSED. COMPLY WITH THE PROCEDURES AND PROCESSES IN SPECIFICATION SECTION 344118.

11. PRIOR TO THE PRE-FINAL/TURN-ON INSPECTION, SUBMIT A TEST RESULT LETTER TO THE ENGINEER THAT THE CABINET INTERNAL AND REAR BOARD CONNECTIONS, THE CONTROLLER, AND THE CONFLICT MONITOR HAVE BEEN TESTED IN ACCORDANCE WITH THE SPECIFICATIONS.

12. ANY CORRECTIONS OR MODIFICATIONS TO THE WORK REQUIRED DURING TRAFFIC SIGNAL PRE-FINAL/TURN-ON AND FINAL INSPECTIONS IN ORDER TO COMPLY WITH THE CONTRACT DRAWINGS SHALL BE MADE AT NO ADDITIONAL COST TO THE AUTHORITY.

13. TEST ALL CIRCUITS AND EQUIPMENT FOR PROPER CONNECTIONS BEFORE THE ELECTRICAL SYSTEM IS ENERGIZED (CONTINUITY CHECKS).

14. THE ELECTRICAL SYSTEM INSTALLATION(S) SHALL COMPLY WITH REQUIREMENTS AS SPECIFIED IN DIVISION 16 SPECIFICATIONS, AND SHALL COMPLY WITH ALL APPLICABLE CODE REQUIREMENTS.

15. TAG ALL WIRES AT POINT OF TERMINATION AT BOTH ENDS AND IN ALL PULL BOXES.

16. FURNISH SPARE TRAFFIC SIGNAL EQUIPMENT ACCORDING TO THE FOLLOWING LIST:

   A. (X) CONTROLLER

   B. (X) SIGNAL CONFLICT MONITOR UNIT

   C. (X) VIDEO DETECTION SENSOR

   D. (X) VIDEO DETECTION PROCESSOR

   E. (X) LOAD SWITCHES

   F. (X) FLASHER UNIT

   G. (X) FLASH TRANSFER RELAY

   H. (X) LOOP DETECTOR AMPLIFIER (IF APPLICABLE)

   I. (X) ELECTRICAL SUPRESSOR

   J. (X) GPS CLOCKS

   K. (X) SOLID STATE RELAYS

   L. (X) TRAFFIC SIGNAL POLES, STEEL (65' MAST ARM DESIGN)

   M. (X) TRAFFIC SIGNAL POLES, STEEL (50' MAST ARM DESIGN)

   N. (X) TRAFFIC SIGNAL POLES, ALUMINUM

   O. (X) FULLY WIRED AND EQUIPPED SPARE CABINET
   ["X" DESIGNATES THE QUANTITY. CONSULT WITH TRAFFIC ENGINEERING TO DETERMINE WHICH APPLICABLE EQUIPMENT SHOULD BE SHOWN AND THE RECOMMENDED QUANTITIES.]

17. FURNISH AND INSTALL GROUND WIRE (GND), 1/C #8 AWG, INSULATED (COLOR GREEN) CONTINUOUSLY THROUGHOUT THE TRAFFIC SIGNAL SYSTEM AND SECURE TO ALL GROUND RODS, CABINET, TRAFFIC SIGNAL BASES, HANDHOLE/BASE PLATE COVERS, AND PULLBOX/SPLICE BOX COVERS.

18. DISCONNECT MANUAL CONTROL FOR TRAFFIC SIGNAL CONTROLLER AND LEAVE CONTROL INSIDE CONTROLLER CABINET PULLOUT DRAWER.

19. WHERE EXISTING DUCTBANK IS SHOWN ON THE CONTRACT DRAWINGS AS ABANDONED, REMOVE ALL CABLES AND WIRES FROM THE DUCTBANK AND PLUG EACH CONDUIT OF THE DUCTBANK.

20. UNLESS OTHERWISE SHOWN ON CONTRACT DRAWINGS, CONCRETE SHALL BE PERFORMANCE CATEGORY IV WITH A MINIMUM 28 DAY COMPRESSIVE STRENGTH (F' C) OF 4000 PSI IN ACCORDANCE WITH SPECIFICATION 033010. SUBMIT MIX DESIGN TO THE ENGINEER FOR APPROVAL.

21. ALL REINFORCING BARS SHALL BE ASTM A615, GRADE 60, 709-01, EPOXY COATED UNLESS OTHERWISE NOTED.

22. DELIVER ALL REMOVED EXISTING ABOVE GROUND TRAFFIC SIGNAL EQUIPMENT TO THE (*SPECIFIC APPLICABLE FACILITY*) ELECTRICAL SHOP LOCATED IN (*SPECIFY LOCATION*). NOTIFY THE ENGINEER PRIOR TO DELIVERY.

23. SUBMIT SHOP DRAWINGS FOR ALL TRAFFIC SIGNAL EQUIPMENT TO THE ENGINEER IN ACCORDANCE WITH THE SUBMITTALS LIST IN SPECIFICATIONS.

24. SUBMIT ALL TRAFFIC SIGNAL EQUIPMENT WARRANTIES AND ALL NECESSARY EQUIPMENT MANUALS TO THE ENGINEER IN ACCORDANCE WITH THE SPECIFICATIONS.

25. ALL NEW TRAFFIC SIGNAL POLES, ARMS, BASES, MOUNTING HARDWARE & EQUIPMENT, AND VIDEO MOUNTING EQUIPMENT & HARDWARE, CABINETS, CABINET SKIRTS, AND BACK SIDE OF BACKPLATES SHALL BE POWDER COATED BASED ON THE SPECIFICATIONS BELOW. THE TRAFFIC SIGNAL HEADS AND VIDEO DETECTION UNIT HOUSINGS SHALL NOT BE POWDER COATED. ALL POWDER COATING SHALL BE PERFORMED BY THE POLE MANUFACTURER DURING FABRICATION.

   ALUMINUM AND STEEL ARMS, POLES AND TRANSFORMER BASES SHALL BE CLEANED PRIOR TO THE POWDER COAT PROCESS. CLEANING OF THE ARMS AND POLES SHALL BE PERFORMED BY THE IMMERSION PROCESS USING BOTH AN ALKALINE AND ACID BATH BEFORE ANY FABRICATION WELDING. TO FACILITATE ADHESION OF THE POWDER, THE ARMS AND POLES SHALL HAVE A MINIMUM 80-GRIT-ROTARY-SANDED-SATIN-BRUSH-FINISH.

   THE APPLIED FINISH SHALL BE A THERMOSETTING POWDER COAT. THE POWDER RESIN SHALL BE A TYPE (Y) OR APPROVED EQUAL PER SPECIFICATION SECTION 099100, PAINT SYSTEM S-10, MEETING THE PERFORMANCE REQUIREMENTS OF AAMA (Z). IF NECESSARY, PRIOR TO THE COATING PROCESS THE ALUMINUM PARTS SHALL BE PREHEATED TO SUFFICIENT TEMPERATURE TO ENSURE ALL WATER VAPOR IS REMOVED AND TO AID IN THE FUSING OF HT POWDER TO THE METAL.
   [DESIGNER NOTE: (Y) REPRESENTS APPLICATION TYPE. REPLACE (Y) WITH PDVF FLUOROPOLYMER IF LOCATED IN LGA FACILITY. REPLACE (Y) WITH TCIG POLYESTER FOR ALL OTHER FACILITIES.]
   [DESIGNER NOTE: (Z) REPRESENTS PERFORMANCE REQUIREMENTS TYPE. REPLACE (Z) WITH 2605 IF LOCATED IN LGA. REPLACE (Z) WITH 605.2 AT ALL OTHER FACILITIES.]

   THE POWDER SHALL BE APPLIED BY ELECTROSTATIC SPRAYING. AFTER SPRAYING, THE PARTS SHALL BE OVEN CURED FOR A CYCLE OF 5 TO 15 MINUTES AT A TEMPERATURE OF 375° - 400°F. THE FINAL COATING FILM THICKNESS SHALL BE IN A RANGE OF 3 - 5 MILS.

   BEFORE SHIPMENT THE MANUFACTURER SHALL PERFORM A THOROUGH VISUAL INSPECTION TO ASSURE THERE ARE NO FINISH FLAWS AND TOUCH-UP OR RECOAT IF NECESSARY. ANY TOUCH-UP RECOATING NECESSARY SHALL BE PERFORMED PRIOR TO SHIPPING.

   A SPRAY CAN OF MATCHING TOUCH-UP PAINT SHALL BE SUPPLIED FOR EVERY UNIT FURNISHED AND INSTALLED. TOUCH-UP SPRAY SHALL BE DELIVERED TO THE ENGINEER AT THE SAME TIME THE POLES, TRANSFORMER BASES AND OTHER HARDWARE IS DELIVERED. THE SPRAY SHALL NOT BE USED TO TOUCH UP SCRATCHES, SCUFFS OR OTHER MARKS MADE DURING HANDLING BY THE CONTRACTOR OR OTHERS. IF ANY POLES, BASES OR HARDWARE ARE DAMAGED, THE CONTRACTOR SHALL CORRECT THE DAMAGE TO THE SATISFACTION OF THE ENGINEER.

   ALL TRAFFIC SIGNAL EQUIPMENT AT THE PORT NEWARK-ELIZABETH PORT AUTHORITY MARINE TERMINAL (PN-EPAMT) FACILITIES SHALL BE POWDER COATED BLACK.

   [OR]

   ALL TRAFFIC SIGNAL EQUIPMENT AT THE NEWARK LIBERTY INTERNATIONAL AIRPORT (EWR) FACILITIES SHALL BE POWDER COATED "UMBER" (CARBOLINE CARBOTHANE 134HG, COLOR CODE #8206).

   [OR]

   ALL TRAFFIC SIGNAL EQUIPMENT AT LAGUARDIA AIRPORT (LGA) SHALL BE POWDER COATED "DURANAR" (CHARCOAL GREY 5LA87818)

26. THE CONTRACTOR SHALL DESIGNATE EXPERIENCED TRAFFIC SIGNAL TECHNICIANS TO THIS CONTRACT TO PERFORM THE SPECIFIED SIGNAL CONSTRUCTION AND MAINTENANCE TASKS AS FOLLOWS:

   A. AT A MINIMUM, ALL TECHNICIANS ASSIGNED TO THIS CONTRACT SHALL BE IMSA TRAFFIC SIGNAL TECHNICIAN LEVEL 1 CERTIFIED.

   B. TECHNICIANS RESPONSIBLE FOR THE TRAFFIC SIGNAL CONTROLLER AND CONFLICT MONITOR CERTIFICATION TESTING TASKS SHALL BE: A) FACTORY TRAINED TO SERVICE THE CONTROLLERS AND CONFLICT MONITORS INCLUDED IN THIS CONTRACT, OR B) SHALL BE IMSA CERTIFIED LEVEL II TRAFFIC SIGNAL FIELD TECHNICIANS AND HAVE A MINIMUM OF 2 YEARS OF VERIFIABLE EXPERIENCE AS A LEVEL II TRAFFIC SIGNAL TECHNICIAN (MINIMUM 4 YEARS EXPERIENCE AS A TRAFFIC SIGNAL TECHNICIAN).

27. REPLACEMENT OF SIGNAL HEADS ON SPAN WIRE SHALL BE STAGED IN A MANNER THAT DOES NOT EXCEED THE STRUCTURAL LOADING REQUIREMENTS OF INSTALLATION.

28. VERIFY THE ACCURACY OF EXISTING INFORMATION PRIOR TO THE COMMENCEMENT OF WORK.

29. OBTAIN ALL NECESSARY INSPECTIONS AND PERMITS FOR OBTAINING ELECTRICAL SERVICE CONNECTIONS.

30. FOUNDATIONS ARE TO BE REMOVED TO A DEPTH OF 12 INCHES BELOW GRADE. HOLE TO BE FILLED AND COVERED TO FINAL FINISHED GRADE.

31. THE LOCATIONS OF TRAFFIC SIGNAL POLES AND SIGNALS SHALL BE INSTALLED AS SHOWN IN THE CONTRACT DRAWINGS. ANY CHANGES IN THE TRAFFIC SIGNAL POLE OR SIGNAL LOCATIONS DUE TO FIELD CONDITIONS SHALL BE APPROVED BY THE ENGINEER.

GENERAL NOTES (PULLBOXES AND SPLICE BOXES):

1. THE LOCATIONS OF THE PULLBOXES ARE APPROXIMATE AND ARE SUBJECT TO APPROVAL BY THE ENGINEER PRIOR TO CONSTRUCTION.

2. PULLBOXES AND SPLICE BOXES SHALL NOT BE INSTALLED AT A PEDESTRIAN ACCESS RAMP.

3. IF INSTALLED WITHIN A SIDEWALK, THE PULLBOX AND SPLICE BOXES SHALL BE ALIGNED FLUSH WITH THE SURFACE OF THE SURROUNDING SIDEWALK.

4. PULLBOXES AND SPLICE BOXES INSTALLED IN ROADSIDE BERMS, SIDEWALKS OR MEDIANS, PAVED OR UNPAVED SHALL BE ALIGNED FLUSH WITH THE SURROUNDING SURFACE.

GENERAL NOTES (INTEGRATION OF TRAFFIC CONTROL SYSTEM):

1. UPON NOTIFICATION FROM THE ENGINEER THAT ALL (SPECIFY COMMUNICATION TYPE) SPLICING AND TERMINATIONS (PERFORMED BY THE AUTHORITY) HAVE BEEN COMPLETED, TRAFFIC SIGNAL CONTROLLERS AND TRANSMISSION EQUIPMENT SHALL BE TESTED AND INTEGRATED WITH THE CURRENT VERSION OF THE SIEMENS TACTICS SOFTWARE. FINAL ACCEPTANCE WILL BE CONTINGENT UPON FULL CONFIGURATION OF THE CONTROLLER, CONFLICT MONITOR, AND VIDEO DETECTION CAMERA/PROCESSOR AT EVERY INTERSECTION.

2. PROGRAM THE TRAFFIC SIGNAL CONTROLLER TO TRANSMIT AND RECEIVE ALL OF THE NTCIP FUNCTIONS TO AND FROM SIEMENS TACTICS, THE AUTHORITY CENTRALIZED TRAFFIC SIGNAL MANAGEMENT SYSTEM.

3. PROVIDE INDIVIDUAL AS-BUILT BLOCK DIAGRAMS OF THE COMMUNICATIONS SYSTEM SHOWING ALL CONNECTIONS AND ATTACHED DEVICES.

USER INSTRUCTIONS

1. THE SAMPLE GENERAL NOTES ARE DESIGNED TO BE USED IN THE CONSTRUCTION OF A VARIETY OF DIFFERENT PROJECTS. THE USER (ENGINEER, DESIGNER, TASK LEADER) IS RESPONSIBLE FOR ENSURING THAT THE GENERAL NOTES USED ARE APPROPRIATE FOR THE APPLICATION AND THAT ANY SPECIFIC PROJECT DATA OR INFORMATION IS FILLED IN ACCORDINGLY.

2. ADDITIONAL NOTES MAY BE USED FOR SPECIFIC PROJECT REQUIREMENTS AND SPECIAL CONDITIONS ENCOUNTERED AT THE VARIOUS PORT AUTHORITY FACILITIES.

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE TRAFFIC SIGNAL GENERAL NOTES

Designed by

Drawn by

Checked by

Date DECEMBER 2018

Contract Number

Drawing Number SG006

PID#

LEGEND

	NEW	EXISTING	REMOVAL	
TRAFFIC SIGNAL CONTROLLER - GROUND MOUNTED				
DUAL TRAFFIC SIGNAL CONTROLLER - GROUND MOUNTED				
TRAFFIC SIGNAL CONTROLLER - POLE MOUNTED				
TRAFFIC SIGNAL UPS SIDE MOUNT ENCLOSURE - GROUND MOUNTED				
TRAFFIC SIGNAL PULLBOX				
LOOP DETECTOR SPLICE BOX	SB	SB	SB	
TRAFFIC SIGNAL VEHICULAR HEAD WITH IDENTIFIER	X	X	X	X IS THE VEHICULAR SIGNAL HEAD NUMBER
TRAFFIC SIGNAL VEHICULAR HEAD (LOUVERED) WITH IDENTIFIER	X	X	X	X IS THE VEHICULAR SIGNAL HEAD NUMBER
TRAFFIC SIGNAL PEDESTRIAN HEAD WITH IDENTIFIER	PX	PX	PX	X IS THE PEDESTRIAN SIGNAL HEAD NUMBER
TRAFFIC SIGNAL PEDESTRIAN PUSH BUTTON WITH IDENTIFIER	PBX	PBX	PBX	X IS THE PEDESTRIAN PUSHBUTTON NUMBER
MAST ARM POLE	X	X	X	X IS THE MAST ARM LENGTH
TRAFFIC SIGNAL POLE				
SPAN WIRE WITH STEEL POLES				
TRAFFIC SIGNAL LOOP DETECTOR WITH IDENTIFIER	DXNZ	DXNZ	DXNZ	DXNZ IS THE LOOP DETECTOR IDENTIFIER
VIDEO DETECTION ZONE	VXNY	VXNY		VXNY IS THE VIDEO AREA IDENTIFIER
VIDEO DETECTOR	VX	VX	VX	X IS THE VIDEO SENSOR NUMBER
TRAFFIC SIGNAL UNDERGROUND CONDUIT				
POLE MOUNTED REGULATORY OR WARNING SIGN				
STREET NAME SIGN MOUNTED ON MAST ARM				
STREET NAME SIGN MOUNTED ON SPAN WIRE				
SERVICE MANHOLE	E	E	E	
DUCTBANK				
DUCTBANK ENCASED IN CONCRETE				
PEDESTRIAN MOVEMENT				
VEHICLE MOVEMENT	ØX			

DUCTBANK FORMATION - THE NUMBER OF CONDUIT AND ARRANGEMENT FOR EACH DUCTBANK SHALL BE PREPARED FROM THE FOLLOWING SYMBOLS:

- DENOTES INSTALLING NEW CONDUIT WITH NEW CABLES OR WIRES
- DENOTES SPARE CONDUITS
- DENOTES EXISTING CONDUIT WITH EXISTING CABLES OR WIRES TO REMAIN
- DENOTES ABANDONING EXISTING CONDUIT AND THE REMOVAL OF EXISTING CABLES OR WIRES
- DENOTES THE INSTALLATION OF NEW CABLES OR WIRES IN EXISTING CONDUIT WITH THE EXISTING CABLES OR WIRES TO REMAIN
- DENOTES THE INSTALLATION OF NEW CABLES OR WIRES IN EXISTING CONDUIT AFTER THE EXISTING CABLES OR WIRES ARE REMOVED

USER INSTRUCTIONS

THE USER (ENGINEER, DESIGNER, TASK LEADER) IS RESPONSIBLE FOR ENSURING THAT ONLY SYMBOLS SPECIFIC TO THE PROJECT ARE PROVIDED ON THIS SHEET AND UTILIZE THE RESPECTIVE SYMBOLS IN THE DESIGN CENTER.

THE PORT AUTHORITY
OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

SAMPLE
TRAFFIC SIGNAL
LEGEND

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG007
PID#

Sheet XX of XX

ABBREVIATIONS (FOR SG DRAWINGS ONLY)

ABS	ACRYLONITRILE BUTADIENE STYRENE
ADA	AMERICANS WITH DISABILITIES ACT
ADJ.	ADJACENT
ALT.	ALTERNATIVE
ALUM./AL.	ALUMINUM
AOA	AIRPORT OPERATIONS AREA
ANSI/SCTE77	AMERICAN NATIONAL STANDARDS INSTITUTE/SPECIFICATIONS FOR UNDERGROUND
AASHTO	AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
APS	ACCESSIBLE PEDESTRIAN SIGNAL
ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIALS
AWG	AMERICAN WIRE GAUGE
AWS	AMERICAN WELDING SOCIETY
B.C.	BOLT CIRCLE
BET.	BETWEEN
BRZ	BRONZE
C	CONDUIT
CBL	CABLE
CCS	CONTROLLER CABINET SKIRT
CHG	CHANGE
CFP	CONTROLLER FOUNDATION, TYPE P
CFP-MC	CONTROLLER FOUNDATION, TYPE P-MC
CL	CENTER LINE
CLR.	CLEARANCE
COF	COEFFICIENT OF FRICTION
COMM	COMMUNICATION
CONC.	CONCRETE
COV.	COVER
CU	CUBIC
DIA	DIAMETER
DIM	DIMENSION
DR	DROP AND REPEAT
DW	DON'T WALK
DWG	DRAWING
EA.	EACH
EXT	EXTENSION
F-MC	FOUNDATION, TYPE MC
FDN.	FOUNDATION
FDW	FLASHING DON'T WALK
FHWA	FEDERAL HIGHWAY ADMINISTRATION
FL.	FLANGE
FL. (SIGNALS)	FLASHING
FOPP	FIBER OPTIC PATCH PANEL
FOSC	FIBER OPTIC SPLICE ENCLOSURE
FRU	FRUTIGER
FSC	FLEXIBLE LIQUID-TIGHT STEEL CONDUIT
FO	FIBEROPTIC
FOD	FIBER OPTIC DATA
FT.	FEET
G (SIGNALS)	GREEN
GALV.	GALVANIZED
GFI	GROUND FAULT INTERRUPT
GND	GROUND
GR	GRADE
H	HENRY
HD.	HEAD/HEAVY DUTY
HH	HAND HOLE
ID	INNERDUCT
I.D.	INSIDE DIAMETER
IMSA	INTERNATIONAL MUNICIPAL SIGNAL ASSOCIATION
IN.	INCH
KSI	KILOPOUNDS PER SQUARE INCH
LB	POUNDS
LBS.	POUNDS
LED	LIGHT-EMITTING DIODE
LDL	LOOP DETECTOR LEAD
LDM	LANE DROP MARKING
LG.	LONG
LOC.	LOCATION
LS	LOAD SWITCH
M	METER
MC	METER CABINET
MIN.	MINIMUM
MM	MILLIMETER
MPH	MILES PER HOUR
MTL	MATERIAL
MUTCD	MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES
N/A	NOT APPLICABLE
NO.	NUMBER
N.T.S	NOT TO SCALE
O.C.	ON CENTER
O.D.	OUTSIDE DIAMETER
PBA	PEDESTRIAN PUSH BUTTON ASSEMBLY
PED	PEDESTRIAN
PERM.	PERMANENT
PI.X	POINT OF INTERSECTION OF CURB LINE EXTENDED
PROWAG	PUBLIC RIGHTS-OF-WAY ACCESSIBILITY GUIDELINES
PSI	POUNDS PER SQUARE INCH
PTS	PEDESTRIAN TRAFFIC SIGNAL (CLAMP MOUNTED ON A SIGNAL POLE)
PVC	POLYVINYL CHLORIDE
PVC-H	POLYVINYL CHLORIDE - HEAVY WALL
R/RAD.	RADIUS
REQ'D	REQUIRED
RD	ROUND
R(SIGNALS)	RED
RHS	RECTANGULAR HOLLOW SECTION
RGS	RIGID GALVANIZED STEEL CONDUIT
RNMC-C	RIGID NON-METALLIC CONDUIT, TYPE PVC-H, ENCASED IN CONCRETE
SAE	SOCIETY OF AUTOMOTIVE ENGINEERS
SCR.	SCREW
SEC.	SECONDS
S.F.	SQUARE FEET
SFT	FOUNDATIONS, TYPE SFT
SFK	FOUNDATIONS, TYPE SFK
SME	SIDE MOUNT ENCLOSURE
SOC./CO.	SOCKET
SP(XX')	SIGNAL PEDESTAL (POLE HEIGHT ABOVE GROUND)
SPEC.	SPECIFICATION
SPF	FOUNDATIONS, TYPE SPF
SQ.	SQUARE
STD.	STANDARD
STF-A	FOUNDATIONS, TYPE STF-A
STF-B	FOUNDATIONS, TYPE STF-B
STL.	STEEL
STN.	STAINLESS
THD	THREAD
THDS.	THREADS
THK.	THICK
TSA	TRAFFIC SIGNAL ASSEMBLIES
TSA-15M-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 15M-1
TSA-15M-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 15M-2
TSA-20M-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 20M-1
TSA-20M-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 20M-2
TSA-25MK-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 25MK-1
TSA-25MK-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 25MK-2
TSA-30SA-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 30SA-1
TSA-30SA-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 30SA-2
TSA-35SA-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 35SA-1
TSA-35SA-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 35SA-2
TSA-40SA-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 40SA-1
TSA-40SA-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 40SA-2
TSA-45SA-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 45SA-1
TSA-45SA-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 45SA-2
TSA-50SA-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 50SA-1
TSA-50SA-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 50SA-2
TSA-55SB-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 55SB-1
TSA-55SB-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 55SB-2
TSA-60SB-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE 60SB-1
TSA-60SB-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE 60SB-2
TSA-C-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE C-1
TSA-MM-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE MM-1
TSA-H-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE H-1
TSA-H-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE H-2
TCS-HC-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE HC-1
TSA-HM-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE HM-1
TSA-SW-1	TRAFFIC SIGNAL ASSEMBLIES, TYPE SW-1
TSA-SW-2	TRAFFIC SIGNAL ASSEMBLIES, TYPE SW-2
TSA-SW-3	TRAFFIC SIGNAL ASSEMBLIES, TYPE SW-3
TSA-SW-4	TRAFFIC SIGNAL ASSEMBLIES, TYPE SW-4
TSH	TRAFFIC SIGNAL HEAD
TSS-T	TRAFFIC SIGNAL SUPPORTS, TYPE T
TSS-K	TRAFFIC SIGNAL SUPPORTS, TYPE K
TSS-SA	TRAFFIC SIGNAL SUPPORTS, TYPE S-A
TSS-SB	TRAFFIC SIGNAL SUPPORTS, TYPE S-B
TYP.	TYPICAL
UNC	UNIFIED NATIONAL COARSE
UPS	UNINTERRUPTIBLE POWER SOURCE
VEH	VEHICLE
VIP	VIDEO INPUT PROCESSOR
VSC	VIDEO SENSOR CABLE
VSC(VX)	VIDEO SENSOR CABLE (WITH RESPECTIVE SENSOR NUMBER(S))
VS	VIDEO SENSOR
VS (VX)	VIDEO SENSOR (WITH RESPECTIVE SENSOR NUMBER(S))
W	WALK
WT.	WEIGHT
Y(SIGNALS)	YELLOW
2/C	TRAFFIC SIGNAL CABLE, 2 CONDUCTOR
5/C	TRAFFIC SIGNAL CABLE, 5 CONDUCTOR
10/C	TRAFFIC SIGNAL CABLE, 10 CONDUCTOR
μ	MICRO

