BUS FACILITY MODERNIZATION

Design Guideline for Bus Maintenance Facilities
Second Edition

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Prepared for

Massachusetts Bay Transportation Authority

Prepared by

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ACRONYMS AND ABBREVIATIONS

Acronym	Definition
˚F	degree(s) Fahrenheit
AASHTO	American Association of State Highway and Transportation Officials
AC	alternating current
ADA	Americans with Disabilities Act
AFF	above finished floor
AHJ	Authority Having Jurisdiction
ASTM	ASTM International
ATF	automatic transmission fluid
ATS	automatic transfer switch
BAS	Building Automation System
BEB	battery electric bus
BFMP	Bus Maintenance Facility Modernization Program
BOD	basis of design
CCTV	closed-circuit television
CMR	Code of Massachusetts Regulations
CMS	Charge Management System
CxA	commissioning authority
DC	direct current
DEF	diesel exhaust fluid
DOER	Massachusetts Department of Energy Resources
EA	Environmental Assessment
EC	engine coolant
EC1	engine coolant type 1
EC2	engine coolant type 2
EJ	environmental justice
ENF	Environmental Notification Form
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration

Acronym	Definition
GFCI	ground-fault circuit interrupter
GO	gear oil
HVAC	heating, ventilation, and air conditioning
Hz	hertz
IEC	International Electrotechnical Commission
IECC	International Energy Conservation Code
IES	Illuminating Engineering Society
IMC	International Mechanical Code
IP	Internet Protocol
IT	information technology
kW	kilowatt(s)
LAN	local area network
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
MassDEP	Massachusetts Department of Environmental Protection
MassDOT	Massachusetts Department of Transportation
MBTA	Massachusetts Bay Transportation Authority
MEPA	Massachusetts Environmental Policy Act
MERV	minimum-efficiency reporting value
MHz	megahertz
MWRA	Massachusetts Water Resources Authority
NEC	National Electrical Code
NEPA	National Environmental Policy Act of 1969, as amended
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PDG	Project Development Group
PLC	programmable logic controller
psi	pound(s) per square inch
PSIM	Physical Security Information Management
RTU	rooftop unit
S+R Admin	Sustainability and Resilience Administrator
S+R Coordinator	Sustainability and Resilience Coordinator

Acronym	Definition
SCADA	supervisory control and data acquisition
SRMP	Sustainability and Resilience Management Plan
SWAN	security wide area network
TIA	Traffic Impact Analysis
UL	Underwriters Laboratories
UPS	uninterruptable power supply
USDOT	U.S. Department of Transportation
V	volt(s)
VAV	variable air volume
VCT	vinyl composition tile
VoIP	Voice over Internet Protocol
WAN	wide area network
WWF	windshield washer fluid

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1 INTRODUCTION

The Massachusetts Bay Transportation Authority (MBTA) prepared this Design Guideline for the MBTA Bus Facility Modernization Program. Informed by MBTA and industry best practices, the document provides a reference to future designers for baseline requirements, standards, and preferences of MBTA.

This second edition of the Design Guideline outlines design criteria for running repair or preventive maintenance facilities that provide daily bus service and maintenance operations. These facilities consist of maintenance, daily service, storage, transportation, and administrative spaces, each with specific functional and operational requirements that will be reflected in the facility design. The Design Guideline pertains to both new construction and major rehabilitation projects.

1.1 Organization

The information presented in the remainder of this document has been arranged into the following three sections.

1.1.1 Section 2, Design Principles and Processes

This section provides an overview of the desired design outcomes for bus maintenance facilities and outlines the requirements, permits, and processes that are specific to the MBTA as follows:

Section 2.1, Design Outcomes — The section describes the desired design outcome to support new MBTA battery electric bus (BEB) facilities. Workflow diagrams visualize typical or primary vehicle and people movements and processes between and within functional areas of MBTA bus maintenance facilities to provide context of bus operations for the future designer. This section also describes MBTA's approach to holistically address sustainability and resiliency to support the Commonwealth's decarbonization targets, ensure worker well-being, and demonstrate adaptability in the face of present and future disruptors.

Section 2.2, Design Process Requirements—This section reviews the local, state, and federal requirements applicable to the MBTA as well as MBTA-specific processes required of the designer. It is the responsibility of the designer to validate all codes and standards referenced herein to ensure the latest version in force and effect is used to develop the facility design.

1.1.2 Section 3, Site and Building Requirements

This section outlines overall engineering requirements and preferences for the fully enclosed structural building and site of the facility. The design disciplines included in this section are civil and landscaping, architectural, structural, mechanical, electrical, plumbing, fire protection, communications and security systems and industrial equipment. Section 3 describes the baseline requirements for each discipline, as well as relevant sustainability and resilience requirements and goals, which are described in more detail in **Appendix A**.

1.1.3 Section 4, Area Modules

This section provides specific design criteria for the facility's functional areas: maintenance, storage, transportation, and administration. Key rooms and spaces within each functional area are described in detail on "room cards," which include associated layout, square footage, interior finish, and engineering requirements. A Facility Program Matrix (**Table 4.1-1**) summarizes bus fleet- and staff-based square footage requirements. Example room plans and equipment included in each room card are provided for visual representation only and do not dictate required layouts unless specified. Room layout and associated equipment requirements will be verified with MBTA unless specifically indicated on the room card. **Appendix B** provides supplemental information on maintenance lift equipment to aid in the design process.

1.1.4 Appendices

Appendix A – Sustainability and Resilience

Appendix B – Maintenance Lift Supplement

2 DESIGN PRINCIPLES AND PROCESSES

This chapter offers an overview of design at MBTA, including both the desired design outcomes for bus maintenance facilities and processes that may be new to designers engaged in the program. **Section 2.1, Design Outcomes**, describes the high-level purpose of the bus electrification transition, specifically electrifying the entire fleet while enhancing the working environment for the MBTA workforce. **Section 2.2, Design Process Requirements**, outlines the requirements, permits, and processes that are specific to the MBTA.

2.1 Design Outcomes

The following section describes the desired outcomes for the design of the new bus maintenance facilities. This section is intended to be an overview and a helpful reference for any designers involved in the program. Additional detail and specific guidance are provided in **Section 3, Site and Building Requirements,** and **Section 4, Area Modules**.

The MBTA aims to transition to an entirely BEB fleet by 2040, and the purpose of the Bus Maintenance Facility Program is to build new facilities that can accommodate this fleet while creating a better working environment. Current bus maintenance facilities are outdated and limit workplace efficiency, and many are in poor condition. The current bus fleet is comprised of both 40- and 60-foot buses that use a mix of propulsion types including diesel, diesel hybrid, compressed natural gas, and BEBs. MBTA aims to transition to an entirely BEB fleet in accordance with the schedule on **Figure 2.1-1**.

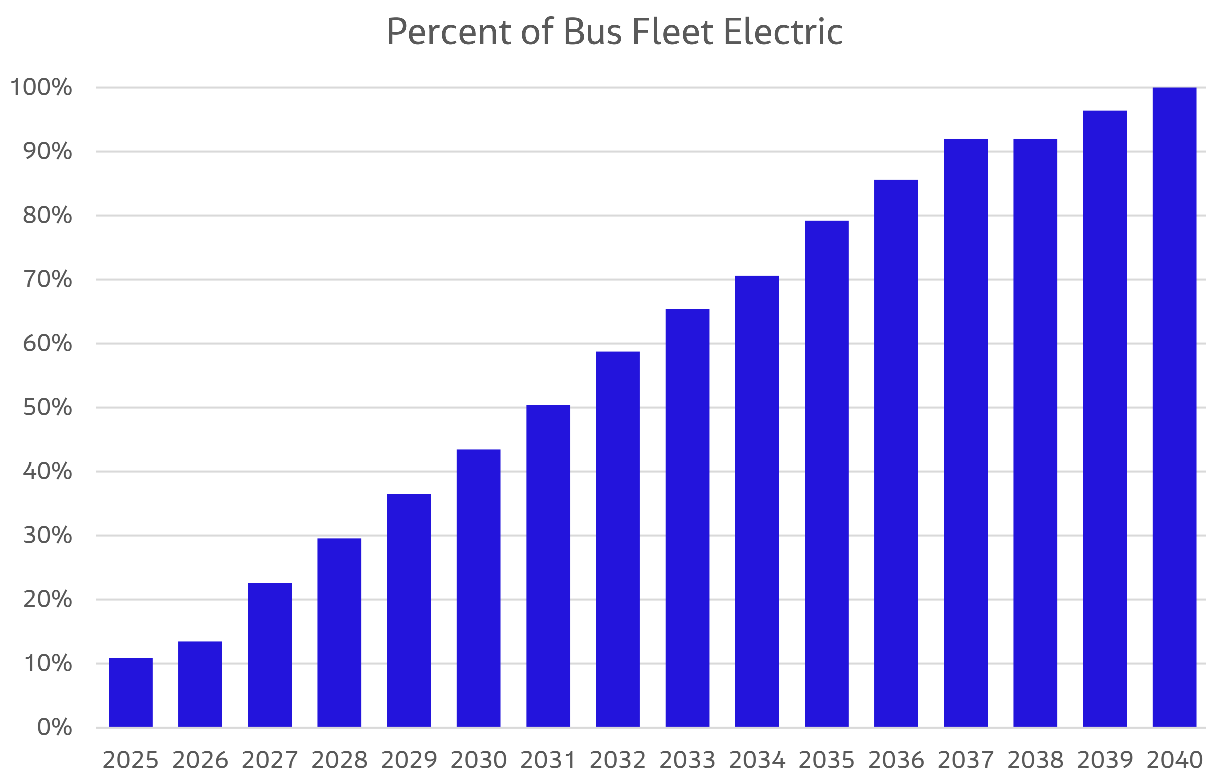


Figure 2.1-1. Fleet Transition to Battery Electric Buses

2.1.1 Facility Layout: Accommodating Workflow

Land efficiency should be maximized whenever possible, including consideration for multi-level alternatives where space is constrained. All facilities should be safe, high-quality environments that promote workforce health and well-being as well as safe and efficient bus movement. Facility layout should accommodate all indoor operations and efficient movements for buses traveling counterclockwise with single movement turns. Layout should accommodate a mix of 40-foot and 60-foot buses (except for the Quincy and Lynn facilities) and must not require reverse movement for 60-foot buses. Please contact the MBTA for a bus size template that can be used in AutoTURN to analyze space requirements.

The design team should consider the most economical option to provide employee parking, given site constraints. The program brief for each facility includes the required number of employee parking spaces when applicable. Employee parking can be accommodated with surface parking or structured parking, or offsite with written agreement from the MBTA. For additional guidance and detail on the deviation process, refer to **Section 2.2.2.6, Deviations**.

2.1.1.1 Facility Layout: Workflow Graphics

The three workflow diagrams (**Figures 2.1-2** through **2.1-4**) visualize the primary people and vehicle movements and activities (arrows color coded according to corresponding legend) that occur within and around the building onsite for the following groups:

- Transportation staff (bus operators and inspectors)
- Maintenance staff (forepersons and machinists)
- Buses

These diagrams represent baseline or typical workflows and do not capture infrequent activities, such as a bus being towed into the maintenance area. The workflow diagrams also do not dictate site or building layout. Space adjacency diagrams in **Section 4, Area Modules,** indicate spatial relationships and connections between the areas included in the workflow diagrams. The designer will validate the design with MBTA to ensure provisions for all required activities are incorporated.