ABBREVIATIONS (FOR REMOVAL PURPOSES ONLY)

TSH (X)	TRAFFIC SIGNAL HEAD (WITH RESPECTIVE HEAD NUMBER(S))
TSMA-A	TRAFFIC SIGNAL MAST ARM, ALUMINUM
TSMA-S	TRAFFIC SIGNAL MAST ARM, STEEL

DESCRIPTION OF THE TRAFFIC SIGNAL ASSEMBLY ABBREVIATIONS:

1. TRAFFIC SIGNAL ASSEMBLIES SHALL CONSIST OF TRAFFIC SIGNAL ARM, FURNISHED AND INSTALLED ON A TRAFFIC SIGNAL SUPPORT COMPLETE WITH MAST ARM HANGER AND SPIDER ASSEMBLIES, OR MOUNTING BRACKET ASSEMBLY, AS REQUIRED, SAFETY CHAINS, TRAFFIC SIGNAL HEADS, MISCELLANEOUS HARDWARE AND FITTINGS, AND TRAFFIC SIGNAL CABLE FROM THE TERMINAL BLOCK OF EACH SIGNAL FACE TO THE BASE OF THE TRAFFIC SIGNAL SUPPORT.
2. TRAFFIC SIGNAL ASSEMBLIES DESIGNATED WITH THE LETTERS M SHALL CONSIST OF ASSEMBLIES HAVING A TRAFFIC SIGNAL ARM OF THE ALUMINUM MAST ARM TYPE WHICH IS TO FIT A SIGNAL POLE, TYPE T.
3. TRAFFIC SIGNAL ASSEMBLIES DESIGNATED WITH THE LETTERS MK SHALL CONSIST OF ASSEMBLIES HAVING A TRAFFIC SIGNAL ARM OF THE ALUMINUM MAST ARM TYPE WHICH IS TO FIT A SIGNAL POLE, TYPE K.
4. TRAFFIC SIGNAL ASSEMBLIES DESIGNATED WITH THE LETTERS SA SHALL CONSIST OF ASSEMBLIES HAVING A TRAFFIC SIGNAL ARM OF STEEL MAST ARM TYPE WHICH IS TO FIT A SIGNAL POLE, TYPE S-A.
5. TRAFFIC SIGNAL ASSEMBLIES DESIGNATED WITH THE LETTERS SB SHALL CONSIST OF ASSEMBLIES HAVING A TRAFFIC SIGNAL ARM OF STEEL MAST ARM TYPE WHICH IS TO FIT A SIGNAL POLE, TYPE S-B.
6. TRAFFIC SIGNAL ASSEMBLY TYPS C-1 SHALL CONSIST OF ONE TRAFFIC SIGNAL HEAD WITH POLE CLAMP MOUNTING FURNISHED AND INSTALLED ON A TRAFFIC SIGNAL SUPPORT. THE ITEM SHALL ALSO INCLUDE MISCELLANEOUS FITTINGS, THE DRILLING OF THE SUPPORT, INSTALLING THE GROMMET, AND TRAFFIC SIGNAL CABLE FROM THE TERMINAL BLOCK OF EACH SIGNAL FACE TO THE BASE OF THE SUPPORT.
7. TRAFFIC SYSTEM ASSEMBLY TYPE MM-1 SHALL CONSIST OF A MIDMOUNTED TRAFFIC SIGNAL HEAD FURNISHED AND INSTALLED ON A MAST ARM, COMPLETE MOUNTING HARDWARE, DRILLING THE ARM, GROMMET, MIDMOUNT BRACKET ASSEMBLY, SAFETY CHAIN, ONE TRAFFIC SIGNAL HEAD, AND TRAFFIC SIGNAL CABLE FROM THE TERMINAL BLOCK OF EACH FACE TO THE BASE OF THE TRAFFIC SIGNAL SUPPORT.
8. TRAFFIC SIGNAL ASSEMBLIES DESIGNATED WITH THE LETTER H SHALL CONSIST OF FURNISHING AND INSTALLING A TRAFFIC SIGNAL HEAD ON EXISTING TRAFFIC SIGNAL EQUIPMENT. THE ITEM SHALL ALSO INCLUDE THE REQUIRED MAST ARM HANGER OR MOUNTING BRACKETS, SAFETY CHAIN, MISCELLANEOUS FITTINGS, AND TRAFFIC SIGNAL CABLE FROM THE TERMINAL BLOCK OF THE TRAFFIC SIGNAL HEAD TO THE BASE OF THE STANDARD.
9. TRAFFIC SIGNAL ASSEMBLIES DESIGNATED WITH HC AND HM SHALL FOLLOW THE H REQUIREMENTS FOR 'C' AND 'MM' ASSEMBLIES, RESPECTIVELY.
10. TRAFFIC SIGNAL ASSEMBLIES DESIGNATED WITH THE LETTERS SW CONSIST OF FURNISHING AND INSTALLING A TRAFFIC SIGNAL HEAD ON SPAN WIRE, COMPLETE MOUNTING HARDWARE, GROMMET, MIDMOUNT BRACKET ASSEMBLY, SAFETY CHAIN, TRAFFIC SIGNAL HEAD, AND TRAFFIC SIGNAL CABLE FROM THE TERMINAL BLOCK OF EACH FACE TO THE BASE OF THE TRAFFIC SIGNAL SUPPORT.
11. [*SEE TABLE BELOW FOR INFORMATION FOR THIS CELL. TABLE MUST BE CUSTOMIZED BASED ON DESIGN.*]

TYPE	ARM LENGTH (FT)	NO. OF SIGNAL HEADS	NO. OF SPIDER ASSEMBLIES
15M-1	15	1	0
15M-2	15	2	1
20M-1	20	1	0
20M-2	20	2	1
25MK-1	25	1	0
25MK-2	25	2	1
30SA-1	30	1	0
30SA-2	30	2	1
35SA-1	35	1	0
35SA-2	35	2	1
40SA-1	40	1	0
40SA-2	40	2	1
45SA-1	45	1	0
45SA-2	45	2	1
50SA-1	50	1	0
50SA-2	50	2	1
55SB-1	55	1	0
55SB-2	55	2	1
60SB-1	60	1	0
60SB-2	60	2	1
C-1	N/A	1	0
H-1	N/A	1	0
H-2	N/A	2	0
HC-1	N/A	1	0
HM-1	N/A	1	0
MM-1	N/A	1	0
SW-1	N/A	1	1
SW-2	N/A	2	2
SW-3	N/A	3	3
SW-4	N/A	4	4

USER INSTRUCTIONS

THE USER (ENGINEER, DESIGNER, TASK LEADER) IS RESPONSIBLE FOR ENSURING THAT ONLY ABBREVIATIONS SPECIFIC TO THE PROJECT ARE PROVIDED ON THIS SHEET IN ACCORDANCE WITH THE PA STANDARD SPECIFICATIONS.

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE TRAFFIC SIGNAL ABBREVIATIONS

Designed by

Drawn by

Checked by

Date DECEMBER 2018

Contract Number

Drawing Number SG008

PID#

DESIGNER'S CHECKLIST

TRAFFIC SIGNAL DRAWING CHECKLIST

VERIFY THAT THE FOLLOWING ITEMS WERE CHECKED:

1. OVERHEAD CONFLICTS ☐
2. UNDERGROUND CONFLICTS ☐
3. CONE OF VISION ☐
4. ADVANCE VISIBILITY OF SIGNAL HEADS ☐
5. POLE OFFSETS FIELD VERIFIED ☐
6. CURB RAMP LOCATIONS ☐
7. DRIVEWAY ACCESS IMPACTS ☐
8. NEED FOR CROSSWALKS ☐
9. NEED FOR PEDESTRIAN SIGNALS ☐
10. PEDESTRIAN PUSHBUTTON ACCESSIBILITY ☐

ADDITIONAL NOTES:

PROVIDE RESPONSES TO THE FOLLOWING ITEMS:

11. POSTED/85TH PERCENTILE SPEED ____________
12. PART OF COORDINATED SYSTEM ____________
13. CROSSWALK WIDTHS ____________
14. GUIDERAIL/TRAFFIC BARRIER NEEDED ____________
15. PEDESTRIAN SIGNAL MOUNTING HEIGHT ____________
16. VEHICLE SIGNAL POLE CLAMPING HEIGHT ____________
17. OVERHEAD CLEARANCE OF SIGNAL HEADS ____________
18. NEED AESTHETIC COATING FOR HARDWARE ____________
19. NEED FOR BACKPLATES ____________
20. STEEL MAST ARMS REQUIRED ____________
21. TYPE OF SIGNAL VISORS ____________
22. NEED FOR LIMITED VISIBILITY SIGNALS ____________
23. VOLUME DENSITY OPERATION APPLICABLE ____________
24. NEED FOR SYSTEM DETECTORS ____________
25. NEED FOR MULTIPLE TIMING PLANS ____________
26. NEED FOR PROTECTED TURNS ____________
27. NEED FOR RIGHT TURN OVERLAP ____________
28. NEED FOR RTOR RESTRICTION ____________
29. ARE UPSTREAM SIGNAL HEADS VISIBLE ____________
30. MAST ARM SIGN AND MOUNTING TYPE ____________
31. MANUAL CONTROL REQUIRED ____________
32. NEED FOR UPS ____________
33. TYPE OF COMMUNICATION ____________

USER INSTRUCTIONS

THE CHECKLIST WILL NOT INCLUDED IN THE DRAWING SET, HOWEVER IT MUST BE SUBMITTED AS BACKUP FOR REVIEW BY PA TRAFFIC

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE DESIGNER'S CHECKLIST

Designed by

Drawn by

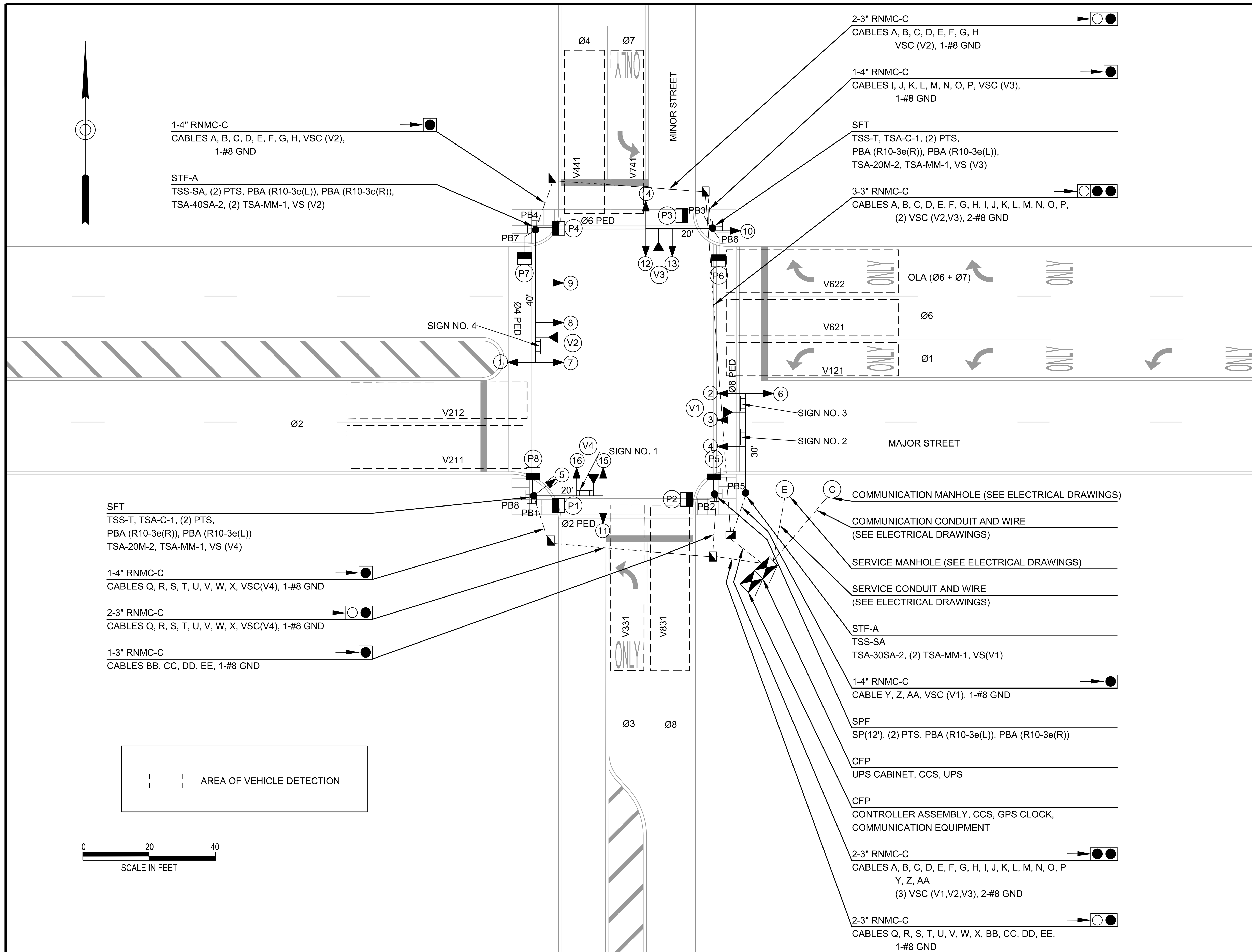
Checked by

Date DECEMBER 2018

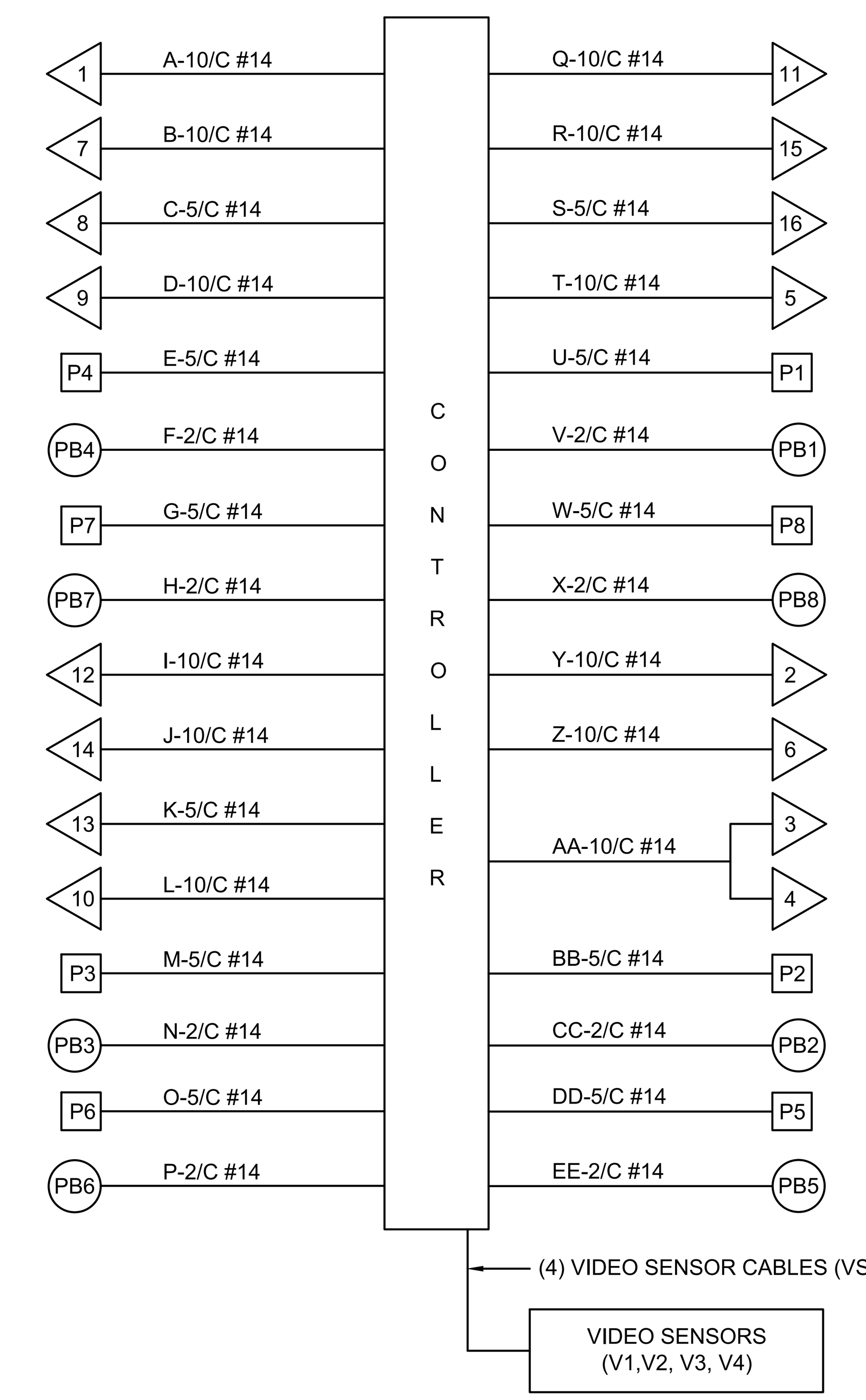
Contract Number

Drawing Number SG009

PID#



BLOCK WIRING DIAGRAM



LEGEND

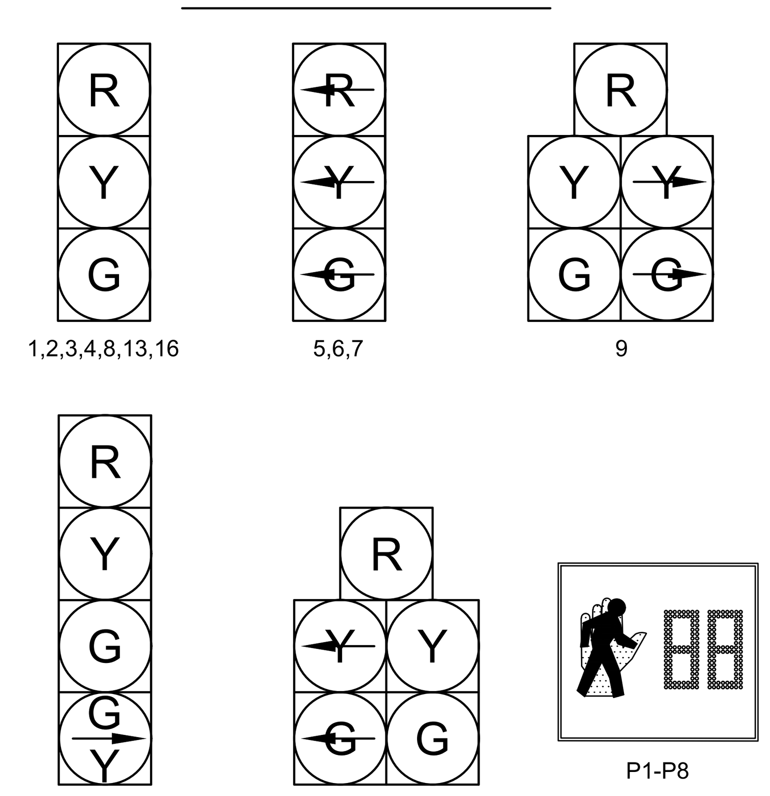
NEW

- VEHICLE SIGNAL HEAD (TYP.)
- PEDESTRIAN SIGNAL HEAD (TYP.)
- PUSH BUTTON (TYP.)

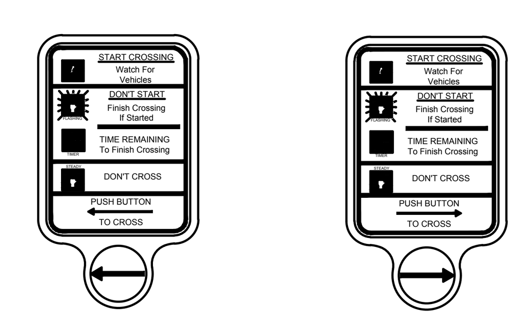
NOTES:

1. THE LOCATIONS OF TRAFFIC POLES AND SIGNALS ARE EXACT AS SHOWN IN THE CONTRACT DOCUMENTS. ANY CHANGES IN TRAFFIC POLE OR SIGNAL LOCATIONS DUE TO FIELD CONDITIONS SHALL BE APPROVED BY THE ENGINEER.
2. ALL VEHICLE AND PEDESTRIAN SIGNAL HOUSINGS SHALL BE FEDERAL YELLOW.
3. VEHICLE SIGNAL HEADS #11, #12, #14, AND #15 SHALL BE ALUMINUM.
4. TRAFFIC SIGNAL INDICATIONS #1, #2, #3, #4, #6, #7, #8, AND #9 SHALL BE EQUIPPED WITH BACKPLATES.
5. ANGLE VISORS SHALL BE FURNISHED AND INSTALLED ON ALL INDICATIONS FOR SIGNAL HEAD #5 TO BLOCK VISIBILITY FROM THE Ø4 APPROACH.
6. PEDESTRIAN PUSHBUTTONS SHALL BE INSTALLED AT THE ORIENTATION SHOWN, AND SHALL BE VISIBLE TO PEDESTRIANS WAITING TO CROSS. PEDESTRIAN SIGNAL SIGNS R10-3e(L/R) SHALL SHOW THE ARROW POINTING TO THE CROSSWALK ACTUATED BY THE PUSHBUTTON
7. UPON ACTUATION OF PEDESTRIAN PUSHBUTTON FOR Ø2 AND Ø6 PED, THE APS UNIT SHALL STATE "WAIT TO CROSS MINOR AT MAJOR WAIT". ONCE THE ASSOCIATED WALK INTERVAL HAS BEEN INITIATED, THE APS UNIT SHALL STATE "MINOR WALK SIGN IS ON TO CROSS MINOR". UPON ACTUATION OF PEDESTRIAN PUSHBUTTON FOR Ø4 AND Ø8, THE APS UNIT SHALL SATE "WAIT TO CROSS MAJOR AT MINOR WAIT". ONCE THE ASSOCIATED WALK INTERVAL HAS BEEN INITIATED, THE APS UNIT SHALL STATE "MAJOR WALK SIGN IS ON TO CROSS MAJOR". THE APS UNIT SHALL PROVIDE AN AUDIBLE COUNTDOWN REPRESENTING THE TIME REMAINING DURING THE PEDESTRIAN CLEARANCE INTERVAL THAT IS AUTOMATICALLY ADJUSTED TO PED CLEAR TIMING.
8. VEHICLE SIGNAL HEADS #5 AND #10 SHALL BE MOUNTED AT 12 FEET.
9. ALL PEDESTRIAN SIGNAL HEADS SHALL BE CLAMP MOUNTED AT 8 FEET.
10. REFER TO SIGN DATA TABLE FOR SIGN DETAILS.

SIGNAL LEGEND



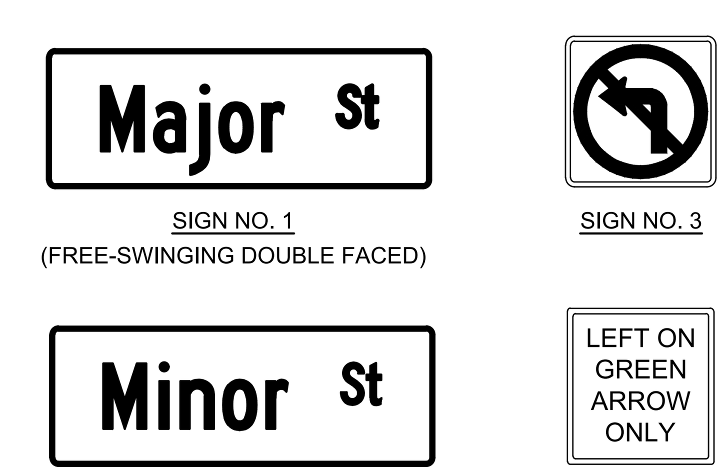
SIGNAL POLE SIGN LEGEND



SIGN NO. X
R10-3e(L)

SIGN NO. X
R10-3e(R)

MAST ARM SIGN LEGEND



SIGN NO. 1
(FREE-SWINGING DOUBLE FACED)

SIGN NO. 3

SIGN NO. 2
(FREE-SWINGING DOUBLE FACED)

SIGN NO. 4

OVERHEAD STREET NAME SIGNS TO MEET FACILITY DETAIL PROVIDED BY PA TRAFFIC.