2.1.1.2 Transportation Workflow Diagram

Figure 2.1-2 illustrates the current workflow in MBTA transportation. The top priority in this area is to reduce or eliminate bus-pedestrian conflicts to ensure employee safety. The pull-out inspector must be located near the location where buses leave the facility. Other work areas should be proximate to bus storage. However, specific arrangements can vary. Facility design should allow for some flexibility to accommodate potential changes in workflow over time as MBTA processes can change to adapt to new technologies and needs of customers and workforce.

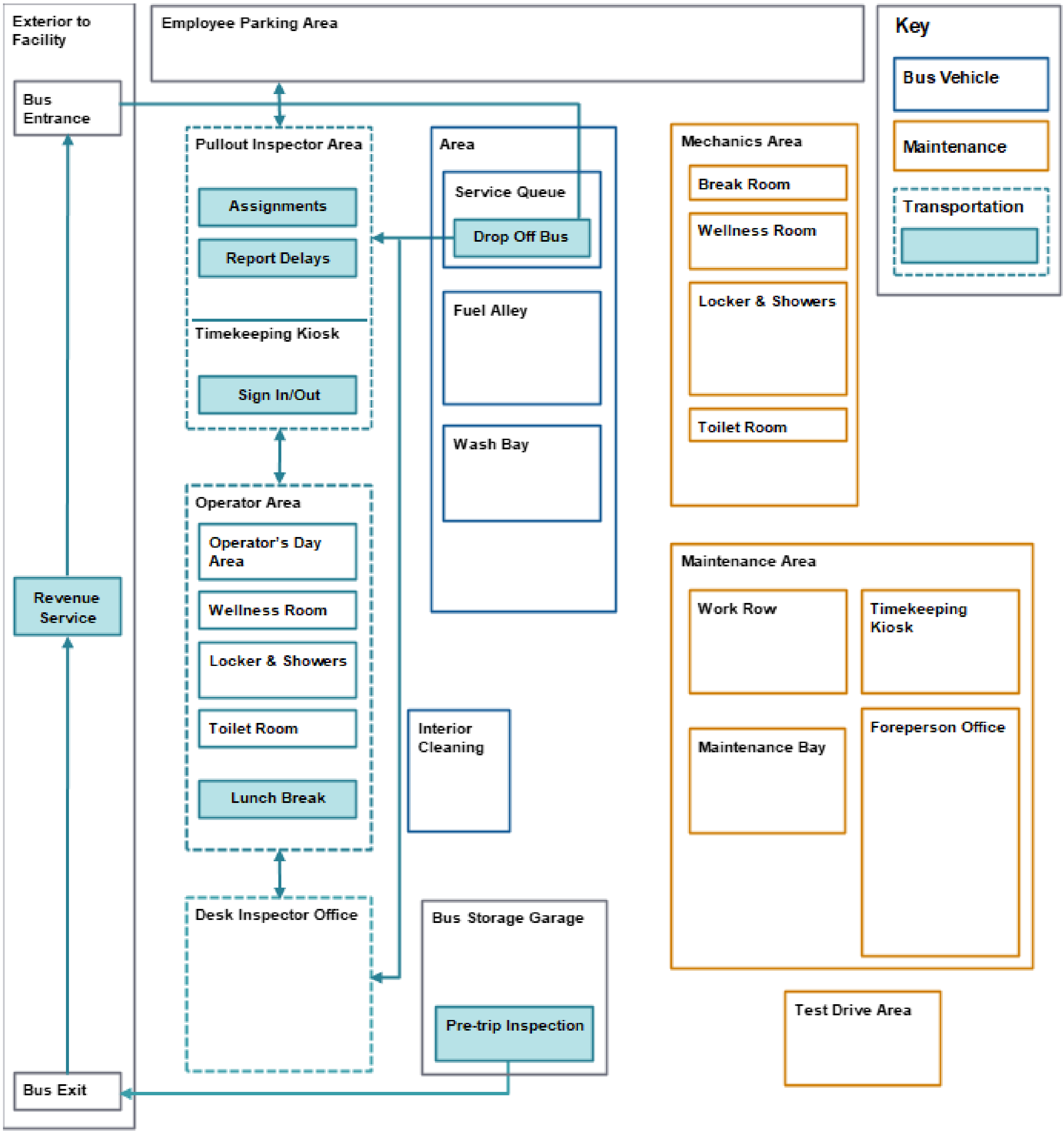


Figure 2.1-2. Transportation Workflow Diagram

Maintenance Workflow Diagram

The maintenance workflow diagram (**Figure 2.1-3**) illustrates typical movements within the facility of maintenance employees, including forepersons and mechanics. It is essential that this area has sufficient space for parts storage in an area easily accessible to technicians. Tool storage and regions to accommodate support shops are also priorities. Part storage, tool storage and support shops should all be on the ground floor and near the maintenance bays. In addition, the maintenance bay aisle should be clearly visible from the foreperson office. Facility design should allow for some flexibility to accommodate potential changes in workflow over time as MBTA processes change to adapt to new technologies and needs of customers and workforce.

Figure 2.1-3 depicts the current situation, with employees moving from employee parking into the mechanic's area, a central area for staff with break room, lockers, toilets, and changing area with showers and uniform storage. Staff move from the mechanic's area into the maintenance area, which includes the forepersons' offices, timekeeping, and bays (work rows) where buses await and undergo maintenance by mechanics. Work rows can be located outside of the maintenance area. Maintenance staff may move buses from the maintenance area to the bus storage or interior cleaning areas, then return by foot to the maintenance area or mechanic's area.

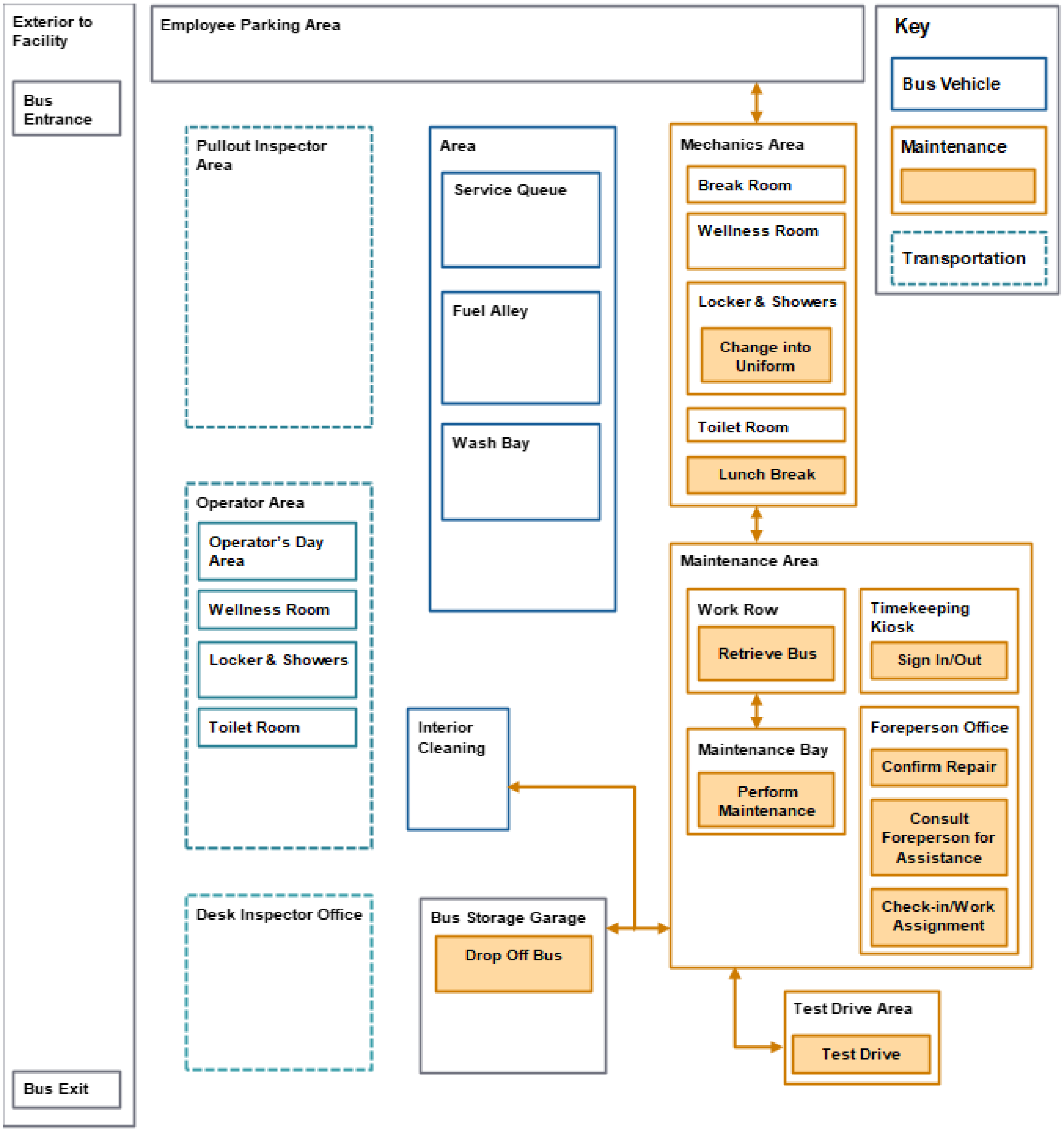


Figure 2.1-3. Maintenance Workflow Diagram

2.1.1.3 Bus Vehicle and Fueler Workflow Diagram

The bus vehicle and fueler workflow diagram (**Figure 2.1-4**) illustrates typical movements that a bus would make around and within the facility and the movements of the fuelers, staff members who perform basic maintenance and cleaning each evening after the buses return to the facility. The priority for the design of this area of the facility is to reduce conflicting movements to ensure safety and reduce or eliminate counterclockwise movement as much as possible.

Currently, when a bus returns from service either at the end of a shift or mid-shift, an operator typically leaves it in the service queue for fueling and washing or bypasses both to directly enter the storage area. The fueler will move the buses through fueling and wash and park the bus in storage. If the bus requires maintenance, a machinist will move into a work row. The mechanic may test drive the vehicle around the site to validate repairs or return the bus to the bus storage or interior cleaning area after maintenance is complete. At the start of the next shift, the operator would take the bus and exit the storage area to proceed to their assigned service route.