Sheet XX of XX

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

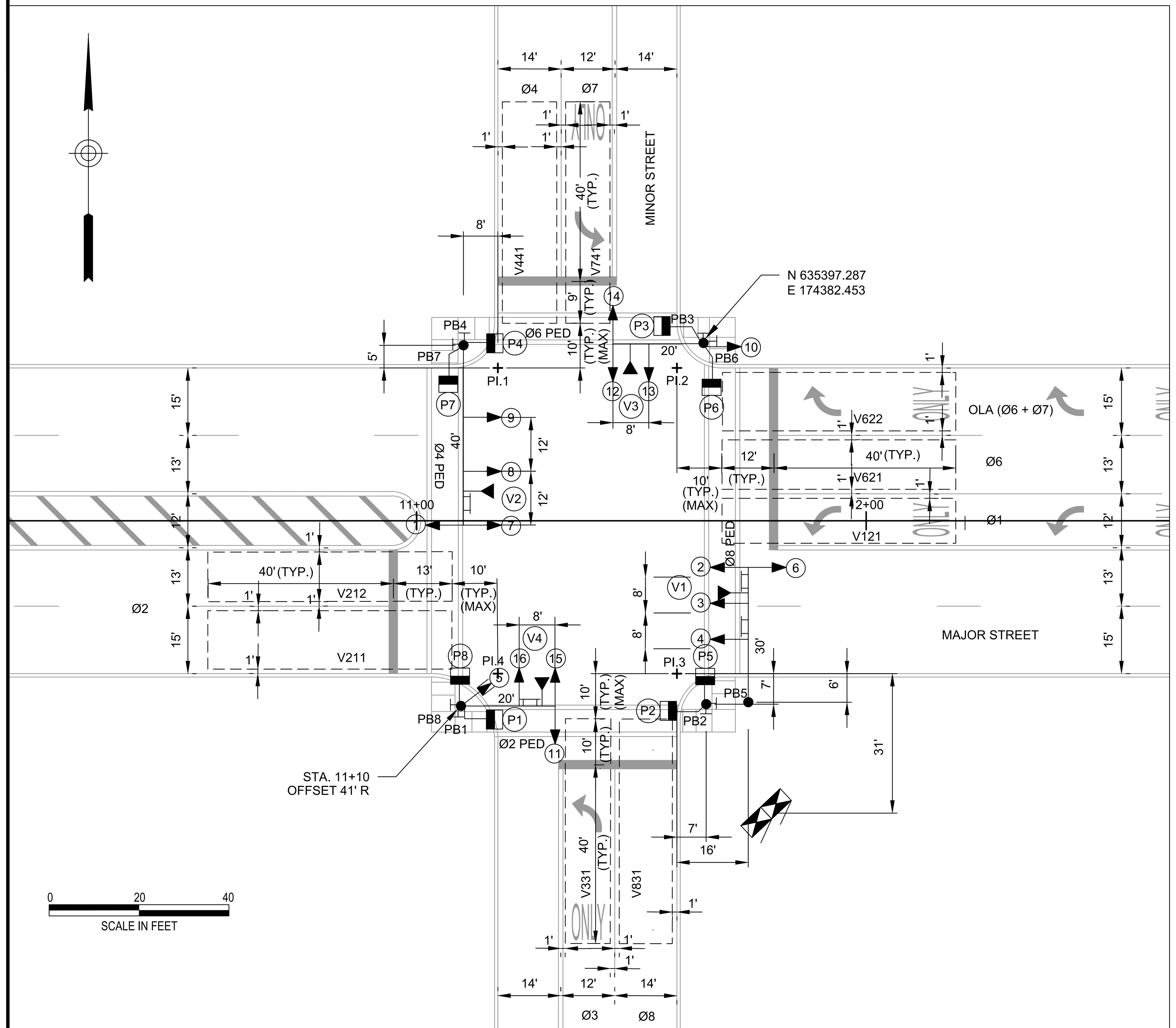
Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

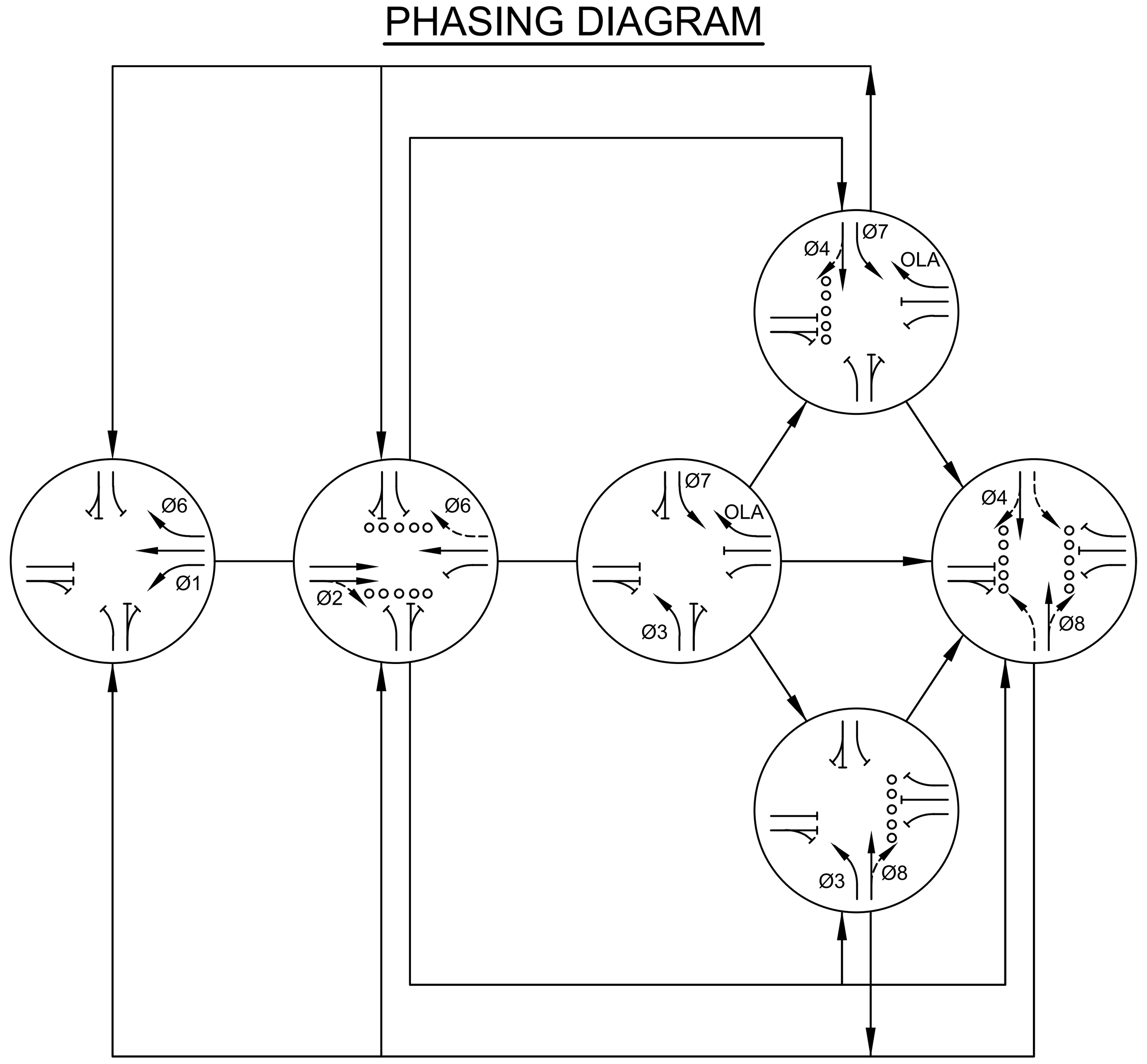
SAMPLE
TRAFFIC SIGNAL
WIRING PLAN
(MAST ARM)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG010
PID#

THE PORT AUTHORITY OF NY & NJ



PHASING DIAGRAM



TRAFFIC SIGNAL TIMING

PHASE DIAGRAM	PHASE		SIGNAL INDICATIONS 1,2,3,4	5,6,7	8	9,10	11,12	13	14,15	16	P1-P2	P3-P4	P5-P6	P7-P8	TIMING I (SEC)	TIMING II (SEC)	DETECTOR MODE	PHASE RECALL	EXT
VEHICLE ACTUATION																			
	Ø1 + Ø6	ROW	R	<G-	G	G,-G>	R	R	R	R	DW	DW	DW	DW	7	7-11	NON-LOCK	-	2.0
		CHG	R	<Y-	G	G,-Y>	R	R	R	R	DW	DW	DW	DW	3.0	3.0			
		CLR	R	<R-	G	G	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø2 + Ø6	ROW	G	<R-	G	G	R	R	R	R	W	W	DW	DW	37-7	37-10	NON-LOCK	MIN. +PED	2.0
		PED CLEAR	G	<R-	G	G	R	R	R	R	FDW	FDW	DW	DW	12	12			
		CHG	Y	<R-	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7 + OLA	ROW	R	<R-	R	R,-G>	R,<G-	R	R,<G-	R	DW	DW	DW	DW	7-11	7-9	NON-LOCK	-	2.0
		CHG	R	<R-	R	R,-Y>	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8	ROW	R	<R-	R	R	G	G	G	G	DW	DW	DW	DW	7-33	7-28	NON-LOCK	-	2.0
		CHG	R	<R-	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
PEDESTRIAN ACTUATION																			
	Ø1 + Ø6	ROW	R	<G-	G	G	R	R	R	R	DW	DW	DW	DW	7	7-11	NON-LOCK	-	2.0
		CHG	R	<Y-	G	G	R	R	R	R	DW	DW	DW	DW	3.0	3.0			
		CLR	R	<R-	G	G	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø2 + Ø6	ROW	G	<R-	G	G	R	R	R	R	W	W	DW	DW	16-7	16-10	NON-LOCK	MIN. + PED	2.0
		PED CLR	G	<R-	G	G	R	R	R	R	FDW	FDW	DW	DW	12	12			
		CHG	Y	<R-	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7 + OLA	ROW	R	<R-	R	R,-G>	R,<G-	R	R,<G-	R	DW	DW	DW	DW	7-11	7-9	NON-LOCK	-	2.0
		CHG	R	<R-	R	R,-Y>	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8 + Ø4 PED. + Ø8 PED.	ROW	R	<R-	R	R	G	G	G	G	DW	DW	W	W	7	7	NON-LOCK	-	2.0
		PED CLR	R	<R-	R	R	G	G	G	G	DW	DW	FDW	FDW	21	21			
		VEHICLE EXT	R	<R-	R	R	G	G	G	G	DW	DW	DW	DW	0-5	0			
		CHG	R	<R-	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
EMERGENCY FLASH			Y	<R-	Y	Y	R	R	R	R	DARK	DARK	DARK	DARK					
														BACKGROUND CYCLE LENGTH	90	90			
														OFFSET	52	16			

1. TIMING I IS TO OPERATE MONDAY - FRIDAY 7:00AM TO 9:00AM AND 4:00PM TO 6:00PM.
   TIMING II IS TO OPERATE AT ALL OTHER TIMES.
2. OFFSET SHALL BE MEASURED FROM THE BEGINNING OF YELLOW TO Ø2 + Ø6 AT THIS INTERSECTION TO THE BEGINNING OF YELLOW TO Ø2 + Ø6 AT THE INTERSECTION OF ____________________.

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE TRAFFIC SIGNAL DIMENSION DIAGRAM AND TIMING DATA (MAST ARM)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG011
PID#

LOAD SWITCH TABLE

LOAD SWITCH NUMBER	PHASE	FACE NUMBER	INDICATIONS	TERMINAL
LS1	ϕ1	5, 6, 7	←R ←Y ←G NEUTRAL WIRE	LS 1R LS 1Y LS 1G NEUTRAL BUS
LS2	ϕ2	1, 2, 3, 4	R Y G NEUTRAL WIRE	LS 2R LS 2Y LS 2G NEUTRAL BUS
LS3	ϕ3	11, 12	* ←Y ←G NEUTRAL WIRE	LS 3R LS 3Y LS 3G NEUTRAL BUS
LS4	ϕ4	14, 15, 16	R Y G NEUTRAL WIRE	LS 4R LS 4Y LS 4G NEUTRAL BUS
LS5	OLA	9,10	* Y→ G→ NEUTRAL WIRE	LS 5R LS 5Y LS 5G NEUTRAL BUS
LS6	ϕ6	8, 9, 10	R Y G NEUTRAL WIRE	LS 6R LS 6Y LS 6G NEUTRAL BUS
LS7	ϕ7	14,15	* ←Y ←G NEUTRAL WIRE	LS 7R LS 7Y LS 7G NEUTRAL BUS
LS8	ϕ8	11, 12, 13	R Y G NEUTRAL WIRE	LS 8R LS 8Y LS 8G NEUTRAL BUS
LS9	ϕ2 PED.	P1, P2	DON'T WALK WALK NEUTRAL WIRE	LS 9R LS 9Y LS 9G NEUTRAL BUS
LS10	ϕ4 PED.	P7, P8	DON'T WALK WALK NEUTRAL WIRE	LS 10R LS 10Y LS 10G NEUTRAL BUS
LS11	ϕ5 PED.	P3, P4	DON'T WALK WALK NEUTRAL WIRE	LS 11R LS 11Y LS 11G NEUTRAL BUS
LS12	ϕ8 PED.	P5, P6	DON'T WALK WALK NEUTRAL WIRE	LS 12R LS 12Y LS 12G NEUTRAL BUS

OLA = Ø6+Ø7

* CONNECT 115V AC TO APPROPRIATE CONFLICT MONITOR RED CHANNEL INPUT TO PREVENT TRIPPING AND SIGNALS FLASHING.

INTERSECTION ACTUATION TABLE

DETECTOR NO.	PHASE	SIZE	MODE	DETECTOR TYPE
V121	ϕ1	48' X 10'	PRESENCE	VIDEO
V211	ϕ2	48' X 10'	PRESENCE	VIDEO
V212	ϕ2	48' X 10'	PRESENCE	VIDEO
V331	ϕ3	47' X 10'	PRESENCE	VIDEO
V441	ϕ4	47' X 12'	PRESENCE	VIDEO
V621	ϕ6	48' X 11'	PRESENCE	VIDEO
V622	ϕ6	48' X 13'	PRESENCE	VIDEO
V741	ϕ7	47' X 10'	PRESENCE	VIDEO
V831	ϕ8	47' X 12'	PRESENCE	VIDEO
PB1	ϕ2	-	-	PUSH BUTTON
PB2	ϕ2	-	-	PUSH BUTTON
PB3	ϕ6	-	-	PUSH BUTTON
PB4	ϕ6	-	-	PUSH BUTTON
PB5	ϕ8	-	-	PUSH BUTTON
PB6	ϕ8	-	-	PUSH BUTTON
PB7	ϕ4	-	-	PUSH BUTTON
PB8	ϕ4	-	-	PUSH BUTTON

THE PORT AUTHORITY
OF NY & NJ

No.	Date	Revision	Approved

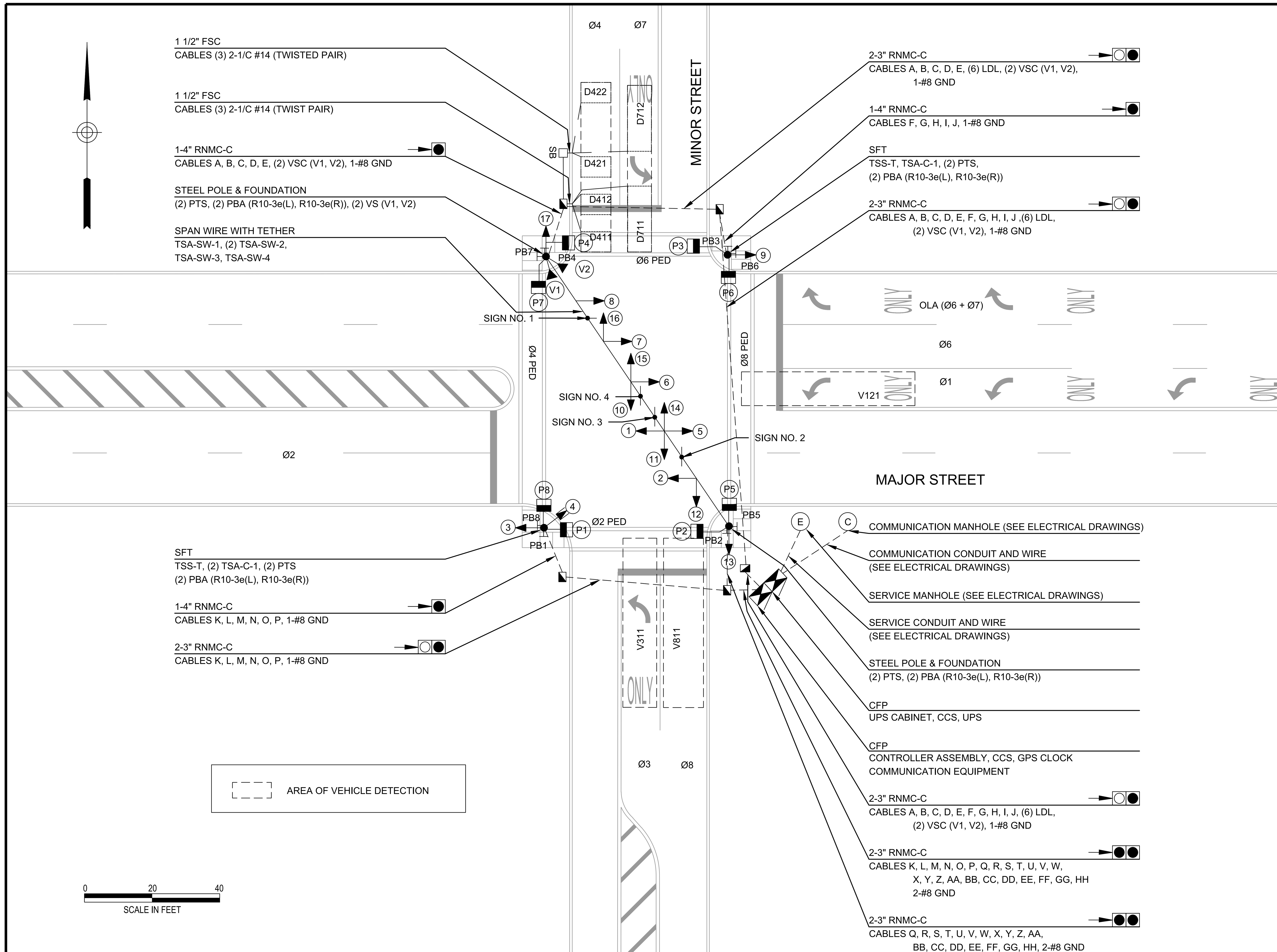
ENGINEERING DEPARTMENT

TRAFFIC

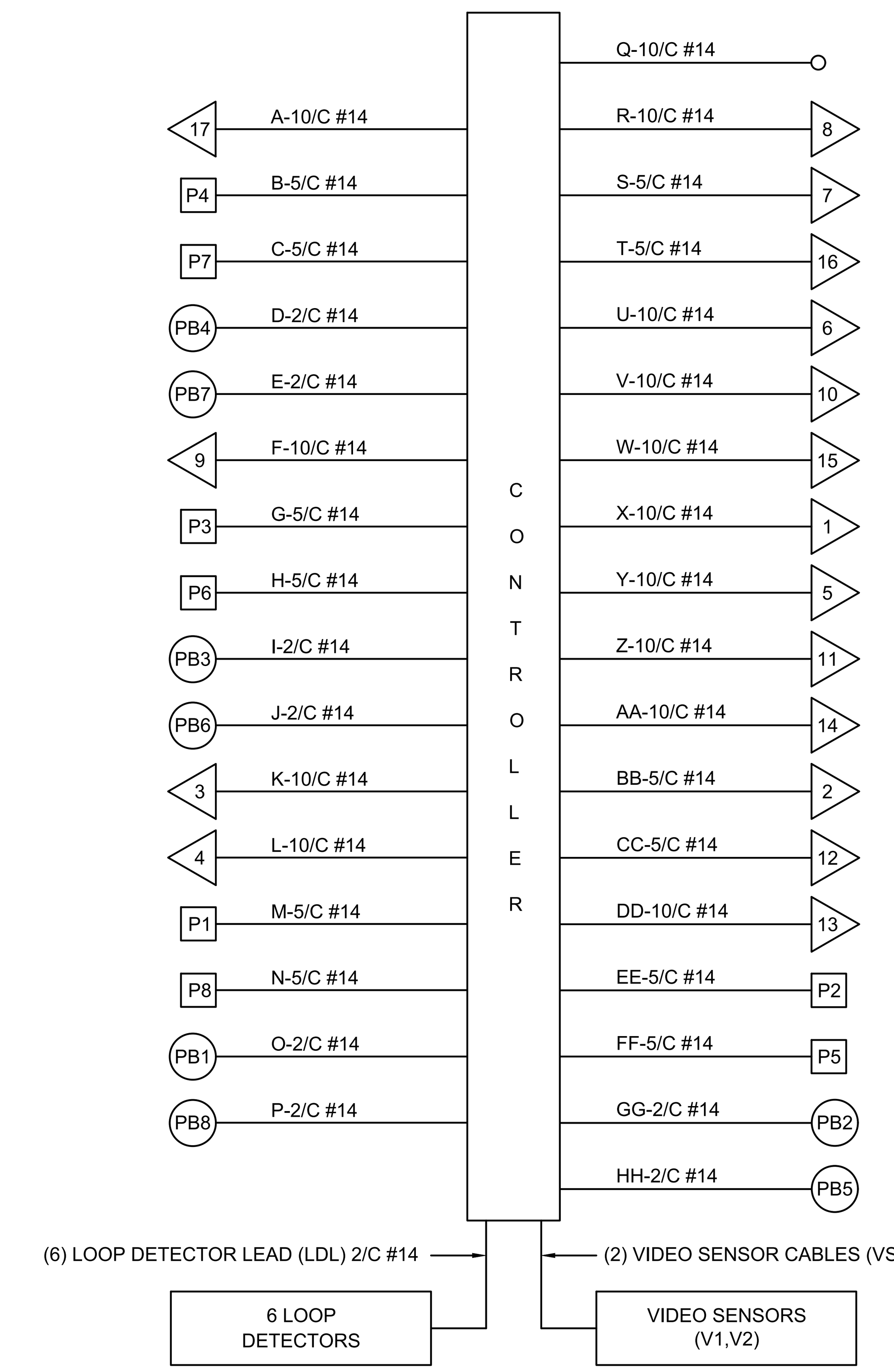
Title
TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

SAMPLE TRAFFIC SIGNAL LOAD SWITCH AND ACTUATION TABLES (MAST ARM)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG012
PID#



BLOCK WIRING DIAGRAM



LEGEND

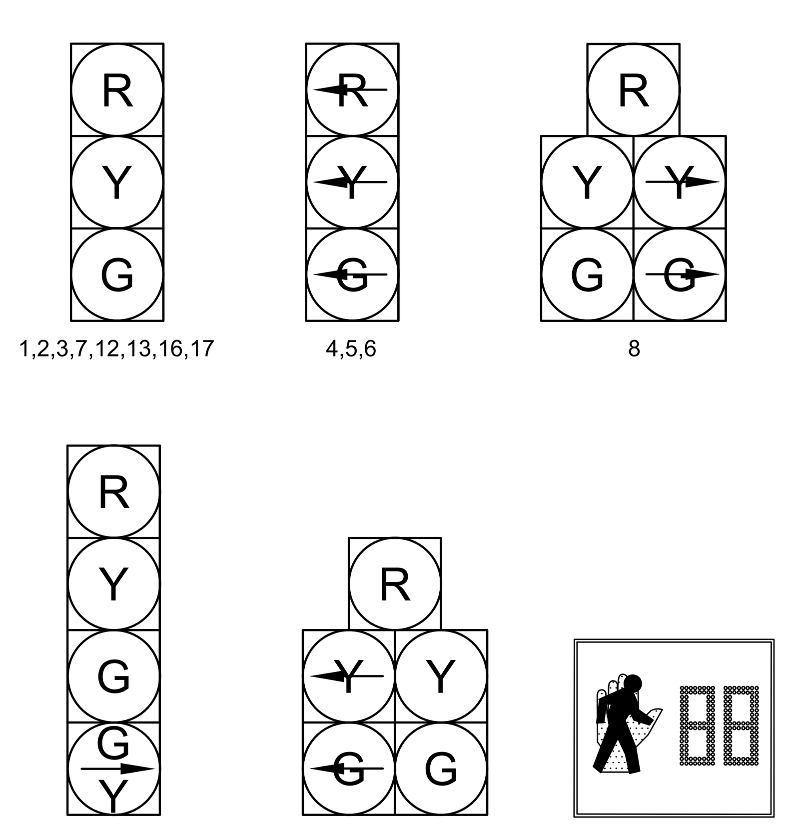
NEW

- VEHICLE SIGNAL HEAD (TYP.)
- PEDESTRIAN SIGNAL HEAD (TYP.)
- PUSH BUTTON (TYP.)
- SPARE (TYP.)

NOTES:

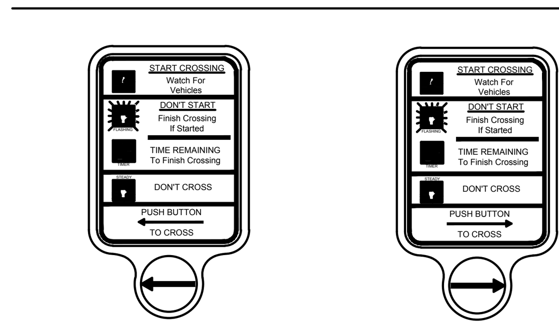
1. THE LOCATIONS OF TRAFFIC POLES AND SIGNALS ARE EXACT AS SHOWN IN THE CONTRACT DOCUMENTS. ANY CHANGES IN TRAFFIC POLE OR SIGNAL LOCATIONS DUE TO FIELD CONDITIONS SHALL BE APPROVED BY THE ENGINEER.
2. ALL TRAFFIC SIGNAL INDICATIONS EXCEPT #3, #4, #9, #13 AND #17 SHALL BE EQUIPPED WITH BACKPLATES.
3. ANGLE VISORS SHALL BE FURNISHED AND INSTALLED ON ALL INDICATIONS FOR SIGNAL HEAD #4 TO BLOCK VISIBILITY FROM THE PHASE 4 APPROACH.
4. VEHICLE SIGNAL HEADS 3 AND 4 SHALL BE ALUMINUM.
5. VEHICLE SIGNAL HEADS #3, #4, #9, #13, & #17 SHALL BE MOUNTED AT A HEIGHT OF 12 FEET.
6. ALL PEDESTRIAN SIGNAL HEADS SHALL BE CLAMPED MOUNTED AT 8 FEET.
7. PEDESTRIAN PUSHBUTTONS SHALL BE INSTALLED AT THE ORIENTATION SHOWN, AND SHALL BE VISIBLE TO PEDESTRIANS WAITING TO CROSS. PEDESTRIAN SIGNAL SIGNS R10-3e(L/R) SHALL SHOW THE ARROW POINTING TO THE CROSSWALK ACTUATED BY THE PUSHBUTTON.
8. UPON ACTUATION OF PEDESTRIAN PUSHBUTTON FOR Ø2 & Ø6 PED, THE APS UNIT SHALL STATE "WAIT TO CROSS MINOR AT MAJOR WAIT". ONCE THE ASSOCIATED WALK INTERVAL HAS BEEN INITIATED, THE APS UNIT SHALL STATE "MINOR WALK SIGN IS ON TO CROSS MINOR". UPON ACTUATION OF PEDESTRIAN PUSHBUTTON FOR Ø4 & Ø8 PED, THE APS UNIT SHALL STATE "WAIT TO CROSS MAJOR AT MINOR WAIT". ONCE THE ASSOCIATED WALK INTERVAL HAS BEEN INITIATED, THE APS UNIT SHALL STATE "MAJOR WALK SIGN IS ON TO CROSS MAJOR". THE APS UNIT SHALL PROVIDE AN AUDIBLE COUNTDOWN PRESENTING THE TIME REMAINING DURING THE PEDESTRIAN CLEARANCE INTER\VAL THAT IS AUTOMATICALLY ADJUSTED TO PED CLEAR TIMING.
9. REFER TO SIGN DATA TABLE FOR SIGN DETAILS.
10. SIGN NO. 3 SHALL BE INSTALLED FACING WEST (EASTBOUND TRAFFIC) AND SIGN NO. 4 SHALL BE INSTALLED FACING EAST (WESTBOUND TRAFFIC).
11. THE CONTROLLER CABINETS SHALL BE INSTALLED AT AN ORIENTATION AS SHOWN ON THE PLAN.
12. SPARE WIRES SHALL TERMINATE AT THE TERMINAL BLOCK IN THE SIGNAL HEAD.
13. SPARE CABLE SHALL BE COILED IN THE BASE ON THE FAR SIDE OF THE SPAN (AWAY FROM THE CONTROLLER).

SIGNAL LEGEND



1,2,3,7,12,13,16,17 | 4,5,6 | 8 | 9 | 10,11,14,15 | P1-P8

SIGNAL POLE SIGN LEGEND



SIGN NO. X
R10-3e(L)

SIGN NO. X
R10-3e(R)

SIGN LEGEND

SIGN NO. 1
(FREE-SWINGING DOUBLE FACED)

SIGN NO. 3
(FREE-SWINGING)

SIGN NO. 2
(FREE-SWINGING DOUBLE FACED)

SIGN NO. 4
(FREE-SWINGING)

OVERHEAD STREET NAME SIGNS TO MEET FACILITY DETAIL PROVIDED BY PA TRAFFIC.

Sheet XX of XX

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

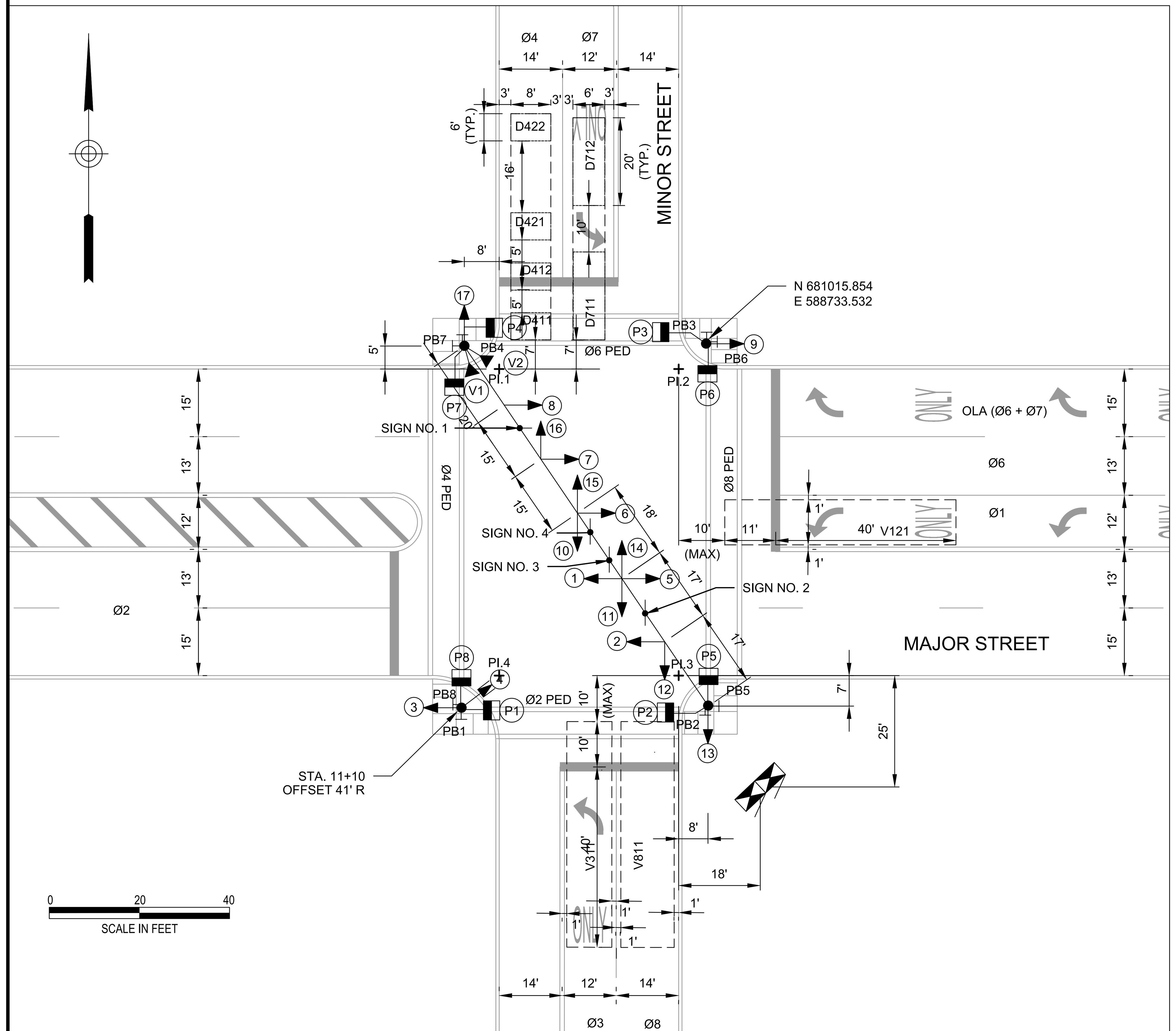
TRAFFIC

Title

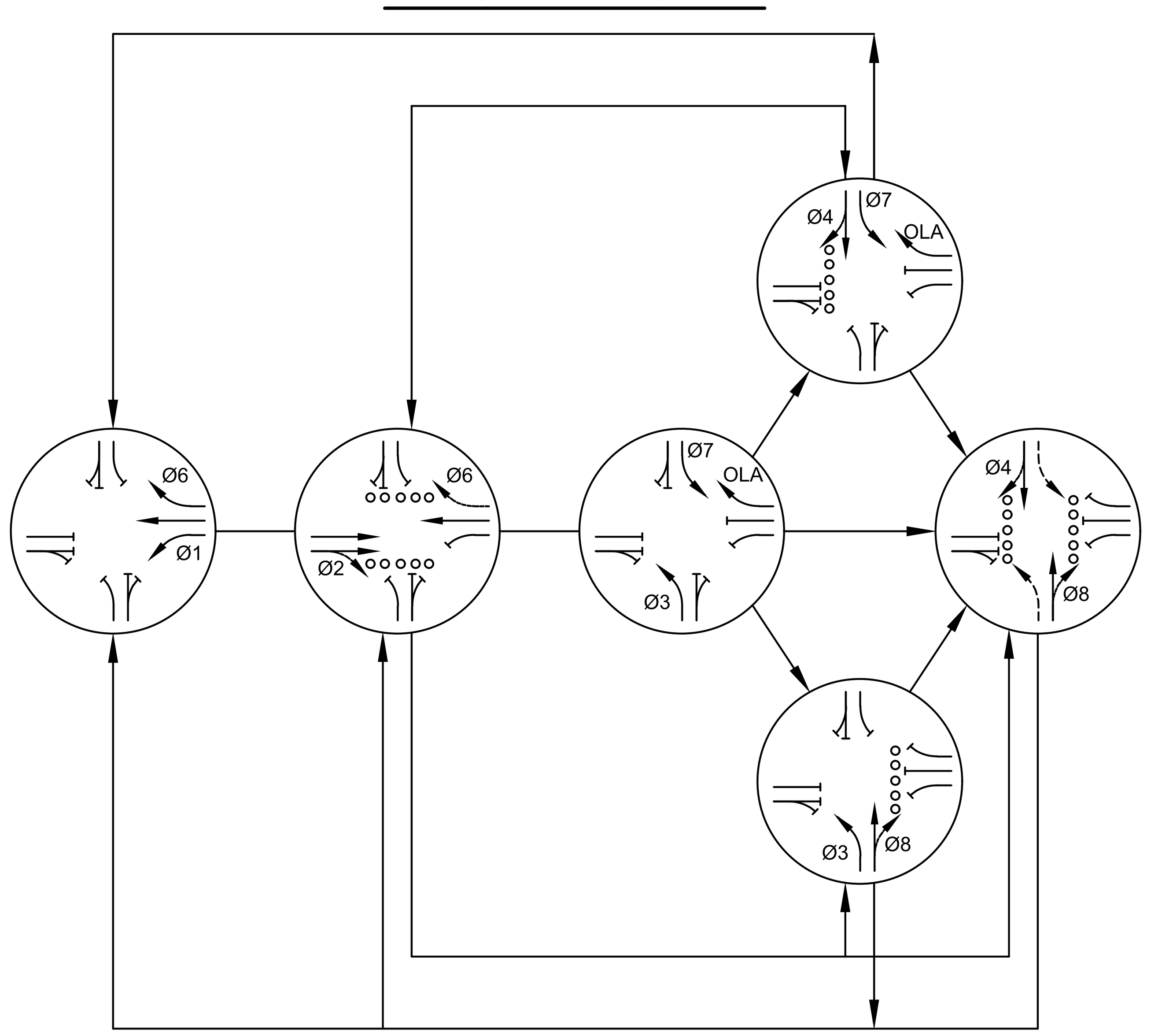
TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE
TRAFFIC SIGNAL
WIRING PLAN
(SPAN WIRE)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG013
PID#



PHASING DIAGRAM



TRAFFIC SIGNAL TIMING

VEHICLE ACTUATION

PHASE DIAGRAM	PHASE		SIGNAL INDICATIONS 1,2,3	4,5,6	7	8,9	10,11	12,13	14,15	16,17	P1-P2	P3-P4	P5-P6	P7-P8	TIMING I (SEC)	TIMING II (SEC)	DETECTOR MODE	PHASE RECALL	EXT
	Ø1 + Ø6	ROW	R	<G-	G	G	R	R	R	R	DW	DW	DW	DW	7	7-11	NON-LOCK	-	2.0
		CHG	R	<Y-	G	G	R	R	R	R	DW	DW	DW	DW	3.0	3.0			
		CLR	R	<R-	G	G	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø2 + Ø6	ROW	G	<R-	G	G	R	R	R	R	DW	DW	DW	DW	15-25	15-19	-	MIN.	-
		CHG	Y	<R-	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7 + OLA	ROW	R	<R-	R	R,-G>	R,<G-	R	R,<G-	R	DW	DW	DW	DW	7-15	7-9	NON-LOCK	-	2.0
		CHG	R	<R-	R	R,-Y>	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8	ROW	R	<R-	R	R	G	G	G	G	DW	DW	DW	DW	7-33	7-27	NON-LOCK	-	2.0
		CHG	R	<R-	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			

PEDESTRIAN ACTUATION

PHASE DIAGRAM	PHASE		1,2,3	4,5,6	7	8,9	10,11	12,13	14,15	16,17	P1-P2	P3-P4	P5-P6	P7-P8	TIMING I (SEC)	TIMING II (SEC)	DETECTOR MODE	PHASE RECALL	EXT
	Ø1 + Ø6	ROW	R	<G-	G	G	R	R	R	R	DW	DW	DW	DW	7	7-11	NON-LOCK	-	2.0
		CHG	R	<Y-	G	G	R	R	R	R	DW	DW	DW	DW	3.0	3.0			
		CLR	R	<R-	G	G	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø2 + Ø6 + Ø2 PED. + Ø6 PED.	ROW	G	<R-	G	G	R	R	R	R	W	W	DW	DW	7	7	-	MIN.	-
		PED CLR	G	<R-	G	G	R	R	R	R	FDW	FDW	DW	DW	12	12			
		VEHICLE EXT	G	<R-	G	G	R	R	R	R	DW	DW	DW	DW	0-6	0			
		CHG	Y	<R-	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7 + OLA	ROW	R	<R-	R	R,-G>	R,<G-	R	R,<G-	R	DW	DW	DW	DW	7-15	7-9	NON-LOCK	-	2.0
		CHG	R	<R-	R	R,-Y>	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8 + Ø4 PED. + Ø8 PED.	ROW	R	<R-	R	R	G	G	G	G	DW	DW	W	W	7	7	NON-LOCK	-	2.0
		PED CLR	R	<R-	R	R	G	G	G	G	DW	DW	FDW	FDW	20	20			
		VEHICLE EXT	R	<R-	R	R	G	G	G	G	DW	DW	DW	DW	0-6	0			
		CHG	R	<R-	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
EMERGENCY FLASH			Y	<R-	Y	Y	R	R	R	R	DARK	DARK	DARK	DARK					
EFFECTIVE MAXIMUM CYCLE LENGTH															100	86			

OLA = Ø6 + Ø7

1. TIMING I IS TO OPERATE MONDAY - FRIDAY 7:00AM TO 9:00AM AND 4:00PM TO 6:00PM.
   TIMING II IS TO OPERATE AT ALL OTHER TIMES.
2. THIS INTERSECTION IS FULL ACTUATED FOR PEDESTRIANS. PEDESTRIAN TRAFFIC SIGNALS ARE TO REMAIN DW UNLESS PUSHBUTTON IS ACTUATED.
3. THE SIGNAL SHALL BE SET TO "FREE OPERATION". THIS INTERSECTION IS NOT COORDINATED WITH ANY OTHER TRAFFIC SIGNALS.
4. OLA SHALL OPERATE WITH MINUS PED OVERLAP FEATURE DURING Ø6 PED.

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE TRAFFIC SIGNAL DIMENSION DIAGRAM AND TIMING DATA (SPAN WIRE)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number

Drawing Number SG014

PID#

INTERSECTION ACTUATION TABLE

DETECTOR NO.	PHASE	SIZE	MODE	DETECTOR TYPE	NUMBER OF TURNS*	ESTIMATED INDUCTANCE (μh)**	DETECTOR UNIT NO.	CHANNEL
V121	ϕ1	48' X 10'	PRESENCE	VIDEO	-	-	-	-
V311	ϕ3	47' X 10'	PRESENCE	VIDEO	-	-	-	-
D411	ϕ4	8' X 6'	PRESENCE	LOOP	5	212	1	1
D412	ϕ4	8' X 6'	PRESENCE	LOOP	5	211	1	2
D421	ϕ4	8' X 6'	PRESENCE	LOOP	5	212	2	1
D422	ϕ4	8' X 6'	PRESENCE	LOOP	5	214	2	2
D711	ϕ7	6' X 20'	PRESENCE	LOOP	3	160	1	1
D712	ϕ7	6' X 20'	PRESENCE	LOOP	3	160	1	2
V811	ϕ8	47' X 12'	PRESENCE	VIDEO	-	-	-	-
PB1	ϕ2	-	-	PUSH BUTTON	-	-	-	-
PB2	ϕ2	-	-	PUSH BUTTON	-	-	-	-
PB3	ϕ6	-	-	PUSH BUTTON	-	-	-	-
PB4	ϕ6	-	-	PUSH BUTTON	-	-	-	-
PB5	ϕ8	-	-	PUSH BUTTON	-	-	-	-
PB6	ϕ8	-	-	PUSH BUTTON	-	-	-	-
PB7	ϕ4	-	-	PUSH BUTTON	-	-	-	-
PB8	ϕ4	-	-	PUSH BUTTON	-	-	-	-

* DESIGNER SHOULD ESTIMATE NUMBER OF TURNS FOR CONTRACT (THE MINIMUM INDUCTANCE IS 150)

** BASED UPON THE FOLLOWING CALCULATION:

$$\text{INDUCTANCE (IN } \mu h) = \frac{\text{PERIMETER}}{4} \times [(\text{NUMBER OF TURNS})^2 + \text{NUMBER OF TURNS}] + \frac{\text{LOOP LEAD-IN}}{100} \times 22$$

(LOOP LEAD-IN = LENGTH OF TWISTED LOOP WIRE MEASURED FROM THE LOOP TO THE NEAREST SPLICE BOX)

LOAD SWITCH TABLE

	PHASE	FACE NUMBER	INDICATIONS	TERMINAL
LS1	ϕ1	4, 5, 6	◄R ◄Y ◄G NEUTRAL WIRE	LS 1R LS 1Y LS 1G NEUTRAL BUS
LS2	ϕ2	1, 2, 3	R Y G NEUTRAL WIRE	LS 2R LS 2Y LS 2G NEUTRAL BUS
LS3	ϕ3	10, 11	* ◄Y ◄G NEUTRAL WIRE	LS 3R LS 3Y LS 3G NEUTRAL BUS
LS4	ϕ4	14, 15, 16, 17	R Y G NEUTRAL WIRE	LS 4R LS 4Y LS 4G NEUTRAL BUS
LS5	OLA	8, 9	* Y► G► NEUTRAL WIRE	LS 5R LS 5Y LS 5G NEUTRAL BUS
LS6	ϕ6	7, 8, 9	R Y G NEUTRAL WIRE	LS 6R LS 6Y LS 6G NEUTRAL BUS
LS7	ϕ7	14,15	* ◄Y ◄G NEUTRAL WIRE	LS 7R LS 7Y LS 7G NEUTRAL BUS
LS8	ϕ8	10, 11, 12, 13	R Y G NEUTRAL WIRE	LS 8R LS 8Y LS 8G NEUTRAL BUS
LS9	ϕ2 PED.	P1, P2	DON'T WALK WALK NEUTRAL WIRE	LS 9R LS 9Y LS 9G NEUTRAL BUS
LS10	ϕ4 PED.	P7, P8	DON'T WALK WALK NEUTRAL WIRE	LS 10R LS 10Y LS 10G NEUTRAL BUS
LS11	ϕ6 PED.	P3, P4	DON'T WALK WALK NEUTRAL WIRE	LS 11R LS 11Y LS 11G NEUTRAL BUS
LS12	ϕ8 PED.	P5, P6	DON'T WALK WALK NEUTRAL WIRE	LS 12R LS 12Y LS 12G NEUTRAL BUS

* CONNECT 115V AC TO APPROPRIATE CONFLICT MONITOR RED CHANNEL INPUT TO PREVENT TRIPPING AND SIGNALS FLASHING.

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE TRAFFIC SIGNAL LOAD SWITCH AND ACTUATION TABLES (SPAN WIRE)

Designed by

Drawn by

Checked by

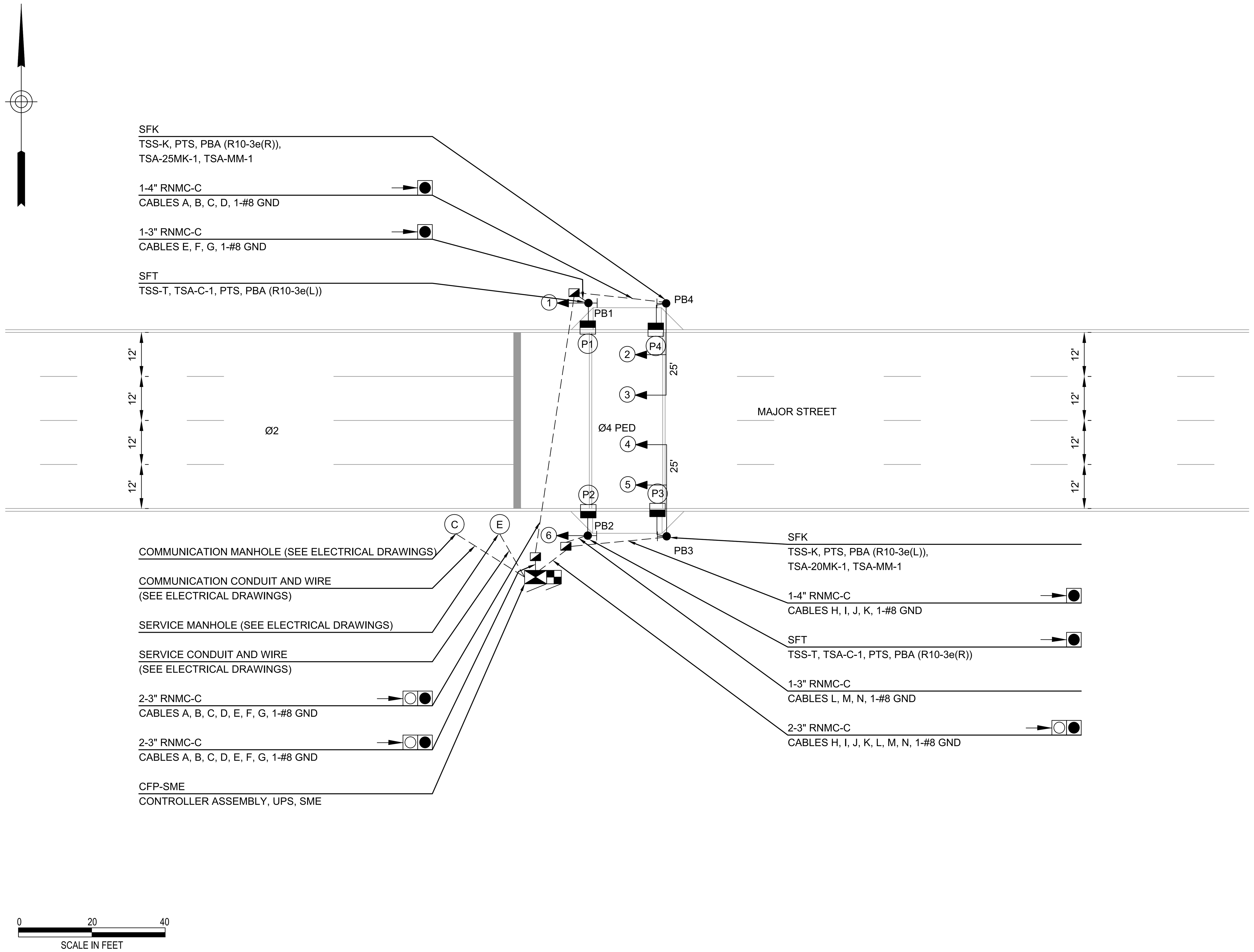
Date DECEMBER 2018

Contract Number

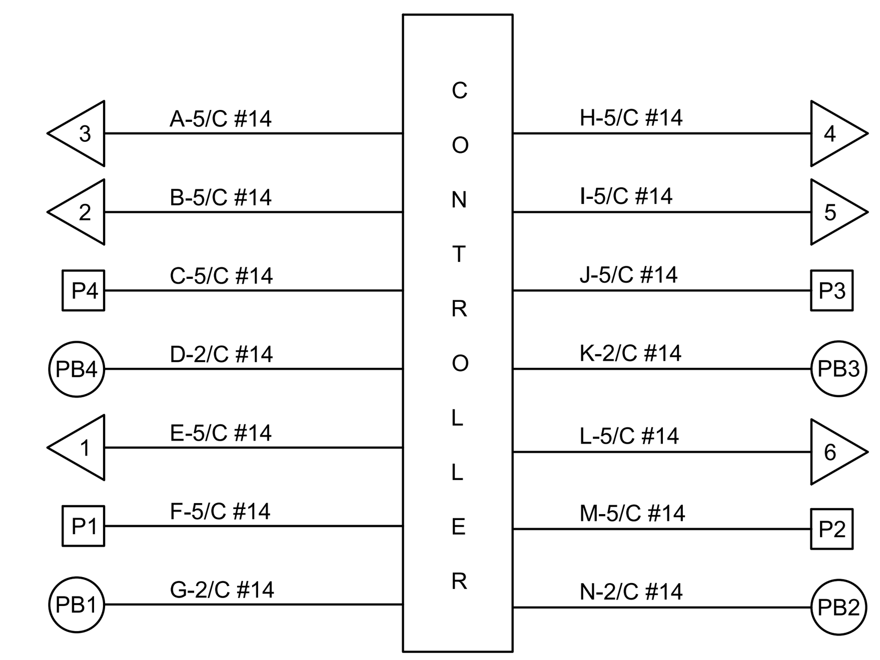
Drawing Number SG015

PID#

THE PORT AUTHORITY OF NY & NJ

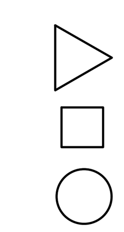


BLOCK WIRING DIAGRAM

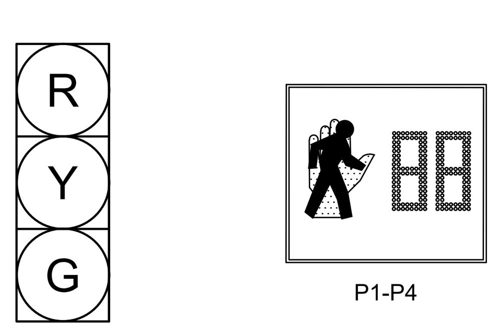


LEGEND

NEW



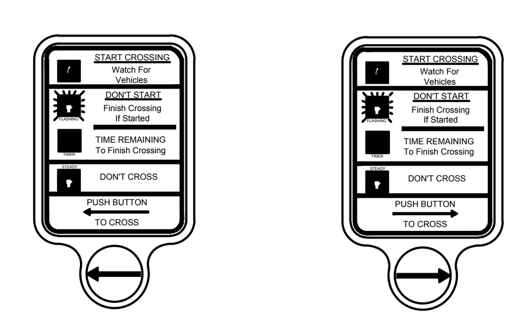
SIGNAL LEGEND



1,2,3,4,5,6

P1-P4

SIGNAL POLE SIGN LEGEND



SIGN NO. X
R10-3e(L)