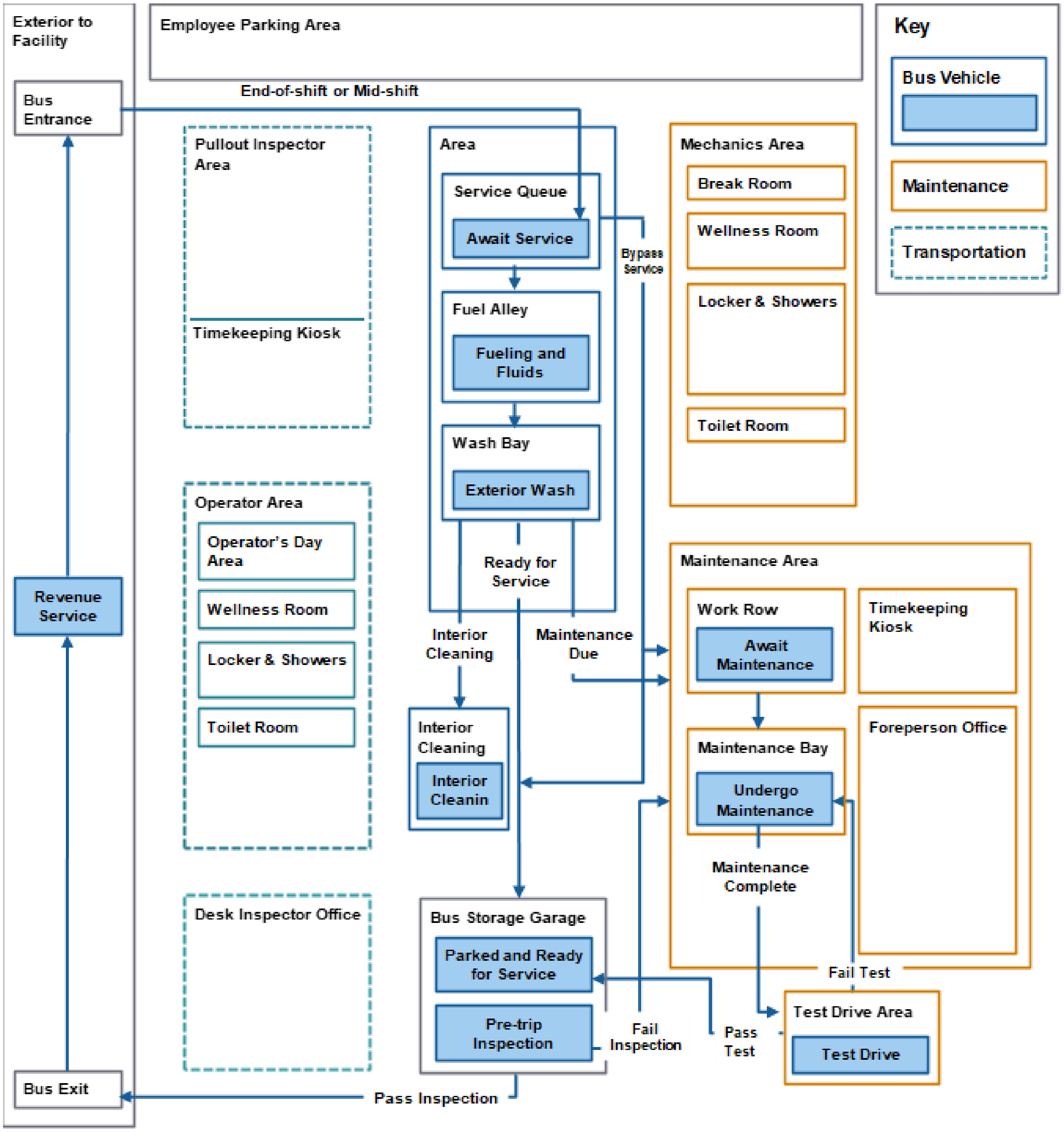


Figure 2.1-4. Bus Vehicle and Fueler Workflow Diagram

2.1.2 Facility Electrification

The facility must meet the following minimum requirements:

- Each facility must include capacity to charge the buses needed for service to a full state of charge (SOC) (95%) based on operational modeling and bus schedules, which will be provided by MBTA.
- The facilities should include pantograph dispensers in the bus storage area and plug-in dispensers in maintenance bays. Each parking location in the bus storage area should have a pantograph.
- The facilities should accommodate a fueling bay to support fueling a diesel auxiliary heater to be used in cold weather, with at least 1 fueling bay per 100 buses, or a minimum of 2 per facility.
- The maintenance bay and bus storage area should be ventilated per building code to accommodate diesel-powered vehicles such as tow trucks.
- Each facility must accommodate isolated space outdoors for the storage of a damaged vehicle, which must be a minimum of 50 feet from any structures.
- Each facility should include storage space for spare large capacity batteries (number to be determined for each facility by the MBTA).
- Chargers, substations, and other critical components will be either elevated above the main level or located in a space physically protected from bus movements, in compliance with the MBTA Flood Resiliency Design Directive for critical assets.

The designer is encouraged to propose appropriate alternatives for MBTA approval as charging technology changes over time. Alternative approaches must meet MBTA operational requirements and will be chosen at the discretion of the MBTA. Refer to the deviation process outlined in **Section 2.2.2.6, Deviations**. The current approach for charging is as follows:

- Use a 3:1 ratio of pantographs to chargers in the bus storage area with chargers of 150 kilowatts (kW) or greater
- Identify select locations for high-capacity (360-kW) chargers on the ground floor of a building (if multi-level storage).
  - Possible locations for high-capacity 360-kW chargers include fueling bay, pass-through lane, head of storage row, work row, or in maintenance bay

2.1.3 Facility Sustainability and Resilience

MBTA bus maintenance facility designs will holistically address sustainability and resiliency to support the Commonwealth's decarbonization targets, ensure worker well-being, and demonstrate adaptability in the face of present and future disruptors. **Figure 2.1-5** shows the functional overlap of Project sustainability and resilience.

In line with the Commonwealth's 2050 Decarbonization Roadmap, the new bus maintenance facilities will eliminate the use of fossil fuels and incorporate high performance building strategies to the extent practicable. Sustainability must be a priority when making decisions about the design of facility systems. In addition, the design team will incorporate passive strategies in the building design to optimize the mechanical and electrical building loads as much as feasible, within the context of this building type. Reducing water consumption and waste generation are also priorities. Finally, the design will protect the site environment and surrounding community with improvements where feasible.
To meet these sustainability goals, the MBTA incorporates industry best practiced, including pursuit of Leadership in Energy and Environmental Design (LEED) certification. A minimum of LEED Silver is required per Leading by Example (refer to **Section 2.2.1.3, Leading by Example**); the MBTA targets LEED Gold certification for all new facilities, and this Design Guideline highlights the Credits required (remaining Credits to meet Gold will be determined by the design team).

The design team will also address regional resilience threats by considering current and future climate trends, such as sea-level rise, increasing intensity of precipitation and flooding, stronger coastal storms, and extreme temperatures. The increasing frequency of storms and natural disasters such as severe winter weather, high winds, and extended heat waves will be considered in the design and operational plan for the facility. For many weather-related disruptors, the loss of power, potable water, and other utilities that can follow an extreme event are generally more challenging than the weather event itself.

Section 3 covers the sustainability and resiliency requirements, including the required LEED Credits, for each discipline; **Appendix A** provides additional detail.

SUSTAINABILITY

- Anticipates impacts of the project site on the community, natural resources, and MBTA staff
- Manages resources responsibly to avoid negative impacts to people, natural resources, and economy

RESILIENCE

- Anticipates impacts of future conditions on project operations and MBTA staff
- Adapts to future climate conditions
- Maintains functionality

BOTH

- Long-term vision and adaptability
- Manages uncertainty
- Considers impact on people and promotes equity
- Wholistic integrated multi-discipline design
- Balances economic, environmental, and social priorities, better long-term functional performance than short-sighted capital cost cutting
- Considers redundancy in both infrastructure and operations

Figure 2.1-5. Sustainability and Resilience Overlap

2.2 Design Process Requirements

The following section describes specific processes that are specific to the MBTA and may be unfamiliar to designers joining the Bus Maintenance Facility Modernization Program (BFMP). It is the responsibility of the designer to validate the codes and standards referenced within this Design Guideline to ensure the latest version in force and effect is used to develop the facility design. If there are discrepancies in codes, standards, or directives, the designer will identify the discrepancy and allow MBTA to review for approval (in general, the stricter requirement will apply). These processes are intended to support the outcomes described in **Section 2.1, Design Outcomes**.

2.2.1 Local, State, and Federal Requirements Applicable to the MBTA

2.2.1.1 Building Codes and Building and Other Permits

All building elements should be designed to meet the requirements outlined in the current edition of the Massachusetts State Building Code, as codified in 780 Code of Massachusetts Regulations (CMR), which must be reviewed by designers before beginning work on the BFMP. This code applies to construction, reconstruction, alteration, repair, demolition, removal, inspection, issuance/revocation of permits/licenses, installation of equipment and/or classification/definition of any building or structure and its use or occupancy.

The State Inspector of the Division of Professional Licensure, Office of Public Safety and Inspection enforces 780 CMR for all buildings and structures owned by the Commonwealth or any departments, commissions, agencies, or authorities of the Commonwealth, such as MBTA. The process is described in detail in 780 CMR. For permits that include fire protection systems under 780 CMR 4.00, 9.00 or 34.00, construction documents will be filed with the building official who will cause them to be filed with the head of the local fire department for review. This process may apply to BFMP facilities as described in 780 CMR. The designer will support MBTA in coordinating with the building official and/or local fire department during preliminary design to identify potential design questions and/or preferred design solutions.

2.2.1.2 Environmental Review – Massachusetts Environmental Policy Act

Massachusetts Environmental Policy Act (MEPA) regulations are codified in 301 CMR 11.00 and implemented under the authority of the Massachusetts Environmental Policy Act Office. Environmental review for MEPA typically occurs during the preliminary design phase of a project (15% design). A bus maintenance facility size, location, and environmental resources in the Project Area determine the MEPA processes in terms of documentation requirements, timeframes, and Project critical path. MEPA review thresholds identify categories of projects that are likely, directly or indirectly, to cause damage to the natural and/or human environment. The level of environmental review for MEPA will be determined through early coordination with the Massachusetts Environmental Policy Act Office.

MEPA review is required when one or more review thresholds are met or exceeded and the subject matter of at least one review threshold is within MEPA jurisdiction. A review threshold that is met or exceeded specifies whether MEPA review will consist of an Environmental Notification Form (ENF) and a mandatory Environmental Impact Report or of an ENF and other MEPA review if the Secretary so requires.

The design team will follow the MBTA Environmental Regulations Design Directive for documentation and incorporation of environmental review into the design process.

2.2.1.3 Leading by Example

The MBTA follows Massachusetts Executive Order No. 594: Leading by Example, which is described and summarized by the Massachusetts Department of Energy Resources at the Leading by Example website. The Leading by Example Executive Order requires that all new construction and major renovations of buildings over 20,000 square feet for use by state agencies must be certified to the Silver Level or higher of the most recent version of the U.S. Green Building Council’s LEED Standard. In addition, building renovations where electrical or heating, ventilation, and air conditioning (HVAC) infrastructure are included in the Project scope, must include as a design option an alternative to fossil fuels for thermal energy. The full text of the Executive Order and guidance can be found at the Massachusetts Department of Energy Resources Leading by Example website.