SIGN NO. X
R10-3e(R)

NOTES:

1. THE LOCATIONS OF TRAFFIC POLES AND SIGNALS ARE EXACT AS SHOWN IN THE CONTRACT DOCUMENTS. ANY CHANGES IN TRAFFIC POLE OR SIGNAL LOCATIONS DUE TO FIELD CONDITIONS SHALL BE APPROVED BY THE ENGINEER.
2. ALL TRAFFIC SIGNAL INDICATIONS EXCEPT #1 & #6 SHALL BE EQUIPPED WITH BACKPLATES.
3. VEHICLE HEADS NOS. 3 AND 4 SHALL BE ALUMINUM.
4. VEHICLE SIGNAL HEAD #1 & #6 SHALL BE MOUNTED AT 12 FEET.
5. ALL PEDESTRIAN SIGNAL HEADS SHALL BE CLAMP MOUNTED AT 8 FEET.
6. THE CONTROLLER CABINET SHALL BE INSTALLED AT AN ORIENTATION AS SHOWN ON THE PLAN.
7. PEDESTRIAN PUSHBUTTONS SHALL BE INSTALLED AT THE ORIENTATION SHOWN, AND SHALL BE VISIBLE TO PEDESTRIANS WAITING TO CROSS. PEDESTRIAN SIGNAL SIGNS R10-3e(L/R) SHALL SHOW THE ARROW POINTING TO THE CROSSWALK ACTUATED BY THE PUSHBUTTON.
8. UPON ACTUATION OF PEDESTRIAN PUSHBUTTON FOR Ø4 PED, THE APS UNIT SHALL STATE "WAIT TO CROSS AT MAJOR WAIT". ONCE THE ASSOCIATED WALK INTERVAL HAS BEEN INITIATED, THE APS UNIT SHALL STATE "MAJOR WALK SIGN IS ON TO CROSS MAJOR". THE APS UNIT SHALL PROVIDE AN AUDIBLE COUNTDOWN REPRESENTING THE TIME REMAINING DURING THE PEDESTRIAN CLEARANCE INTERVAL THAT IS AUTOMATICALLY ADJUSTED TO PED CLEAR TIMING.

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

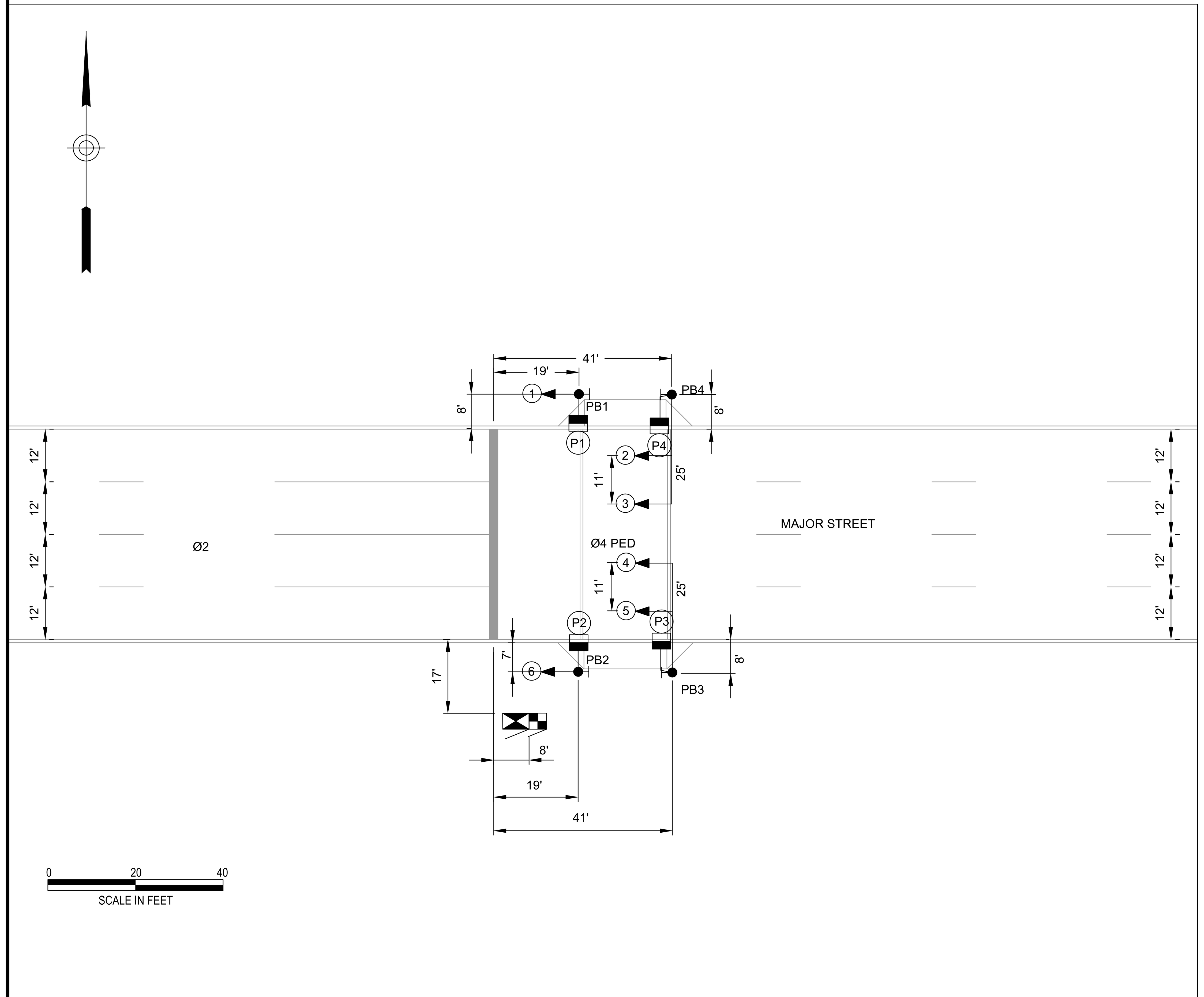
SAMPLE
TRAFFIC SIGNAL
WIRING PLAN
(MID-BLOCK CROSSING)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG016
PID#

Sheet XX of XX

THE PORT AUTHORITY
OF NY & NJ

TRAFFIC SIGNAL DIMENSION DIAGRAM



TRAFFIC SIGNAL TIMING

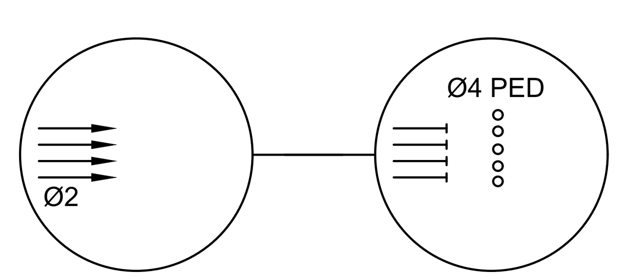
PHASE DIAGRAM	PHASE		SIGNAL INDICATIONS 1,2,3,4,5, 6	SIGNAL INDICATIONS P1, P2, P3, P4	TIMING I (SEC)	TIMING II (SEC)	DETECTOR MODE	PHASE RECALL	EXT
	Ø2	ROW	G	DW	60	30	-	MIN.	-
		CHG	Y	DW	4.0	4.0			
		CLR	R	DW	2.0	2.0			
	Ø4 PED	ROW	R	W	7	7	-	PED	-
		PED CHG	R	FDW	14	14			
		BUFFER	R	DW	3.0	3.0			
EMERGENCY FLASH			Y	DARK					
EFFECTIVE MAXIMUM CYCLE LENGTH					90	60			

1. TIMING I IS TO OPERATE MONDAY - FRIDAY 6:00AM TO 9:00PM.
   TIMING II IS TO OPERATE AT ALL OTHER TIMES.
2. THE SIGNAL SHALL BE SET TO "FREE OPERATION". THIS INTERSECTION IS NOT COORDINATED WITH ANY OTHER TRAFFIC SIGNALS.

INTERSECTION ACTUATION TABLE

DETECTOR NO.	PHASE	SIZE	MODE	DETECTOR TYPE
PB1	Ø4 PED	-	-	PUSH BUTTON
PB2	Ø4 PED	-	-	PUSH BUTTON
PB3	Ø4 PED	-	-	PUSH BUTTON
PB4	Ø4 PED	-	-	PUSH BUTTON

PHASING DIAGRAM



LOAD SWITCH TABLE

LOAD SWITCH NUMBER	PHASE	FACE NUMBER	INDICATIONS	TERMINAL
LS1	-	-	-	-
LS2	Ø2	1,2,3,4,5,6	R Y G NEUTRAL WIRE	LS 2R LS 2Y LS 2G NEUTRAL BUS
LS3	-	-	-	-
LS4	-	-	-	-
LS5	-	-	-	-
LS6	-	-	-	-
LS7	-	-	-	-
LS8	-	-	-	-
LS9	-	-	-	-
LS10	Ø4 PED	P1,P2,P3,P4	DON'T WALK WALK NEUTRAL WIRE	LS10R LS 10Y LS 10G NEUTRAL BUS
LS11	-	-	-	-
LS12	-	-	-	-

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE TRAFFIC SIGNAL DIMENSION DIAGRAM AND DATA TABLES (MID-BLOCK CROSSING)

Designed by

Drawn by

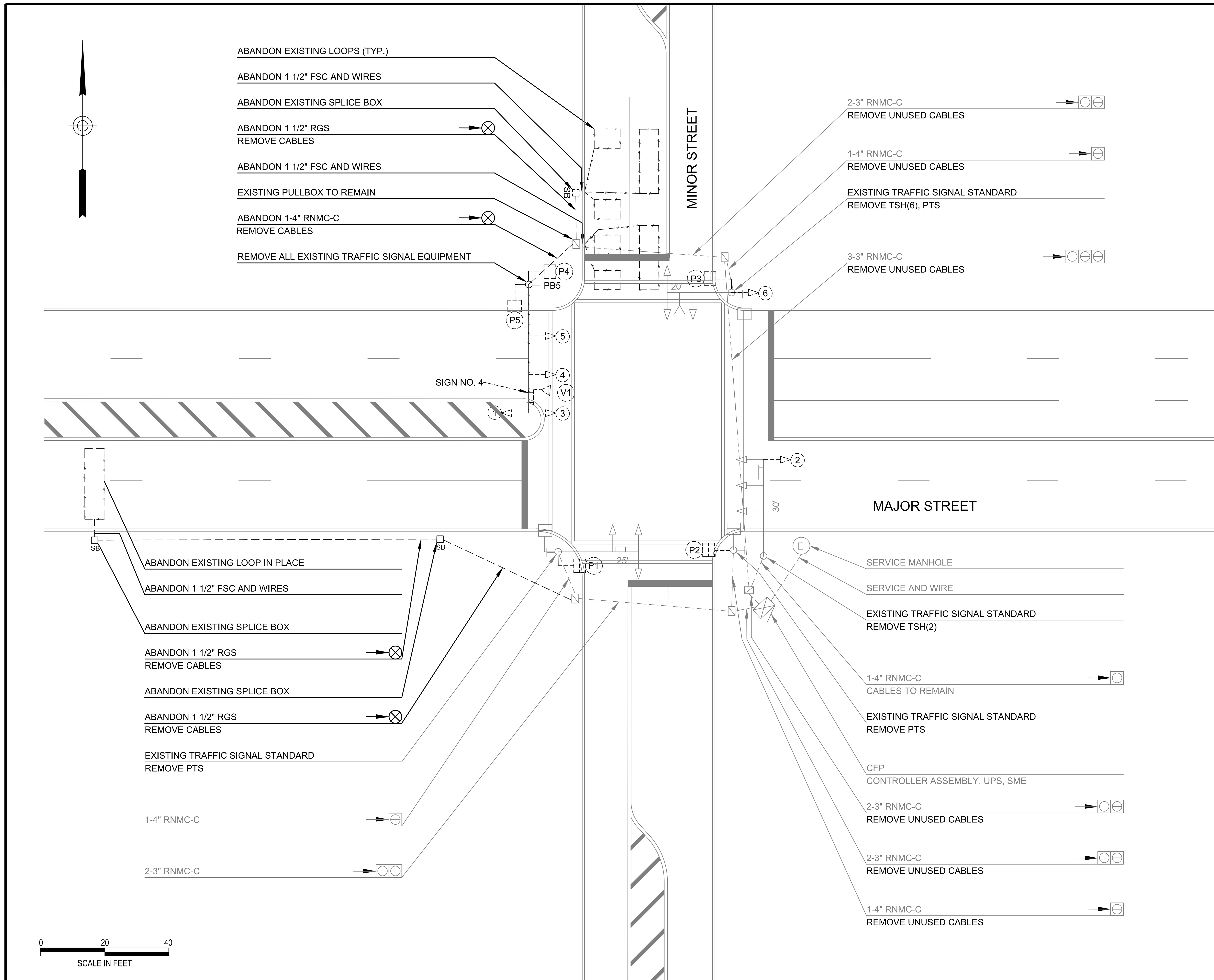
Checked by

Date DECEMBER 2018

Contract Number

Drawing Number SG017

PID#



NOTES:

1. ALL REMOVED ABOVE GROUND TRAFFIC SIGNAL EQUIPMENT SHALL BE SALVAGED AND DELIVERED TO THE (specify) FACILITY ELECTRICAL SHOP LOCATED AT (specify location). THE ENGINEER SHALL BE NOTIFIED PRIOR TO DELIVERY.
2. FOUNDATIONS SHALL BE REMOVED TO A DEPTH OF 12 INCHES BELOW GRADE. THE HOLE SHOULD THEN BE FILLED AND COVERED TO GRADE TO MATCH WITH THE FUTURE CONDITIONS OF THE SURROUNDING AREA (SEE CIVIL AND LANDSCAPE DRAWINGS).
3. THOSE LOOPS WITHIN THE PAVING LIMITS SHOULD BE REMOVED AND HAVE BEEN MARKED AS SUCH ON THE CONTRACT DRAWING. ABANDONED LOOPS OUTSIDE THE PAVING LIMITS SHALL REMAIN.
4. REFER TO THE MODIFIED TRAFFIC SIGNAL WIRING PLAN FOR THE RELOCATION OF ANY EXISTING EQUIPMENT.

REMOVAL SIGN LEGEND

LEFT
ON
GREEN
ARROW
ONLY

SIGN NO. 1

THE PORT AUTHORITY
OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

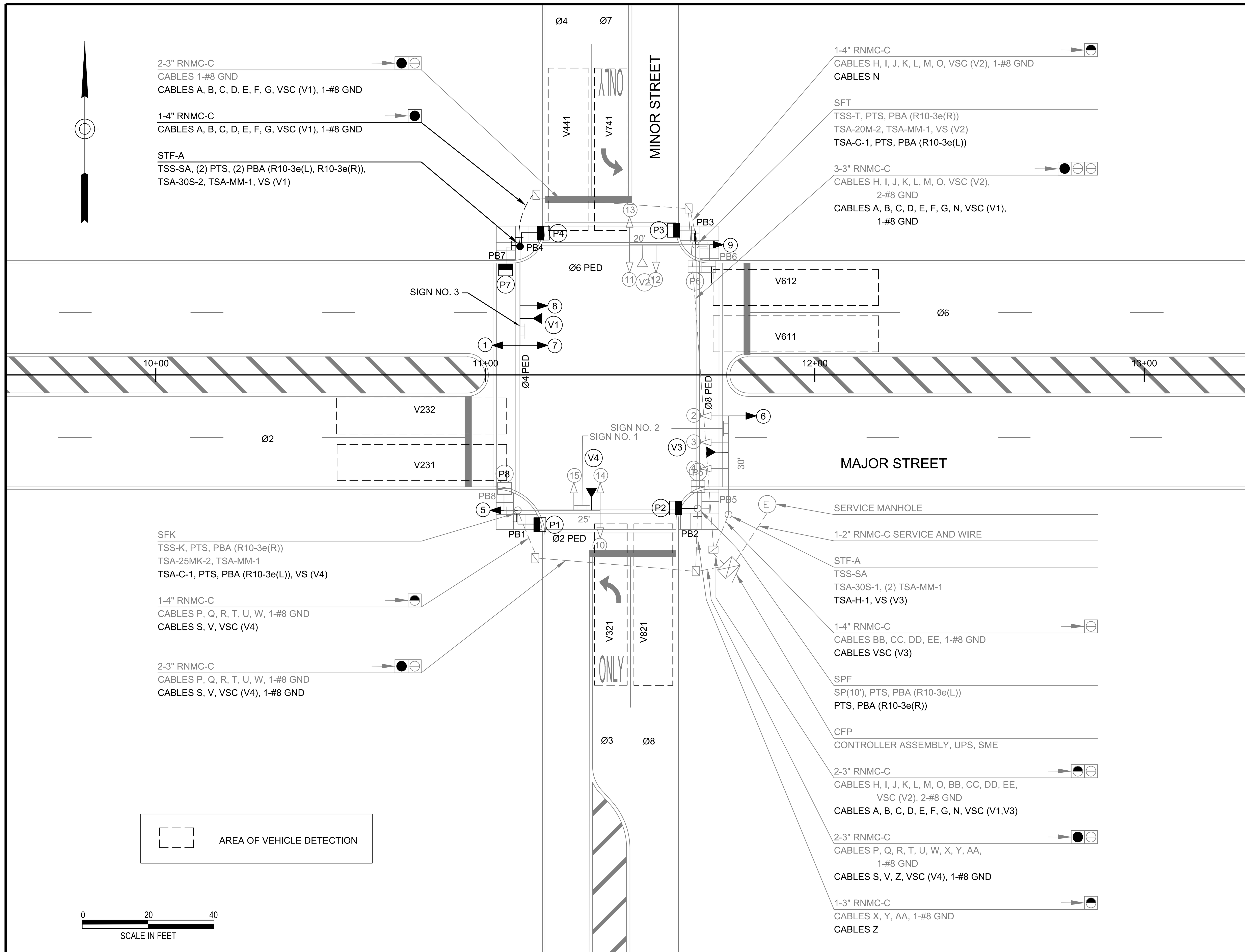
Title

TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

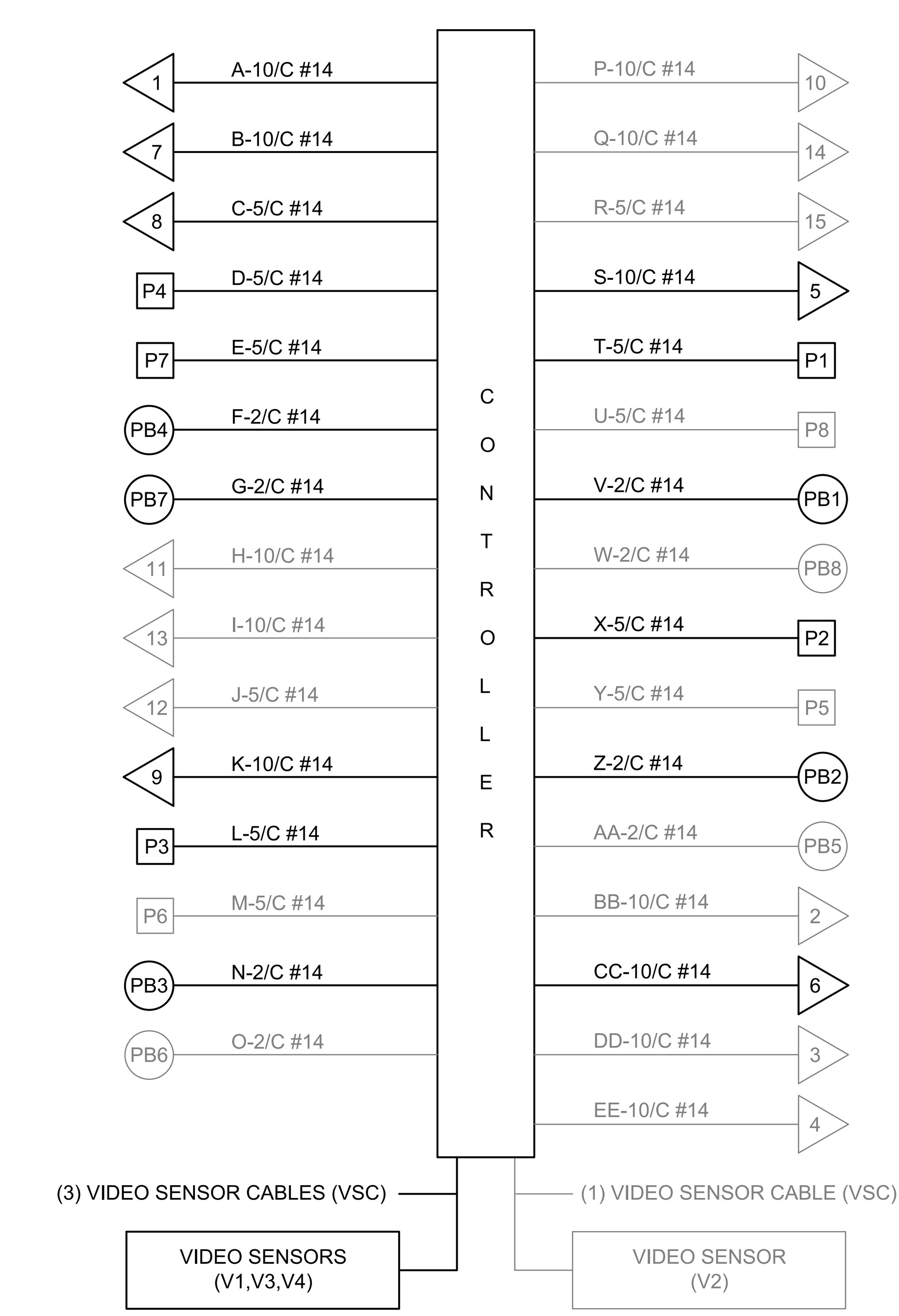
SAMPLE
TRAFFIC SIGNAL
REMOVAL PLAN

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG018
PID#

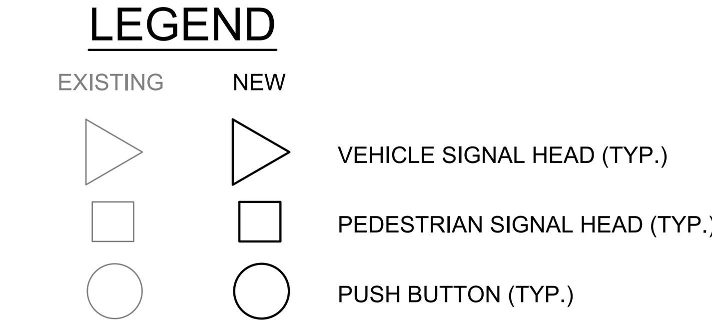
Sheet XX of XX



BLOCK WIRING DIAGRAM



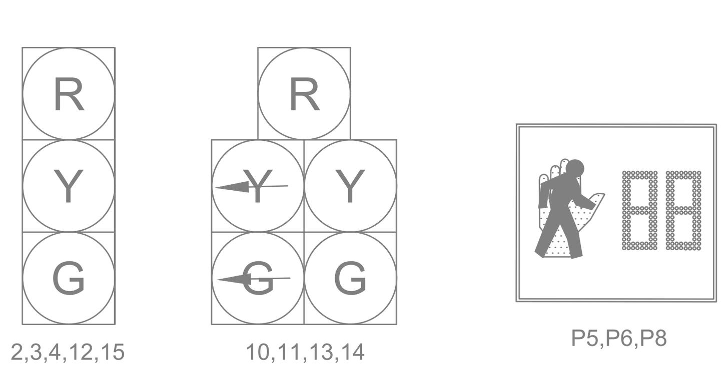
LEGEND



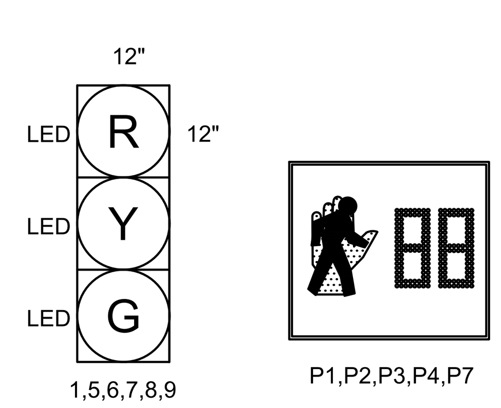
NOTES:

1. THE LOCATIONS OF TRAFFIC POLES AND SIGNALS ARE EXACT AS SHOWN IN THE CONTRACT DOCUMENTS. ANY CHANGES IN TRAFFIC POLE OR SIGNAL LOCATIONS DUE TO FIELD CONDITIONS SHALL BE APPROVED BY THE ENGINEER.
2. PEDESTRIAN PUSHBUTTONS SHALL BE INSTALLED AT THE ORIENTATION SHOWN, AND SHALL BE VISIBLE TO PEDESTRIANS WAITING TO CROSS. PEDESTRIAN SIGNAL SIGNS R10-3e SHALL SHOW THE ARROW AND FINGER POINTING TO THE CROSSWALK ACTUATED BY THE PUSHBUTTON.
3. TRAFFIC SIGNAL INDICATIONS #1, #6, #7 AND #8 SHALL BE EQUIPPED WITH BACKPLATES.
4. REFER TO SIGN DATA TABLE FOR SIGN DETAILS.
5. VEHICLE SIGNAL HEAD #5 & #9 SHALL BE MOUNTED AT 12 FEET.
6. PEDESTRIAN SIGNAL HEADS P1, P2, P3, P4 & P7 SHALL BE CLAMP MOUNTED AT 8 FEET.
7. SIGN NO. 3 SHALL BE INSTALLED FACING WEST (EASTBOUND TRAFFIC).

EXISTING SIGNAL LEGEND

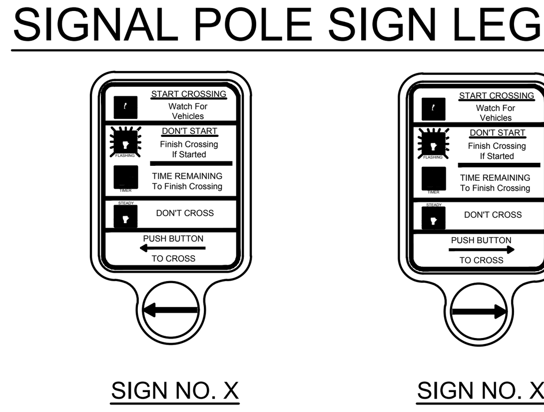


NEW SIGNAL LEGEND



MAST ARM SIGN LEGEND

SIGNAL POLE SIGN LEGEND



THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

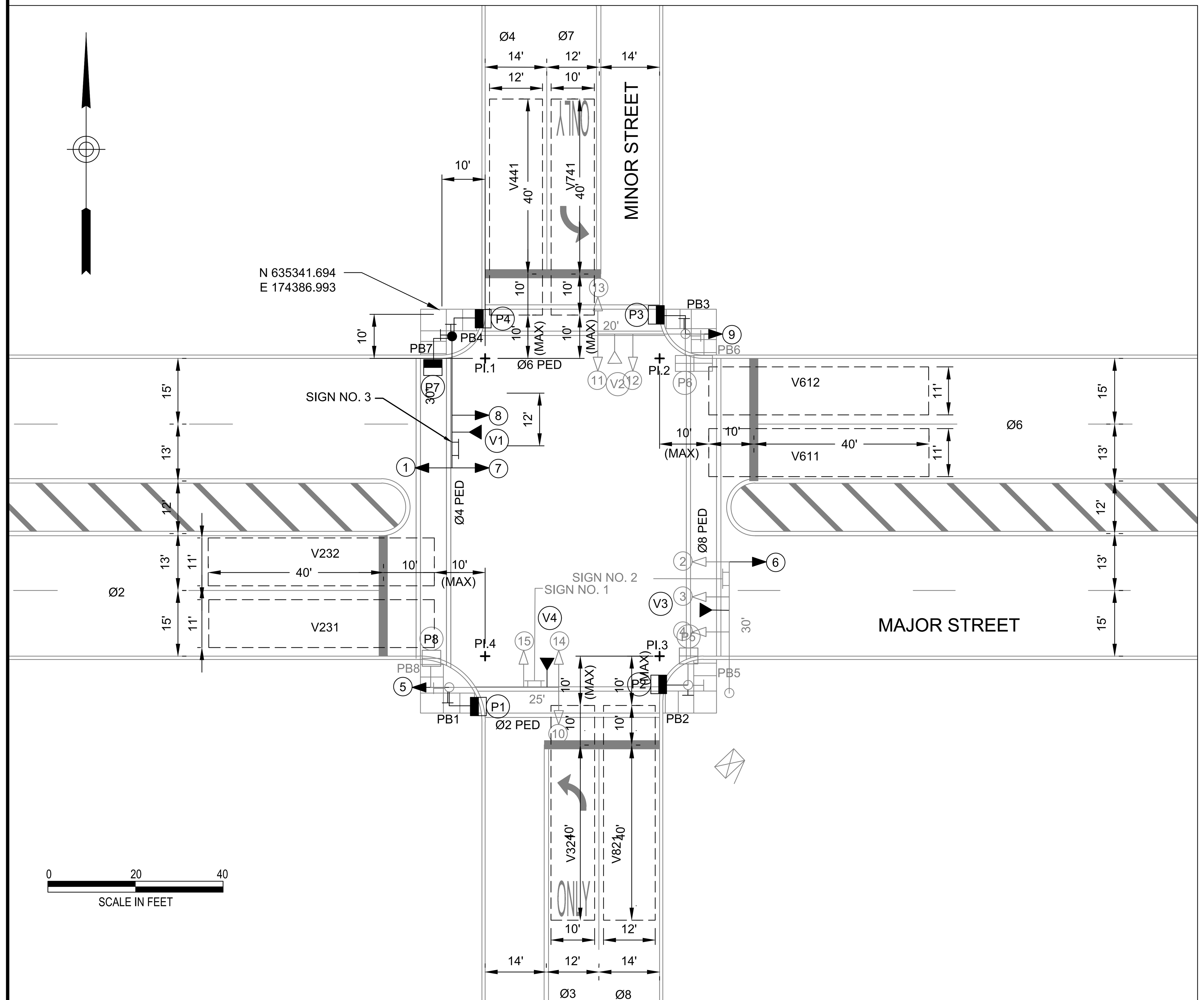
ENGINEERING DEPARTMENT

TRAFFIC

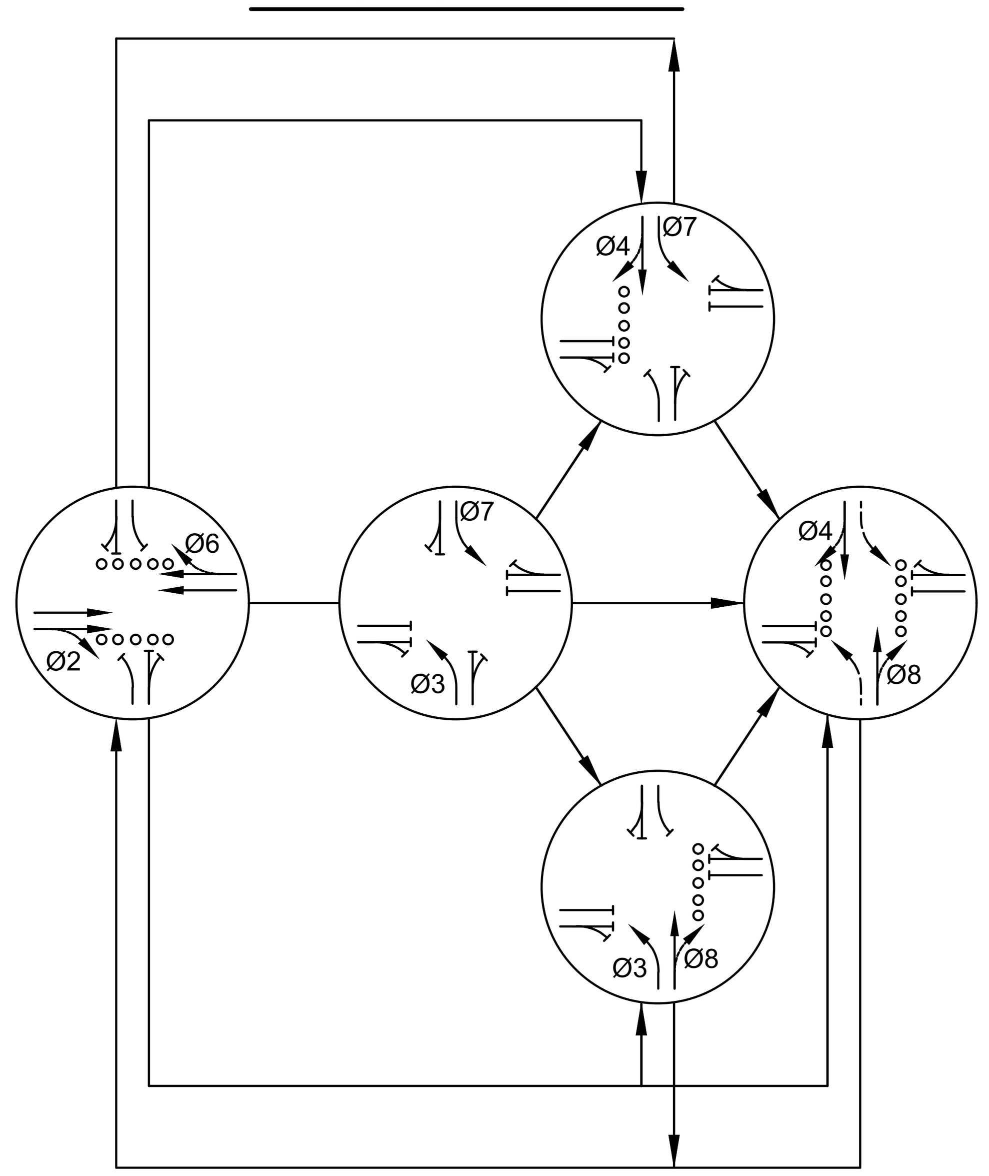
Title
TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE MODIFIED TRAFFIC SIGNAL WIRING PLAN

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG019
PID#



PHASING DIAGRAM



TRAFFIC SIGNAL TIMING

VEHICLE ACTUATION

PHASE DIAGRAM	PHASE		SIGNAL INDICATIONS 1,2,3,4,5	6,7,8,9	10,11	12	13,14	15	P1-P2	P3-P4	P5-P6	P7-P8	TIMING I (SEC)	TIMING II (SEC)	DETECTOR MODE	PHASE RECALL	EXT
	Ø2 + Ø6	ROW	G	G	R	R	R	R	DW	DW	DW	DW	15-21	15-21	NON-LOCK	MIN.	2.0
		CHG	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7	ROW	R	R	R,<G-	R	R,<G-	R	DW	DW	DW	DW	10	7-9	NON-LOCK	-	2.0
		CHG	R	R	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8	ROW	R	R	G	G	G	G	DW	DW	DW	DW	7-34	7-28	NON-LOCK	-	2.0
		CHG	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			

PEDESTRIAN ACTUATION

PHASE DIAGRAM	PHASE		1,2,3,4,5	6,7,8,9	10,11	12	13,14	15	P1-P2	P3-P4	P5-P6	P7-P8	TIMING I (SEC)	TIMING II (SEC)	DETECTOR MODE	PHASE RECALL	EXT
	Ø2 + Ø6 + Ø2 PED. + Ø6 PED.	ROW	G	G	R	R	R	R	W	W	DW	DW	7-9	7-9	NON-LOCK	MIN.	2.0
		PED CLR	G	G	R	R	R	R	FDW	FDW	DW	DW	12	12			
		VEHICLE EXT	G	G	R	R	R	R	DW	DW	DW	DW	0-2	0-2			
		CHG	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7	ROW	R	R	R,<G-	R	R,<G-	R	DW	DW	DW	DW	10	7-9	NON-LOCK	-	2.0
		CHG	R	R	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8 + Ø4 PED. + Ø8 PED.	ROW	R	R	G	G	G	G	DW	DW	W	W	7	7	NON-LOCK	-	2.0
		PED CLR	R	R	G	G	G	G	DW	DW	FDW	FDW	21	21			
		VEHICLE EXT	R	R	G	G	G	G	DW	DW	DW	DW	0-6	0			
		CHG	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
EMERGENCY FLASH			Y	Y	R	R	R	R	DARK	DARK	DARK	DARK					
EFFECTIVE MAXIMUM CYCLE LENGTH													82	75			

1. TIMING I IS TO OPERATE MONDAY - FRIDAY 7:00AM TO 9:00AM AND 4:00PM TO 6:00PM.
   TIMING II IS TO OPERATE AT ALL OTHER TIMES.
2. THE SIGNAL SHALL BE SET TO "FREE OPERATION". THIS INTERSECTION IS NOT COORDINATED WITH ANY OTHER TRAFFIC SIGNALS.
3. THIS INTERSECTION IS FULLY ACTUATED FOR PEDESTRIANS.

Sheet XX of XX

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD DESIGN GUIDELINES

SAMPLE MODIFIED TRAFFIC SIGNAL DIMENSION DIAGRAM AND TIMING DATA

Designed by

Drawn by

Checked by

Date DECEMBER 2018

Contract Number

Drawing Number SG020

PID#

INTERSECTION ACTUATION TABLE

DETECTOR NO.	PHASE	SIZE	MODE	DETECTOR TYPE
V231	ϕ2	50' X 11'	PRESENCE	VIDEO
V232	ϕ2	50' X11'	PRESENCE	VIDEO
V321	ϕ3	50' X 10'	PRESENCE	VIDEO
V441	ϕ4	50' X 12'	PRESENCE	VIDEO
V611	ϕ6	50' X 12'	PRESENCE	VIDEO
V612	ϕ6	50' X 11'	PRESENCE	VIDEO
V741	ϕ7	50' X 10'	PRESENCE	VIDEO
V821	ϕ8	50' X 12'	PRESENCE	VIDEO
PB1	ϕ2 PED	-	-	PUSH BUTTON
PB2	ϕ2 PED	-	-	PUSH BUTTON
PB3	ϕ6 PED	-	-	PUSH BUTTON
PB4	ϕ6 PED	-	-	PUSH BUTTON
PB5	ϕ8 PED	-	-	PUSH BUTTON
PB6	ϕ8 PED	-	-	PUSH BUTTON
PB7	ϕ4 PED	-	-	PUSH BUTTON
PB8	ϕ4 PED	-	-	PUSH BUTTON

LOAD SWITCH TABLE

LOAD SWITCH NUMBER	PHASE	FACE NUMBER	INDICATIONS	TERMINAL
LS1	-	-	-	-
LS2	ϕ2	1, 2, 3, 4, 5	R Y G NEUTRAL WIRE	LS 2R LS 2Y LS 2G NEUTRAL BUS
LS3	ϕ3	10, 11	* ~~Y~~ ~~G~~ NEUTRAL WIRE	LS 3R LS 3Y LS 3G NEUTRAL BUS
LS4	ϕ4	13, 14, 15	R Y G NEUTRAL WIRE	LS 4R LS 4Y LS 4G NEUTRAL BUS
LS5	-	-	-	-
LS6	ϕ6	6, 7, 8, 9	R Y G NEUTRAL WIRE	LS 6R LS 6Y LS 6G NEUTRAL BUS
LS7	ϕ7	13, 14	* ~~Y~~ ~~G~~ NEUTRAL WIRE	LS 7R LS 7Y LS 7G NEUTRAL BUS
LS8	ϕ8	10, 11, 12	R Y G NEUTRAL WIRE	LS 8R LS 8Y LS 8G NEUTRAL BUS
LS9	ϕ2 PED.	P1, P2	DON'T WALK WALK NEUTRAL WIRE	LS 9R LS 9Y LS 9G NEUTRAL BUS
LS10	ϕ4 PED.	P7, P8	DON'T WALK WALK NEUTRAL WIRE	LS 10R LS 10Y LS 10G NEUTRAL BUS
LS11	ϕ6 PED.	P3, P4	DON'T WALK WALK NEUTRAL WIRE	LS 11R LS 11Y LS 11G NEUTRAL BUS
LS12	ϕ8 PED.	P5, P6	DON'T WALK WALK NEUTRAL WIRE	LS 12R LS 12Y LS 12G NEUTRAL BUS

* CONNECT 115V AC TO APPROPRIATE CONFLICT MONITOR RED CHANNEL INPUT TO PREVENT TRIPPING AND SIGNALS FLASHING.

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

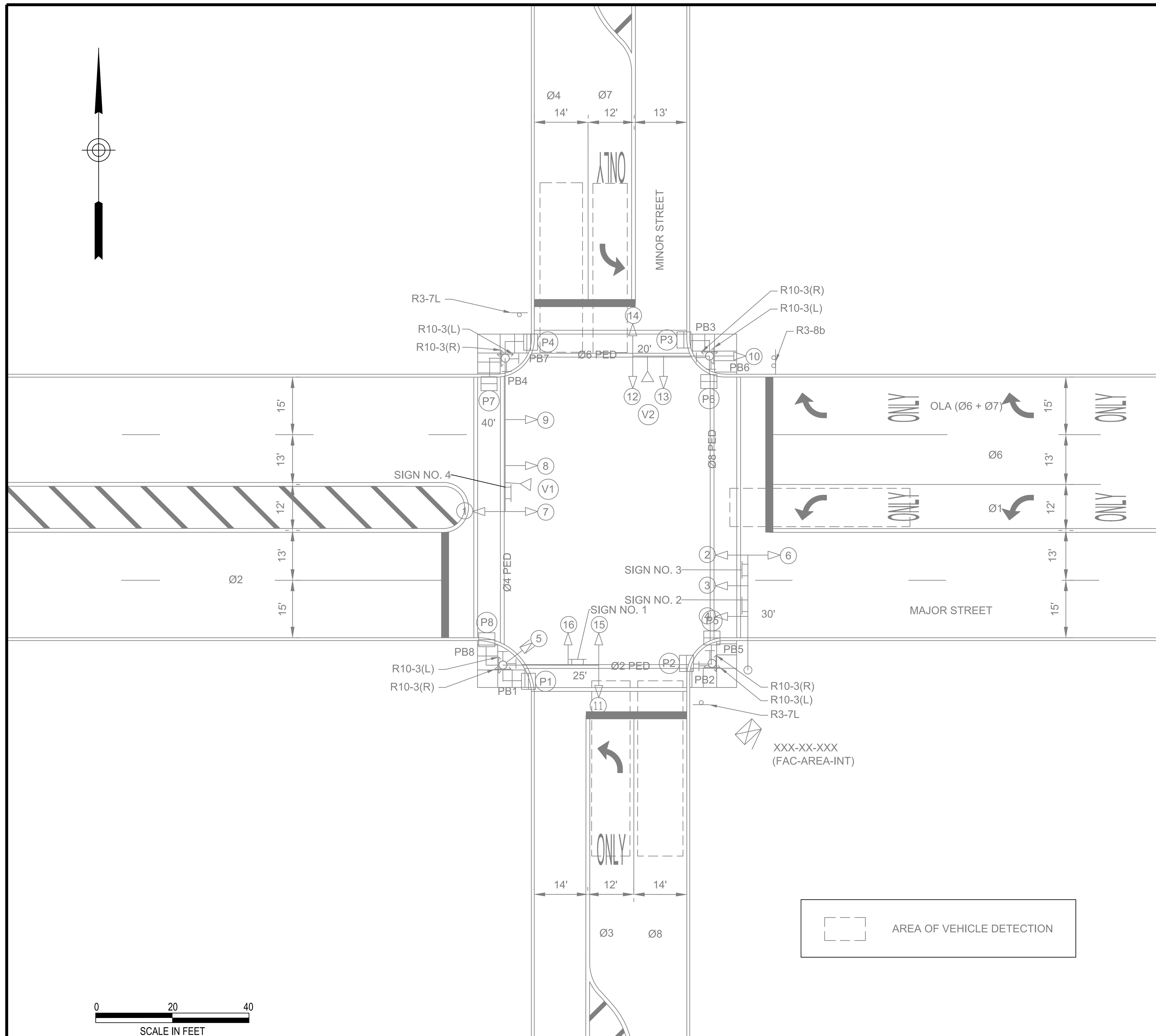
ENGINEERING DEPARTMENT

TRAFFIC

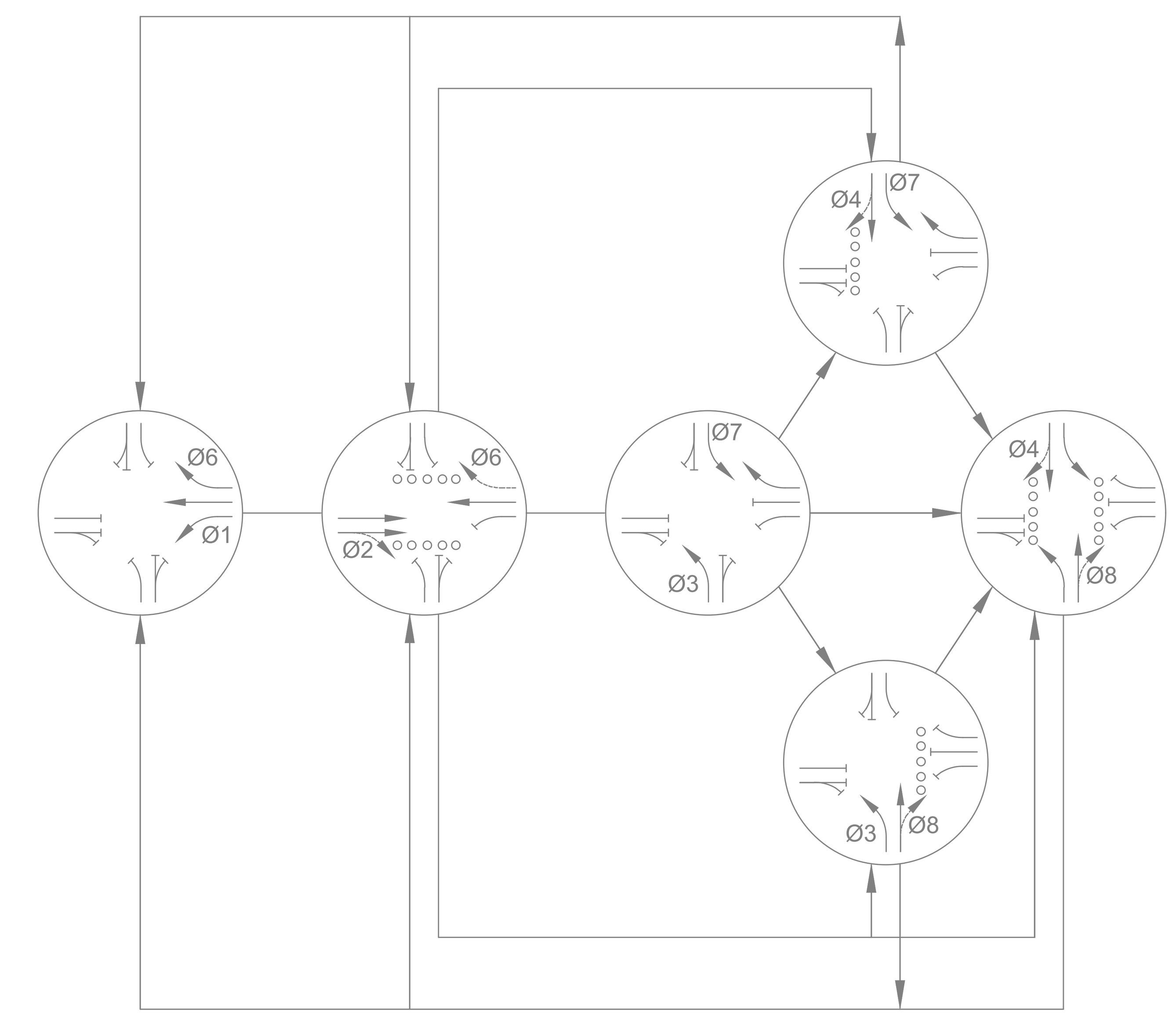
Title
TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