2.2.1.4 Massachusetts Department of Energy Resources Stretch Code

Massachusetts updates its building code every 3 years to be consistent with the most recent version of the International Energy Conservation Code (IECC). The Stretch Code is an above-code appendix to the "base" building energy code that emphasizes energy performance, as opposed to prescriptive requirements, and is designed to result in cost-effective construction that is more energy efficient than that built to the "base" energy code. The Stretch Energy Code regulations have been published in MA 780CMR chapters 115.aa and previously 780 CMR 110.aa under the jurisdiction of the Board of Building Regulations and Standards; however, the Climate Act of 2021 moved the authority to the Massachusetts Department of Energy Resources (DOER). This Act also required that a Specialized Code be developed to ensure new construction is consistent with Massachusetts greenhouse gas limits. The updated Stretch Code is divided into two chapters, following the format of the IECC and appear as new regulations in 225 CMR 22.00 (residential) and 225 CMR 23.00 (commercial and other). At the writing of this document, regulatory language was still in draft form; refer to DOER Building Energy Code for current information.

2.2.1.5 Utility Coordination

MBTA will work collaboratively with the local power utilities to determine equipment upgrades needed, specified rate structures, secondary power sources, potential site-generated power returns, and a programmed schedule for accommodation. Coordination will be required before 15% design is finalized. The utility may need to install or upgrade substations, install new circuits and transformers, run new transmission lines, and develop a new cost schedule specific to charging the buses. Discussions with the utility about review of existing feeders, dedicated feeders, and/or power factor correction equipment will occur in the early stages of the Project design. To give the utility time to design the service, conduct a survey, and complete construction, they will need to know how much power will be required early in the process. However, determining connected and peak load may be a challenge at early stages of design. Therefore, working collaboratively with the utility starting at concept stage and throughout the process is imperative. Refer to **Section 3.5, Electrical,** and **Section 3.1, Civil and Landscaping,** for additional guidance and information.

2.2.1.6 Environmental Review - National Environmental Policy Act

The National Environmental Policy Act of 1969, as amended (NEPA) requires federal agencies, and thereby all federal actions to incorporate environmental considerations into their planning and decision-making through a systematic interdisciplinary approach. NEPA is normally conducted during preliminary design (when the footprint and major components of the project are defined). The Federal Transit Administration (FTA), Federal Highway administration (FHWA), and Federal Railroad Administration have issued joint regulations implementing NEPA in 23 CFR part 771. An “action” is defined as a highway, transit, or railroad project proposed for federal funding. It also can include activities such as joint and multiple use permits, changes in access control, or rulemakings, which may or may not involve a commitment of federal funds. All BFMP projects will be required to complete NEPA.

The class of action for MBTA’s bus maintenance facilities will be determined through early coordination with the Planning & Program Development department at FTA’s Region 1 office. There are three classes of actions that prescribe the level of documentation required in the NEPA process: (1) Environmental Impact Statements are required for actions that significantly affect the environment, (2) Categorical Exclusions are required if the proposed action does not individually or cumulatively have a significant environmental effect, and (3) Environmental Assessments (EAs) are prepared for actions for which the FTA has not clearly established the significance of the environmental impact.

The design team will follow the MBTA Environmental Regulations Design Directive for documentation and incorporation of environmental review into the design process.

2.2.1.7 Title VI and Environmental Justice

As a recipient of federal funds, MBTA is subject to the statutory obligation under Title VI of the Civil Rights Act (Title VI) to ensure nondiscrimination and the administrative directive under Executive Order 12898 to address disproportionate adverse impacts of activities on minority and low-income populations (environmental justice [EJ]).

Title VI

Title VI prohibits discrimination by recipients of federal financial assistance on the basis of race, color, and national origin, including the denial of meaningful access for limited English proficient persons. Under the U.S. Department of Transportation's (USDOT's) Title VI regulations, recipients of federal financial assistance are prohibited from, among other things, using "criteria or methods of administering its program which have the effect of subjecting individuals to discrimination."

In order to comply with Title VI MBTA is required to prepare a Title VI Program, which documents how the agency complies with the notification, documentation, reporting and public outreach requirements. MBTA is also required to prepare an equity analysis before making changes to service, fare and/or when determining the site or location of a facility.

A Title VI equity analysis for a bus maintenance facility is conducted during the planning stage (pre-design) to ensure the facility location is selected without regard to race, color, or national origin (refer to FTA's Title VI Circular 4702.1B).

Environmental Justice

An EJ analysis must be conducted as part of NEPA decision-making, regardless of the class of action, so it is often conducted concurrently with NEPA documentation and may also be incorporated in the Title VI equity analysis. For a bus maintenance facility an EJ analysis is normally conducted during preliminary design (when the footprint and major components of the project are defined).

Presidential Executive Order 12898 directs federal agencies and thereby recipients of federal funding such as MBTA to make EJ part of their mission by identifying and addressing disproportionately high and adverse human health or environmental effects of programs, policies, and activities on EJ populations – the goal is to achieve an equitable distribution of benefits and burdens. This includes the full and fair participation by all potentially affected communities in the transportation decision-making process.

Agencies must consider whether a project, after weighing the adverse effects and the potential benefits, will have a disproportionately high and adverse effect on EJ populations. And if so, to determine whether further mitigation measures or alternatives are practicable before moving forward with the activity. For more details about conducting an EJ analysis, refer to FTA's EJ Circular 4703.1.