SAMPLE MODIFIED TRAFFIC SIGNAL LOAD SWITCH AND ACTUATION TABLES

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number SG021
PID#



PHASING DIAGRAM



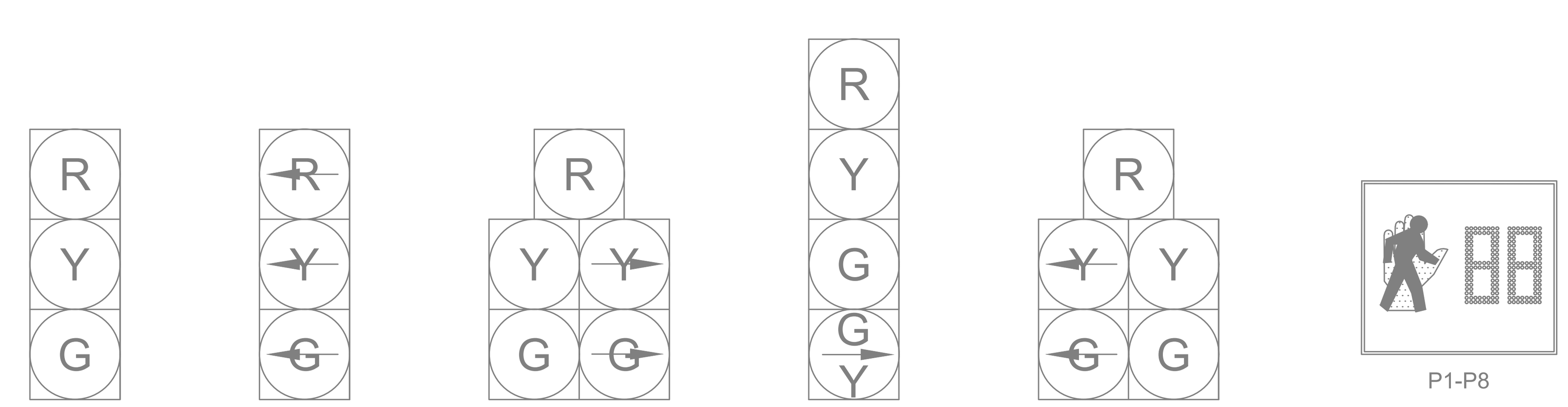
MAST ARM SIGN LEGEND

SIGN NO. 1 | SIGN NO. 2 | SIGN NO. 3 R3-2 | SIGN NO. 4 R10-5

SYMBOL LEGEND

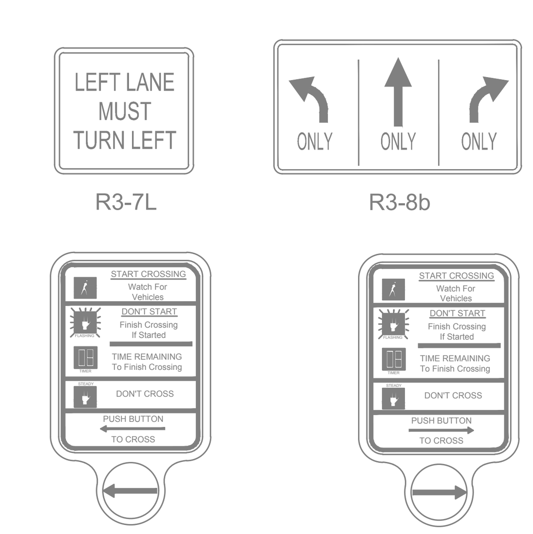
- VEHICULAR SIGNAL HEAD WITH IDENTIFIER
- VIDEO SENSOR WITH IDENTIFIER
- PEDESTRIAN SIGNAL HEAD WITH IDENTIFIER
- PEDESTRIAN PUSHBUTTON WITH IDENTIFIER
- MAST ARM SIGN
- TRAFFIC SIGNAL STANDARD WITH MAST ARM LENGTH
- TRAFFIC CLAMP/POST-TOP MOUNTED SIGNAL
- SIGNAL CONTROLLER AND CABINET GROUND MOUNTED

SIGNAL LEGEND



1,2,3,4,8,13,16 | 5,6,7 | 9 | 10 | 11,12,14,15 | P1-P8

SIGN LEGEND



R3-7L | R3-8b

SIGN NO. X R10-3e(L) | SIGN NO. X R10-3e(R)

THE PORT AUTHORITY OF NY & NJ

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

MAJOR STREET AND
MINOR STREET
(SAMPLE FINAL RECORD
TS DRAWING)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number FAC-INT
PID#

THE PORT AUTHORITY
OF NY & NJ

TRAFFIC SIGNAL TIMING

VEHICLE ACTUATION

PHASE DIAGRAM	PHASE		SIGNAL INDICATIONS 1,2,3,4	5,6,7	8	9,10	11,12	13	14,15	16	P1-P2	P3-P4	P5-P6	P7-P8	TIMING I (SEC)	TIMING II (SEC)	DETECTOR MODE	PHASE RECALL	EXT
	Ø1 + Ø6	ROW	R	<G-	G	G,-G>	R	R	R	R	DW	DW	DW	DW	7	7-11	NON-LOCK	-	2.0
		CHG	R	<Y-	G	G,-Y>	R	R	R	R	DW	DW	DW	DW	3.0	3.0			
		CLR	R	<R-	G	G	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø2 + Ø6	ROW	G	<R-	G	G	R	R	R	R	W	W	DW	DW	37-7	37-10	NON-LOCK	MIN. +PED	2.0
		PED CLEAR	G	<R-	G	G	R	R	R	R	FDW	FDW	DW	DW	12	12			
		CHG	Y	<R-	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7 + OLA	ROW	R	<R-	R	R,-G>	R,<G-	R	R,<G-	R	DW	DW	DW	DW	7-11	7-9	NON-LOCK	-	2.0
		CHG	R	<R-	R	R,-Y>	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8	ROW	R	<R-	R	R	G	G	G	G	DW	DW	DW	DW	7-33	7-28	NON-LOCK	-	2.0
		CHG	R	<R-	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
PEDESTRIAN ACTUATION																			
	Ø1 + Ø6	ROW	R	<G-	G	G	R	R	R	R	DW	DW	DW	DW	7	7-11	NON-LOCK	-	2.O
		CHG	R	<Y-	G	G	R	R	R	R	DW	DW	DW	DW	3.0	3.0			
		CLR	R	<R-	G	G	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø2 + Ø6	ROW	G	<R-	G	G	R	R	R	R	W	W	DW	DW	16-7	16-10	NON-LOCK	MIN. + PED	2.0
		PED CLR	G	<R-	G	G	R	R	R	R	FDW	FDW	DW	DW	12	12			
		CHG	Y	<R-	Y	Y	R	R	R	R	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
	Ø3 + Ø7 + OLA	ROW	R	<R-	R	R,-G>	R,<G-	R	R,<G-	R	DW	DW	DW	DW	7-11	7-9	NON-LOCK	-	2.0
		CHG	R	<R-	R	R,-Y>	R,<Y-	R	R,<Y-	R	DW	DW	DW	DW	3.0	3.0			
	Ø4 + Ø8 + Ø4 PED. + Ø8 PED.	ROW	R	<R-	R	R	G	G	G	G	DW	DW	W	W	7	7	NON-LOCK	-	2.0
		PED CLR	R	<R-	R	R	G	G	G	G	DW	DW	FDW	FDW	21	21			
		VEHICLE EXT	R	<R-	R	R	G	G	G	G	DW	DW	DW	DW	0-5	0			
		CHG	R	<R-	R	R	Y	Y	Y	Y	DW	DW	DW	DW	4.0	4.0			
		CLR	R	<R-	R	R	R	R	R	R	DW	DW	DW	DW	2.0	2.0			
EMERGENCY FLASH			Y	<R-	Y	Y	R	R	R	R	DARK	DARK	DARK	DARK					
														BACKGROUND CYCLE LENGTH	90	90			
														OFFSET	52.0	16.0			

1. Ø4 + Ø8 SHALL ALWAYS PRECEDE Ø1 + Ø6.
2. TIMING I IS TO OPERATE MONDAY - FRIDAY 7:00AM TO 9:00AM AND 4:00PM TO 6:00PM.
   TIMING II IS TO OPERATE AT ALL OTHER TIMES.
3. OFFSET SHALL BE MEASURED FROM THE BEGINNING OF YELLOW TO Ø2 + Ø6 AT THIS INTERSECTION TO THE BEGINNING OF YELLOW TO Ø2 + Ø6 AT THE INTERSECTION OF ______________________.

No.	Date	Revision	Approved

ENGINEERING DEPARTMENT

TRAFFIC

Title

TRAFFIC SIGNAL STANDARD
DESIGN GUIDELINES

MAJOR STREET AND
MINOR STREET
(SAMPLE FINAL RECORD
TS DRAWING)

Designed by
Drawn by
Checked by
Date DECEMBER 2018
Contract Number
Drawing Number FAC-INT
PID#

Appendix E – Asset Commissioning Form

Traffic Signal Asset Commissioning Form

THE PORT AUTHORITY OF NY & NJ

Facility: select facility…

Intersection:

Signal Number:

Prime Contractor:

Electrical Contractor:

Contract Number:

Retro Commissioning? ☐ Yes ☐ No

This checklist must be completed to the satisfaction of the Port Authority before the PA can commission assets constructed and installed under the Contract.

1	Has the Traffic Signal Pre-Final/Turn-On Inspection Checklist been completed?	
2	Have all punchlist items from Traffic Signal Pre-Final/Turn-On Inspection Checklist been resolved?	
3	Has the Traffic Signal Final Inspection Checklist been completed?	
4	Have all punchlist items from Traffic Signal Final Inspection Checklist been resolved?	
5	Has the 30-day test period been completed to the satisfaction of the Authority?	

Notes:

This is to certify that the traffic signal at the intersection specified above and installed under the Contract has been commissioned and transferred to the Port Authority of NY & NJ for full operation and maintenance.

Resident Engineer/ Appointed Representative:

Signature: ______________________________

Date: ______________________________

Manager of Plant & Structure/ Chief Electrical Maintenance Supervisor:

Signature: ______________________________

Date: ______________________________

Chief Traffic Engineer:

Signature: ______________________________

Date: ______________________________

This space intentionally left blank.

Traffic Signal Inspection Checklist - Pre-Final / Turn-On

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	
Electrical Contractor:	Engineer of Record:
EADD Traffic Engineer:	Consulting Firm:
CMD Inspector:	Date:

- All prerequisite items descibed below must be completed before pre-final / turn-on signal inspection can begin.
- This checklist must be completed to the satisfaction of the Authority before traffic signal activation can be authorized.

Pre-requisite		Y | N | n/a	Comments
At least 2 weeks prior to the traffic signal inspection, provide confirmation in writing to the Authority from the authorized signal vendor confirming the following prerequisites have been completed:			
1.	Have the cabinet internal & rear board connections been tested?		
2.	Has the controller been tested for 24 hours/ 7 days while programmed?		
3.	Has conflict monitor been tested and board been programmed according to signal phasing?		
4.	Have 3 hard copies and an electronic copy of satisfactory test results for the controller with the controller's serial number been provided to the Engineer? (Engineer to provide one hard copy and electronic copy each to Traffic Engineering and to Electric Shop)		
5.	Have 3 hard copies and an electronic copy of satisfactory test results for the conflict monitor been provided to the Engineer? (Engineer to provide one hard copy and electronic copy each to Traffic Engineering and to Electric Shop)		
6.	Have 3 hard copies and an electronic copy of satisfactory test results for the cabinet internal & rear board connections been provided to the Engineer? (Engineer to provide one hard copy and electronic copy each to Traffic Engineering and to Electric Shop)		
7.	Have 3 hard copies and an electronic copy of Warranty documentation been provided to the Engineer? (Engineer to provide one hard copy and electronic copy each to Traffic Engineering and to Electric Shop)		

A - Poles & Mast Arms		Y | N | n/a	Comments
A1.	Are all signal poles and push button posts installed according to contract documents?		
A2.	Are all poles the correct size, according to contract documents?		
A3.	Have all pole caps been installed?		
A4.	Have all mast arm end caps been installed?		
A5.	Are all rubber gromets installed on cable openings on poles per contract documents?		
A6.	Are the angles and length of mast arms according to contract documents?		

***** Denotes Electrical Items

Traffic Signal Inspection Checklist - Pre-Final / Turn-On

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

A - Poles & Mast Arms (continued)		Y | N | n/a	Comments
A7.	Are hand hole covers and transformer base doors installed according to contract documents?		
A8.*	Are all poles grounded?		

B - Signal Heads (Veh. & Ped.) & Push Buttons		Y | N | n/a	Comments
B1.	Are vehicular signal heads installed according to contract documents?		
B2.	Are mounting heights of vehicular signal heads according to contract documents?		
B3.	Do bottom of vehicular signal heads align, if applicable?		
B4.	Are the colors, size, configuration and back-plates of the vehicular signal heads according to contract documents?		
B5.	Is the material of the vehicular signal housings according to the contract documents?		
B6.	Are all safety chains installed?		
B7.	Is upper tether wire installed according to contract documents?		
B8.	Are all optically programmed signals provided (if required) and fixed mounted according to contract documents?		
B9.	Are louvers installed according to contract documents?		
B10.	Are open tunnel visors installed (unless other type has been specified in contract documents)?		
B11.	Are angle visors installed if required and fixed mounted according to contract documents?		
B12.	Are pedestrian signal heads installed according to contract documents?		
B13.	Are mounting heights of pedestrian signals according to contract documents?		
B14.	Are upraised hand, walking person, and number indications fully illuminated?		
B15.	Are pedestrian signal heads aligned toward crossing direction?		
B16.	Is the material of the pedestrian signal housings according to the contract documents?		
B17.	Are pedestrian pushbuttons installed in proper orientation according to contract documents?		
B18.	Are backs of buttons sealed?		
B19.	Are mounting heights of pedestrian pushbuttons according to contract documents?		
B20.	Is the correct pedestrian push button sign used, according to contract documents?		

* Denotes Electrical Items

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

B - Signal Heads (Veh. & Ped.) & Push Buttons (continued)		Y | N | n/a	Comments
B21.*	Is mounting hardware correctly installed including serrated and lock rings and with matching size serration (use bucket truck to verify)?		

C - Cabinet		Y | N | n/a	Comments
C1.	Is the controller cabinet orientation such that the door opens away from the intersection?		
C2.	Is the bottom of cabinet sealed where it meets the foundation?		
C3.	Is a 12-position loadbay provided and have load switches been installed according to signal phasing?		
C4.	Does signal go into flashing mode when conflict monitor is disconnected?		
C5.	Have flashing relays been installed and does the signal flash according to contract documents (red or yellow)?		
C6.	Does controller and conflict monitor have proper time/date/daylight savings time programmed?		
C7.	Is uninterruptible power supply (UPS) installed as per contract documents?		
C8.*	Does signal go into flashing mode when conflicting outputs are connected to load switches?		
C9.*	Is ground rod installed properly and connected to cabinet and conduits?		
C10.*	Have unused conductors been taped and coiled in cabinet?		
C11.*	Are all conduits leading to cabinet duct sealed?		
C12.*	Is there a bonding jumper between neutral ground bus and chassis ground bus? Has polarity of cabinet neutral and ground been checked?		
C13.*	Are loop lead-in cable shields grounded to cabinet bus bar?		
C14.*	Has power line surge protector been installed?		
C15.*	Has AC receptacle been installed (GFI and non-GFI) and has polarity been checked?		
C16.*	Has input/output wiring been attached properly and neatly labeled per contract documents?		
C17.*	Is fan provided and operational?		
C18.*	Is thermostat provided and operational?		

* Denotes Electrical Items

Traffic Signal Inspection Checklist - Pre-Final / Turn-On

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

D - Signal Operations		Y | N | n/a	Comments
D1.	Are signal controller phasing and all controller parameters according to contract documents?		
D2.	Are phase split times, offsets & cycle lengths according to contract documents?		
D3.	Are all signal faces illuminated properly (no burn-outs)?		
D4.	Do all signal faces operate according to assigned phases and load switches (including left turn phases, overlaps and double clearances, etc)?		
D5.	Do all walk/don't walk and countdown indications cycle properly after activation?		
D6.	Does the controller time through all preemption intervals according to contract documents and enter/exit preemption operation in proper phase sequence from external call(s) to preemption (rail hut, track circuit, pushbutton, video, etc)?		
D7.	Do all auxiliary equipment receive proper controller output and display proper indications as per contract documents? (such as blankout signs, flashers, bells, sirens, etc.)		
D8.*	Does the UPS operate properly when power is interrupted to cabinet (power feed to cabinet must be turned off at the source to test)?		

E - Detection		Y | N | n/a	Comments
E1.	Do vehicle detectors get activated by vehicles in lane? (Video zones or inductance loops, vehicle must be used to activate each detector)? Also check lock/non-lock mode.		
E2.	Are video zones configured as per contract? Is the proper phase activated by video zone location?		
E3.	Do video zones exclude vehicles in adjacent lanes as well as other objects that may enter the zone? (Applies to vehicle/pedestrian/rail detection)		
E4.	Is video detection monitor installed? Is mouse for video detection monitor installed?		
E5.	Are cameras positioned to give proper detection coverage for each lane? (Applies to vehicle/pedestrian/rail detection)		
E6.	Are loops centered in travel lanes?		
E7.	Are loops the correct size according to contract documents?		
E8.	Are loops the correct distance from stop line, according to contract documents?		
E9.	Are loops the correct distance from each other, according to contract documents?		
E10.	Has sawcut been completely filled?		

***** Denotes Electrical Items

Traffic Signal Inspection Checklist - Pre-Final / Turn-On

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

E - Detection (continued)		Y | N | n/a	Comments
E11.	Is loop cut to proper standard (triangle cuts on corners)?		
E12.	Has curb been nicked where loops are installed?		
E13.	Has proper loop cable been installed? (To be verified by construction inspector)		
E14.	Are loop harnesses identified and labeled with phases and loop designation according to contract documents?		
E15.	Have loop detector amplifiers been installed according to specified phases in contract documents?		
E16.	Are loop detector amplifiers/video processors functioning properly and set for the required sensitivity, delays and extension, if any?		
E17.	Are loop detector amplifiers labeled according to phases and detector numbers as shown in contract documents?		
E18.	Are all detector toggle switches provided? Are they operating properly?		
E19.	Do pedestrian pushbuttons operate properly and match assigned signal phase (buttons shall be pushed for testing)?		
E20.	Are video cables labeled according to phases and detector numbers as shown in contract documents?		
E21.*	Are video cables continously run from camera to processor module in cabinet (no splices)?		

F - Pullboxes		Y | N | n/a	Comments
F1.*	Are all conduits mortared and grounded (if not PVC)?		
F2.*	Is grounding rod installed?		

G - Markings & Signs (Signal related only)		Y | N | n/a	Comments
G1.	Have all signs been installed according to signal contract documents?		
G2.	Are all sign sizes and text according to signal contract documents?		
G3.	Are mounting heights of signs according to contract documents?		
G4.	Have all pavement markings (crosswalks, stop lines, dotted lines for dual turns & symbols, etc) been installed according to contract documents?		
G5.	Are signal head distances to stop line according to contract documents?		

* Denotes Electrical Items

Traffic Signal Inspection Checklist - Pre-Final / Turn-On

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

Comments

***** Denotes Electrical Items

Traffic Signal Inspection Checklist - Final

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	
Electrical Contractor:	Engineer of Record:
EADD Traffic Engineer:	Consulting Firm:
CMD Inspector:	Date:

- All pre-requisite items described below must be completed before final inspection can begin.
- This checklist must be completed to the satisfaction of the Authority.
- A 30-day acceptance test period shall be conducted after completing all outstanding inspection issues to the satisfaction of the Authority, before the Authority can assume maintenance and operational responsibility.

Pre-requisite		Y | N | n/a	Comments
1.	Have all punchlist items been resolved from the pre-final / turn-on inspection checklist?		
2.	Have 3 hard copies and an electronic copy of final cabinet wiring schematics reflecting all field modifications been provided to the Engineer? (Engineer to provide one hard copy and electronic copy each to Traffic Engineering and to Electric Shop)		
3.**	Has fiber optic cable been terminated in fiber optic patch panel? (to be performed by TSD)		
4.**	Has network connectivity for ethernet switch been checked? Is ethernet switch operational? (to be performed by TSD)		
5.**	Is ethernet switch, terminal server and/or wireless transmitter turned on? (to be performed by TSD)		

A - Poles & Mast Arms		Y | N | n/a	Comments
A1.	Are all poles in good condition (No rust or visible physical damage)?		
A2.	Are all signal pole foundation pedestal elevations higher than surrounding surface levels?		
A3.	Are all leveling nuts installed properly to balance span wire poles (underneath base plate)?		
A4.	Have all bolt covers on aluminum poles been installed?		
A5.	Are span wire poles stamped (capacity & height)?		

B - Signal Heads (Veh. & Ped.) & Push Buttons		Y | N | n/a	Comments
B1.	Are span wire drip loops the correct length?		
B2.	Do vehicular signal head cables have adequate slack?		
B3.	Are eggcrate visors installed on pedestrian signal indications?		

C - Cabinet		Y | N | n/a	Comments
C1.	Has a copy of signal phasing, timing, electrical, signal plan, load switch table (LST) and cabinet wiring diagram been placed in a weatherproof pouch in the cabinet?		

***** Denotes Electrical Items ****** Denotes Communications Items to be verified by Technology Services Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

C - Cabinet (continued)		Y | N | n/a	Comments
C2.	Has signal cabinet activity log been established starting with turn-on date? (to be provided by Traffic Engineering)		
C3.	Are operation/maintenance manuals and warranty information for controller, conflict monitor, detector equipment and other specified equipment placed in cabinet?		
C4.	Is the cabinet clean with cables neatly coiled and out of the way?		
C5.	Is LED lamp installed? Does it turn on from the door switch?		
C6.*	Has all spare equipment been provided to the engineer?		
C7.*	Has all salvageable equipment been returned to the Electric Shop?		

D - Communications		Y | N | n/a	Comments
D1.	Is controller, conflict monitor, and video processor properly configured wth ethernet switch, terminal server and/or wireless transmitter?		
D2.	Is interconnect cable/fiber labeled and identified?		
D3.	Is ethernet switch, terminal server, and/or wireless transmitter working properly with the central system?		
D4.	Have the IP addresses for the controller, detectors, and conflictor monitor been labelled on the inside of cabinet wall? (to be provided by the Authority)		
D5.	Have all communication connections been labeled?		
D6.	Is fiber optic cable installed in flexible conduit from underground conduit to fiber optic patch panel?		

E - Pullboxes		Y | N | n/a	Comments
E1.	Is pullbox in the correct place according to contract documents?		
E2.	Is pullbox the correct size according to contract documents?		
E3.	Is pullbox set to grade?		
E4.	Does cover say “Traffic Signal”?		
E5.*	Is frame mortared?		
E6.*	Are all conduits into pullbox no more than 3" long?		

* Denotes Electrical Items ** Denotes Communications Items to be verified by Technology Services Department

Traffic Signal Inspection Checklist - Final

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

E - Pullboxes (continued)		Y | N | n/a	Comments
E7.*	Have loops been spliced according to contract documents?		
E8.*	Have cables been coiled and hung?		
E9.*	Is all debris removed from pullbox?		
E10.*	Can the pullbox be easily opened (make sure it is not sealed shut)?		
E11.*	Is manhole cover grounded to the ground rod in the pullbox?		
E12.*	Are all wires tagged at the point of termination at both ends and in all pullboxes?		

Comments

* Denotes Electrical Items   ** Denotes Communications Items to be verified by Technology Services Department

Traffic Signal Inspection Checklist - Temporary Signal Conformance

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	
Electrical Contractor:	Engineer of Record:
EADD Traffic Engineer:	Consulting Firm:
CMD Inspector:	Date:
Emergency Contact (1):	Affiliation:
	Phone Number:
Emergency Contact (2):	Affiliation:
	Phone Number:

- All prerequisite items described below must be completed before the signal inspection can begin.
- This checklist must be completed to the satisfaction of the Authority before traffic signal activation can be authorized.

Pre-requisite		Y | N | n/a	Comments
At least 2 weeks prior to the traffic signal inspection, provide confirmation in writing to the Authority from the authorized signal vendor confirming the following prerequisites have been completed:			
1.	Has the controller been tested while programmed?		
2.	Has conflict monitor been tested and board been programmed according to signal phasing?		

A - Poles & Mast Arms		Y | N | n/a	Comments
A1.	Are all signal poles and push button posts installed according to contract documents?		
A2.	Are all poles the correct size, according to contract documents?		
A3.	Are all poles grounded?		
A4.	Are span wire drip loops the correct length?		
A5.	Are all guy wires installed according to contract documents?		
A6.	Are all portable signal units (trailers) installed according to contract documents?		
A7.	Are the angles and length of mast arms according to contract documents?		
A8.	Are solar panels properly positioned?		
A9.	Are all units/trailers secured in place per manufacturer's specifications to prevent any inadvertent movements?		
A10.	Are all arms locked properly in place per manufacturer's specifications?		

Traffic Signal Inspection Checklist - Temporary Signal Conformance

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

B - Signal Heads (Veh. & Ped.) & Push Buttons		Y | N | n/a	Comments
B1.	Are vehicular signal heads installed according to contract documents?		
B2.	Are mounting heights of vehicular signal heads according to contract documents?		
B3.	Do bottom of vehicular signal heads align, if applicable?		
B4.	Are the colors, size, configuration and back-plates of the vehicular signal heads according to contract documents?		
B5.	Is the material of the vehicular signal housings according to the contract drawings?		
B6.	Are tether wire(s) installed according to contract documents?		
B7.	Are louvers installed according to contract documents?		
B8.	Are open tunnel visors installed (unless other type has been specified in contract documents)?		
B9.	Are angle visors installed if required and fixed mounted according to contract documents?		
B10.	Are pedestrian signal heads installed according to contract documents?		
B11.	Are mounting heights of pedestrian signals according to contract documents?		
B12.	Are upraised hand, walking person, and number indications fully illuminated?		
B13.	Are pedestrian signal heads aligned toward crossing direction?		
B14.	Is the material of the pedestrian signal housings according to the contract drawings?		
B15.	Are pedestrian pushbuttons installed in proper orientation according to contract documents?		
B16.	Are mounting heights of pedestrian pushbuttons according to contract documents?		
B17.	Is the correct pedestrian push button sign used, according to contract documents?		

C - Cabinet		Y | N | n/a	Comments
C1.	Does signal go into flashing mode when conflict is detected?		
C2.	Does the signal flash according to contract documents (red or yellow)?		
C3.	Does controller and conflict monitor have proper time/date/daylight savings time programmed?		
C4.	Are all cabinets properly labeled with which one is the master controller?		
C5.	Are all cabinets properly grounded per manufacturer's specifications?		
C6.	Have access keys to the cabinet been provided to the Engineer?		

Traffic Signal Inspection Checklist - Temporary Signal Conformance

Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

D - Signal Operations		Y | N | n/a	Comments
D1.	Are signal controller phasing and all controller parameters according to contract documents?		
D2.	Is the wireless communication between all units operating appropriately?		
D3.	If interfacing with an existing controller cabinet, has a temporary interface panel been installed or a temporary hardwire connection in place?		
D4.	Are phase split times, offsets & cycle lengths according to contract documents?		
D5.	Are all signal faces illuminated properly (no burn-outs)?		
D6.	Do all signal faces operate according to assigned phases?		
D7.	Do all walk/don't walk and countdown indications cycle properly after activation?		

E - Detection		Y | N | n/a	Comments
E1.	Do vehicle detectors get activated by vehicles in lane? (Video zones or radar, vehicle must be used to activate each detector)?		
E2.	Do pedestrian pushbuttons operate properly and match assigned signal phase (buttons shall be pushed for testing)?		

F - Markings & Signs (Signal related only)		Y | N | n/a	Comments
F1.	Have all signs been installed according to signal contract documents?		
F2.	Are all sign sizes and text according to signal contract documents?		
F3.	Are mounting heights of signs according to contract documents?		
F4.	Have all pavement markings (crosswalks, stop lines, dotted lines for dual turns & symbols, etc.) been installed according to contract documents?		
F5.	Are signal head distances to stop line according to contract documents?		

Traffic Signal Inspection Checklist - Temporary Signal Conformance

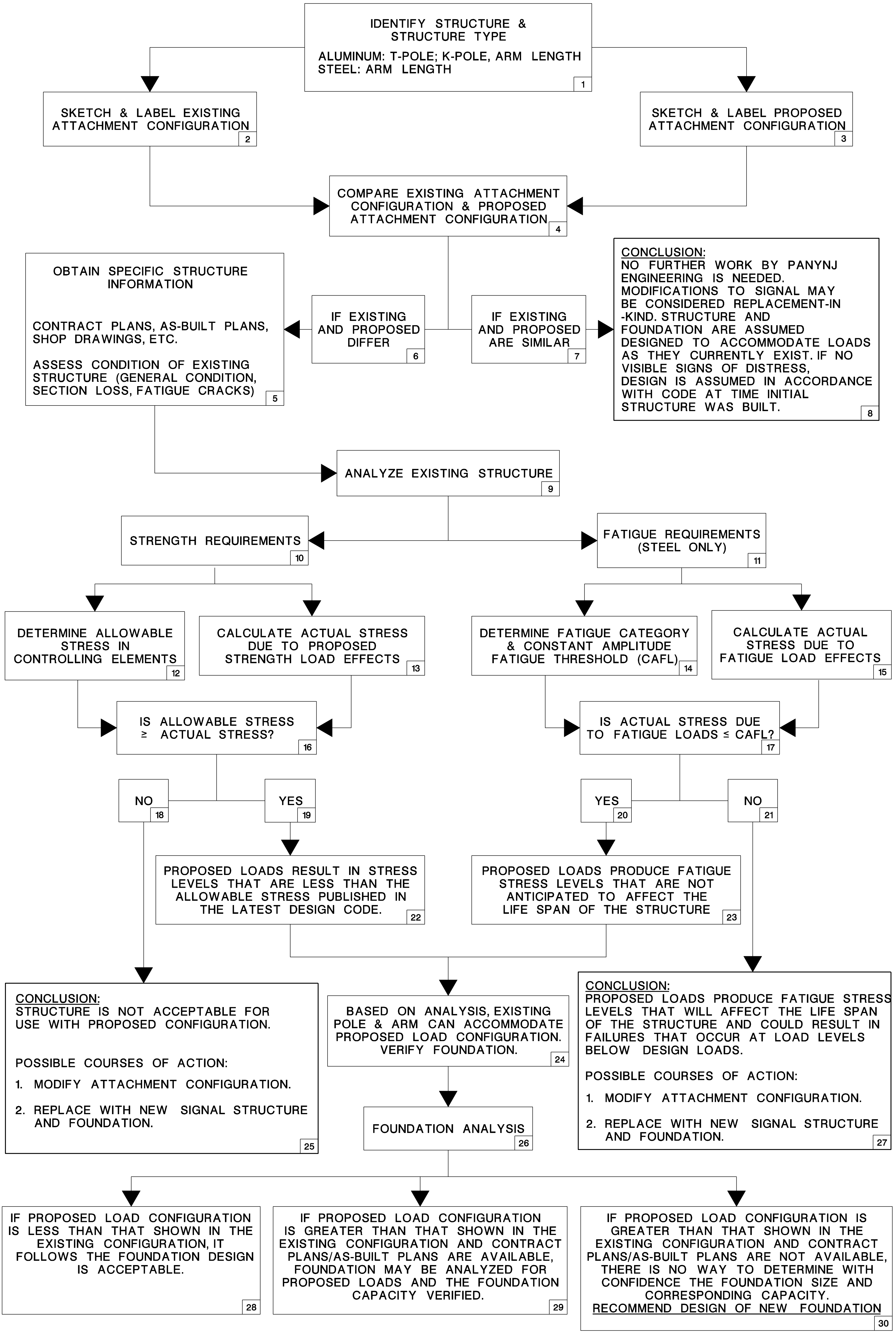
Engineering Department

Facility:	**Contract Number:**
Intersection:	
Signalized Intersection Number:	

Comments

Appendix G – Procedure for the Re-Use of Existing Signal Pole Structures Memo and Flowchart

PA NY&NJ PROCEDURE FOR RE-USING EXISTING TRAFFIC SIGNAL STRUCTURES



Procedure for Re-Use of Existing Signal Pole Structures
Port Authority of New York and New Jersey

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1. The Port Authority of New York & New Jersey (PANYNJ) shall identify the existing traffic signal pole structure to be modified.
2. PANYNJ shall identify the existing attachment configuration.
3. PANYNJ shall determine the proposed attachment configuration including the number, orientation/direction and location of:
    a. Fixed Signal Heads with or without backplates
    b. Free Swinging Signal Heads with or without backplates
    c. Signs
    d. Any significant changes to the existing attachment configuration that alters the load effects of the structure
4. If the proposed configuration matches the existing configuration (i.e. work such as routine maintenance, attachment replacement-in-kind, etc.) no further action from PANYNJ Engineering is required.
5. If the proposed configuration is different from the existing configuration:
    a. Where available, obtain contract plans, as-built plans, and shop drawings for the signal pole structure in question.
    b. Obtain specific information about the signal pole structure elements in question:
        i. Material
        ii. Dimensions & Section Properties
        iii. Age (Code/Criteria to which it was designed)
        iv. If existing documentation is not available or is incomplete, complete an In-Depth Inspection of the signal structure
            1. Inspection findings shall be certified by a licensed engineer
            2. Record measurements/locations of all structure elements including:
                a. Foundation size
                b. Anchor bolt diameter, bolt pattern and projection out of the foundation
                c. Base plate dimensions, thickness, height above foundation
                d. Pole diameter, pole wall thickness, arm diameter, arm wall thickness, opening sizes and locations
                e. Orientation of arm(s)
                f. Connection details
                g. Location and magnitude of section loss or damage
                h. Overall structure condition
                i. Any differences between as-inspected structure and as-built structure (if plans are available)
            3. Determine presence of fatigue cracks
                a. Use non-destructive testing techniques to identify and quantify cracks in the base and weld metal in and around connections and/or locations where high stress ranges exist
                b. Note fatigue cracking can reduce section properties and ultimately lead to failure at reduced load levels
            4. Evaluate inspection reports when available
    c. The existing foundation depth, the type and anchorage depth of the anchor bolts are not visible and thus cannot be verified in the field. As such, the structural capacity cannot be determined.

6. Use the information gathered and apply the latest/prevailing AASHTO Code to analyze the effects of the proposed loads acting on the structure
    a. Determine the capacity of the controlling element
        i. Determine the allowable stress based on the service load combination analyzed
        ii. Determine the allowable fatigue stress threshold
    b. Determine the stress in the controlling element
        i. Calculate section properties for the controlling element
        ii. Calculate load effects for the controlling element
        iii. Calculate stress in the controlling element
    c. Compare the actual stress to the allowable stress for both Service and Fatigue Combinations
7. IF the analysis does not permit installation of the proposed signal head configuration, provide documentation and a recommendation to strengthen the existing signal structure or replace the signal structure with a new structure
    a. Include Service Load Analysis and Fatigue Load Analysis
    b. Identify the elements where the proposed loads cause stress levels greater than allowable levels
    c. Provide recommendations and costs associated with strengthening existing signal structure and compare with costs for replacement

Appendix H – Installation and Approval of Traffic Signals spreadsheet

Installation and Approval of Traffic Signals

Steps	Installation Process												
1	Project Kick-off meeting	Varies											
2	Follow-up meeting with RE's office and Signal Contractor. Traffic Engineering to discuss installation and approval process		Varies										
3	Shop drawing approval			Varies									
4	Signal Installation				Varies								

Steps	Approval Process												
1	Notification Prior to Pre-final inspection					2 wks		1 day					
2	Pre-final Inspection												
3	Completion of punch list items from Pre-final inspection							2 wks					
4	Notification Prior to Final Inspection								2 wks		1 day		
5	Final Inspection												
6	Complete punch list items from Final Inspection										2 wks		
7	Signal Operation Test Period*											30 days	
8	Completion of Asset Commissioning form												1 wk
9	Assume Maintenance and Operations Responsibilities												

*Note: Prior to initiating the 30 day test period, the signal shall operate in flashing mode for a minimum of one week for new traffic signal installations

APPENDIX F

PA DIVISION 1 MAINTENANCE OF TRAFFIC SPECIFICATION

1. MAINTENANCE OF TRAFFIC AND WORK AREA PROTECTION

A. Definitions

As used in this numbered Section, and this Section only, the terms used herein shall have the following meaning:

1.) The terms "Traffic Lane", "Lane", "Active Roadway", "Street" and "Roadway" shall mean, in addition to the normally traveled pavement areas, other areas including but not limited to ramp terminal gore areas, roadway shoulders and all other areas that may foreseeably be occupied by moving vehicles.

2.) "Flashing Arrow Sign Unit" (FASU) shall mean an engine/generator-, solar- or battery-powered flashing light sign with lights displayed in the shape of an arrow.

3.) "Variable Message Sign Unit" (VMSU) shall mean an engine/generator-, solar- or battery-powered variable text sign using a matrix composed of light-emitting diode (LED).

4.) "Slow-Moving Vehicles" shall mean vehicles or equipment that travel at or under a speed corresponding to 15 mph less than the posted speed limit.

5.) "Work Area" shall mean the area immediately surrounding the Work in progress, typically where workers are afoot, and/or the space within a Roadway where Work on the Roadway is being performed by the Contractor.

B. General Requirements

Conform to requirements of this numbered Section, the Contract Drawings and the following:

1.) Portions of the latest editions, including all amendments thereto, of the Federal Highway Administration (FHWA): "Manual on Uniform Traffic Control Devices" (MUTCD) Part VI as hereinafter specified and applicable portions of the companion "Traffic Control Devices Handbook" (TCDH); "Standard Highway Signs"; and "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects".

2.) The latest edition of the American Association of State Highway and Transportation Officials (AASHTO): "Roadside Design Guide", Chapter 9: "Traffic Barriers, Traffic Control Devices, and Other Safety Features for Work Zones"; and "Standard Specifications for Highway Bridges", as hereinafter specified.

3.) The requirements of the Americans with Disabilities Act (ADA) laws in all respects as specified in the "2010 Standards for Accessible Design".

4.) FHWA's "Portable Changeable Message Signs Handbook" (PCMS).

5.) Maintenance of traffic and Work Area protection features specified herein and as shown on Contract Drawings and/or sketches to be furnished to the Contractor.

6.) In the event of a technical conflict between a requirement in the publications referenced herein and the Specifications and Contract Drawings, the requirements of the Specifications and Contract Drawings shall control.

7.) There may be more than one Work Area within the confines of a closed Roadway or Traffic Lane. Each Work Area shall be individually protected as specified herein.

8.) There may be other ongoing construction contracts within the vicinity of the Work Area. The Contractor shall not move, modify or relocate any item associated with these other contracts without prior approval of and coordination with the Engineer.

9.) Perform Work in such a manner and sequence as to interfere as little as possible with the passage of vehicles, pedestrians and other kinds of public traffic.

10.) All existing roadway items such as guiderail, pavement markings, curbs, signals and signs damaged by the Contractor shall be restored by him to the satisfaction of the Engineer at no additional cost to the Authority.

C. Contractor-Furnished Materials and Equipment

1.) Provide and maintain in good working order all materials, equipment, temporary construction signs and facilities required for proper maintenance of traffic and Work Area protection, as specified herein and/or shown on the Contract Drawings. All said equipment/devices shall remain the property of the Contractor, unless otherwise shown on the Contract Drawings.

2.) All traffic control devices shall be properly installed prior to the commencement of the work to which they apply, and shall be properly maintained by the Contractor thereafter. The devices shall remain in place as long as the conditions or restrictions to which they apply exist. Traffic control devices not applicable to existing conditions and restrictions shall be removed or covered over. Where roadway operations are implemented in stages, only those devices that apply to existing conditions and restrictions shall be in place.

3.) All items provided under paragraph C.1 shall be new or undamaged previously used materials in serviceable condition conforming to requirements specified herein.

4.) Provide and maintain in serviceable condition the following, where shown on the Contract Drawings:

a. Portable Changeable Message Signs

(i) Trailer Mounted Flashing Arrow Sign Unit (FASU).

(ii) Trailer Mounted Variable Message Sign Unit (VMSU).

b. Channelizing Devices

(i) Cones.

(ii) Drums.

(iii) Type I, II and III Barricades.

(iv) Traffic Guide or Channelizing Posts.

c. Vehicle-strong Barriers

(i) Precast Concrete Barrier: Conform to the Contract Drawings.

(ii) Water-filled Barrier: Conform to Specification Section 347121 "Temporary Water Filled Barrier" and Test Level 2 as per National Cooperative Highway Research Program (NCHRP). Water-filled barriers shall not be used where the posted speed limit exceeds 45 MPH.

d. Temporary Signs: Conform to requirements of Specification Section 347130 "Plywood Sign Panels and Wood Sign Posts" (ASTM Type IX, unless otherwise shown on the Contract Drawings) and/or Specification Section 101423 "Aluminum Sign Panels and Supports" hereof.

e. Temporary Sign Supports: All temporary maintenance of traffic and Work Area protection sign supports and mountings shall be constructed to hold the signs in their proper position and to resist swaying in the wind.

(i) Wooden Sign Supports: Wood conforming to requirements of Specification Section 347130.

(ii) Portable Sign Supports: "Windmaster" as manufactured by Marketing Displays, Inc., Farmington Hills, MI.; or approved equal.

f. Portable impact attenuator.

g. Back-Up Trucks: Nominal actual weight of 15,000 lbs. with nominal 24,000 lbs. gross vehicle weight registration and rear-most wheels situated close to rear of truck body. Standard "ICC" type rear bumpers are not an acceptable substitute for the required rear wheel location. Actual vehicle weight may vary depending on recommendations of the manufacturer of the vehicle-mounted impact attenuator selected. In addition, equip trucks with:

(i) Standard 4-lamp flashing hazard signal lights (parking and tail lights);

(ii) Four-lamp sealed beam rotating yellow warning light providing 35,000 candle power per lamp with an apparent flash rate of 120 flashes per minute. Truck mount such lights 7 to 10 feet above the Roadway and locate so as to be visually unobstructed by any part of truck body, load or equipment;

(iii) Vehicle-Mounted Impact Attenuator: "TMA" units as manufactured by Energy Absorption Systems, Inc., Chicago, IL; or approved equal.

h. Temporary Roadway Plates: Steel plates, sized to cover Roadway excavations with thickness and edge support adequate to accommodate HS-20-44 loading per Section 3.7.6 in the AASHTO "Standard Specifications for Highway Bridges".

i. Temporary Reflectorized Pavement Markings

(i) On Finished Wearing Surfaces: New, unused removable temporary marking tape conforming to the requirements of Specification Section 321728 "Preformed Removable Retro-Reflective Pavement Marking Tape". For removal, see paragraph D.3.d.

(ii) On Roadway Surfaces to be Subsequently Resurfaced or Replaced under This Contract: An approved traffic paint conforming to Specification Section 321725 "Traffic Paint Pavement Markings" with glass beads applied at the rate of 3.0 pounds per 100 linear feet per 4-inch wide line, unless otherwise shown on the Contract Drawings. For removal, see paragraph D.3.d.

5.) Submit the following to the Engineer in accordance with "Shop Drawings, Catalog Cuts and Samples" of Division 01 - GENERAL PROVISIONS:

a. Catalog Cuts and Data Sheets: Complete manufacturer's data for all equipment and materials.

D. General Work Area Protection

1.) Contractor shall designate a supervisory-level employee with requisite onsite experience to act as the Traffic Control Coordinator (TCC). The TCC shall supervise the Traffic Management crew who shall be properly trained, supplied, staffed and equipped to deploy and remove the maintenance of traffic and Work Area protection elements required for each of the Contractor's construction activities, as shown on the Contract Drawings and in paragraph D.3 herein.

2.) Traffic Maintenance crew training shall be specifically developed from this Section. The contents of Contractor's Training programs shall specifically include the Contract Drawings, Traffic Standard Details and all other requirements included on the Contract Drawings.

3.) Prior to commencement of each day's Work, furnish and install where shown on the Contract Drawings, the traffic control delineations, guiding devices, signals, signs and pedestrian protection, roadway plates, barricades and barriers. Periodically inspect, maintain, relocate, replace, cover, remove or reconstruct the devices. Maintain safe control of traffic flow and demarcate areas of Work at all times.

a. Ensure that construction material and equipment not removed from areas of Work during non-working periods are protected in such a manner that they shall not constitute a traffic hazard.

b. Do not park any vehicles other than construction vehicles required for construction operations within the demarcated protected areas of Work.

c. Promptly remove traffic control delineations, guiding devices, signals, signs, pedestrian protection, roadway plates, barricades and barriers, where shown on the Contract Drawings, whenever operations under this Contract no longer require said Work Area protection.

d. Where shown on the Contract Drawings, existing permanent and temporary pavement markings and traffic guides that conflict with markings and traffic guides to be installed shall be concurrently removed prior to placement of new pavement markings and traffic guides as follows:

(i) On wearing surfaces that will be subsequently replaced, resurfaced or abandoned during the Work of this Contract, remove obsolete temporary marking tape and remove or obliterate obsolete thermoplastic or paint markings by grinding, scraping or other means as approved by the Engineer so as to completely obscure all obsolete markings for the duration of the Work.

(ii) On finished wearing surfaces, completely remove temporary marking tape and completely remove obsolete permanent markings by grinding, scraping or other means as approved by the Engineer. Use of blackout paint or other coating material on any finished wearing surface is prohibited.

(iii) Grind or chip off all adhesive residue resulting from removed or relocated traffic guides.

e. Prior to the end of each work period and not less than twice a day on non-work days, the TCC shall visually inspect and maintain all elements of the maintenance of traffic and Work Area protection installations.

4.) Throughout Progress of Work of This Numbered Section

a. Maintain visual and physical accessibility to fire hydrants. Provide 24-hour advance notice to the Engineer in the event of hydrant obstruction.

b. Conduct Work Area protection operations so that Traffic Lane ingress and egress to intersecting Roadways, adjacent structures or property, and bus and taxi stops, where present, can be maintained. Obtain the approval of the Engineer and provide 24-hour advance notice to the Engineer in the event that Work Area protection operations obstruct access to Work Areas.

5.) Placement and Removal of Temporary Signs and Traffic Control Devices

a. Do not locate signs or other traffic delineations, guiding devices and signs in a manner that would: obstruct or interfere with motorists' view of approaching, merging or intersecting traffic; obstruct other permanent signs or route markers; or mislead or misdirect the motorist.

b. Do not place traffic control signs under an overpass or elevated building, or within overpass or building shadow areas, unless otherwise shown on the Contract Drawings.

c. On Roadways passing below an overpass or elevated building, do not begin or end traffic cone or other delineation and guiding devices under or less than 100 feet from an overpass or building. Extend delineation and guiding devices as required to comply with this requirement.

d. The work for installation and removal of temporary traffic control devices shown on the Contract Drawings shall be completed utilizing a moving maintenance and protection of traffic operation having a back-up vehicle with impact attenuator and FASU spaced a short distance from the operation (approximately 50 feet) as approved by the Engineer. Devices shall be installed in the direction of traffic. Devices shall be removed as approved by the Engineer.

6.) Temporary roadway plates, where shown on the Contract Drawings, shall be supported on all edges, and shall maintain the surface condition of the active roadway consistent with the posted speed limit. Where shown on the Contract Drawings, secure plates against displacement by use of suitable steel pins.

a. Secure plate against displacement and bed in well-tamped pre-mixed cold patch material ramped 1:30 at exposed edges, or

b. Cut a recess in the Roadway surface sized to snugly fit the plate and evenly support the plate around its perimeter. Locate the top of the plate flush with or less than one inch below the adjacent Roadway surface. Secure the plate in the recess in a manner approved by the Engineer.

c. Submit construction details of all Roadway plating and pedestrian planking installations for approval by the Engineer before its placement.

7.) Where excavations within pedestrian walkways including Traffic Lane crosswalks will be open to walkway pedestrian traffic prior to completion of construction, provide appropriate pedestrian railings and steel plate, wood plank or plywood covers surfaced with an approved heavy duty non-skid paint coating containing a grit additive. Temporary walkway covers over excavations shall be a minimum of 4-feet wide, designed and constructed to carry a minimum of 150 psf. Railings shall be approximately 3 feet 6 inches above the walkway cover and consist of a 2-inch by 4-inch wood top rail, 1-inch by 4-inch intermediate rail and a toe board 5-1/2 inches high all securely fastened to 2-inch by 4-inch wood posts spaced not more than 8 feet apart. Securely fasten wood walkway covers and posts to wood sleepers spanning excavation trench. Chamfer or asphalt ramp exposed edges and secure against displacement. Where applicable, Contractor's installations shall meet the requirements of the ADA laws in all respects.

8.) Use Vehicle-strong Barriers where the Work Area contains open excavations or when materials and/or equipment are left in the Work Area without the presence of workers, unless otherwise shown on the Contract Drawings. Flare exposed ends of the barriers away from the Active Roadway by extending and terminating the barriers beyond the clear zone, in accordance with AASHTO's "Roadside Design Guide". Where flaring of the barriers beyond the clear zone cannot be achieved, protect the barrier end with Portable Impact Attenuators. Tapered barrier end section shall not be used unless approved by the Engineer.

9.) Each Work Area not protected by Vehicle-strong Barriers shall be protected by a back-up truck when workers are present, unless otherwise shown on the Contract Drawings.

10.) Vehicles used by the Contractor during performance of Work shall be considered as equipment vehicles and when not protected by a Vehicle-strong Barrier, said vehicle shall be protected by a back-up truck, unless otherwise shown on the Contract Drawings.

11.) Construction material and equipment shall not be stored outside the Work Area, without approval by the Engineer.

12.) Slow-Moving Vehicles traveling on a Roadway outside of demarcated protected Work Areas shall be followed (approximately 50 feet behind) by a vehicle displaying the same flashing hazard signal lights and sealed beam rotating yellow warning light as required for back-up trucks.

13.) Traffic lanes and other areas closed by the Contractor shall be cleared of all materials, equipment and debris to the satisfaction of the Engineer, prior to reopening the lanes to traffic.

E. Spare Materials and Equipment

1.) Where shown on the Contract Drawings, initially furnish and subsequently maintain the quantities of spare materials and equipment at the construction site, or at another nearby location approved by the Engineer.

2.) Totally relamp FASU after each single bulb failure.

F. Notwithstanding provisions herein requiring or permitting the Authority to approve or disapprove of any traffic control or delineation and guiding device provided by the Contractor, the Contractor shall ensure the suitability and performance of all such traffic control devices such that inconvenience to the traveling public is held to an absolute minimum.

END OF SECTION