2.2.2 MBTA-specific Processes

2.2.2.1 Project Development Group Process

The MBTA Project Development Group (PDG) is a set of internal stakeholders who have an opportunity to provide comments on every milestone design submittal. The PDG is composed of senior managers and representatives from various MBTA departments as established by the Office of the Chief Engineer. Departments represented in the group may include Capital Delivery, Risk Management, QA/QC, Project Controls, Planning, Real Estate, Engineering & Maintenance, Communication, Environmental Affairs, Bus Operations, Safety, Government and Public Affairs, and others depending on the nature of the specific project. The PDG will help the Project Team identify alternatives and solutions to design issues that affect MBTA maintenance and operations and monitor progress in achieving MBTA design and operational goals. It is the responsibility of the design team to identify major issues that potentially have a negative effect on cost, schedule, design, maintenance or operations and address PDG comments and document outcome.

The review process occurs at the 15%, 30%, 75%, and 100% stages and includes PDG meetings and Project deliverable review. At 15% (Conceptual Design), the PDG will review Project program options and recommendations and provide direction for the Project Team on the Project program. At 30% (Preliminary Design), the PDG will review the Project scope and budget and evaluate whether it supports the Project program and provide direction for the Project Team on scope and budget. At 75% (Design Progress Review), the PDG will review Project design progress and focus on the resolution of prior PDG review comments and budget and scope concurrence. At 100% Design (Overview of Project Design), the PDG will conduct a final Project review and focus on the resolution of prior PDG review comments.

2.2.2.2 Safety Certification

The MBTA Safety Department requires that all projects complete a safety certification to verify that the project design and construction process incorporates the proper legal documentation for all items on an MBTA-created project-specific safety certification checklist. These items will include standard safety features for buildings, as well as specific safety features pertaining to MBTA activities that will be identified for the final designer in a timely manner during the design process. Early coordination with the MBTA Safety Department is required to ensure a more efficient safety certification process. Typically, this coordination begins at 30% design.

2.2.2.3 MBTA Design Directives and Standard Specifications

The designer is responsible for reviewing and complying with MBTA's Engineering Directives, Design Standards and Guidelines, Standard Specifications, and other design and construction policy and procedure manuals, as applicable. More information can be found at the Engineering page and the Capital Programs page of the MBTA website.

2.2.2.4 Sustainability and Resilience Administration and Management

MBTA bus maintenance facility designs will address sustainability and regional resilience. Design teams will designate two individuals dedicated to coordinating, enforcing, and documenting sustainability and resilience requirements throughout design and construction who will establish, maintain, and hand off information to the MBTA.

- The Sustainability and Resilience Administrator (S+R Admin) will serve as both the design phase lead and the overarching representative of the Project's holistic sustainability and resilience design process. The S+R Admin is responsible for final delivery of the completed efforts to the MBTA. In the event that a project has more than one occupied facility, the S+R Admin will provide the role for the project in its entirety.
- The Sustainability and Resilience Coordinator (S+R Coordinator) will work side-by-side with the contractor to implement sustainability and resilience requirements and document all related efforts during the construction phase. In the event that a project has more than one occupied facility, the S+R Coordinator will provide the role for the project in its entirety.

In conjunction with the Project Team, the S+R Admin will develop an initial Sustainability and Resilience Management Plan (SRMP) at the time of Project design award and maintain the SRMP throughout the Project until final turnover to the MBTA. An SRMP enables a project team to set goals, objectives, and policies; establish plans and programs; review performance against a plan; and take corrective actions across the full dimensions of sustainability and resilience. The plan will chart how the Project will meet the target of LEED Gold and ensure it meets LEED Silver at a minimum, as well as meet sustainability- and resiliency-related MBTA Design Directions, as well as other sustainability and resiliency goals set by the MBTA in Project scoping. Refer to **Appendix A** for more information on the SRMP.

The design team is responsible for providing directives for the construction team in the form of construction drawings and specifications. The SRMP will also describe construction documentation needed for third-party certification submittal and documentation of other MBTA requirements. The SRMP is not contractually binding by itself, therefore the specifications will include explicit requirements for contractor performance and documentation for the contractor to fairly price and staff these actions in the bid. The requirements outlined in **Appendix A** instruct the Project Team and the S+R Admin on aspects that will be specifically required of the construction team to achieve an integrative and iterative holistic approach to a highly sustainable and resilient project.

Construction activities requirements include the following topics at a minimum:

- Construction-specific energy and water use reduction
- Health and safety procedures
- Temporary applications
- Demo and waste management and indoor air quality during construction
- Post-design commissioning activities

2.2.2.5 Commissioning and Asset Management

Commissioning and asset management optimizes performance, risk, and cost over the entire life-cycle of an asset. The designer will conform to the asset inventory hierarchy set forth in the MBTA Asset Data Standard and the MBTA Asset Definitions and Data Dictionary Document (AD4) for Facilities. In addition, the design will facilitate condition assessment activities set forth in the MBTA Facility Condition Assessment Methodology.

A commissioning authority (CxA) must be engaged with the design team no later than the end of the design development phase and maintain coordination with the Project Team and MBTA throughout the design and construction phases, and into operations. The CxA must be able to perform the activities outlined in the LEED Reference Guide, as well as those required by MBTA, if different. Additional requirements related to commissioning activities are located in **Appendix A.**

The facility design team will ensure visibility or easy access to systems and assets for regular operation, maintenance, periodic inspections and performance evaluation processes. This means that entering limited access areas such as crawl spaces, utility pits, and sloped roofs is not necessary and that their condition can be observed from an easy and convenient access point.

The design team will consider building designs that support ease of installation of wire or wireless networks that power and link communications systems, which rapidly evolve. Just like other systems, the design of these networks will allow easy access for maintenance, upgrades, and replacements.

2.2.2.6 Deviations

If conditions warrant deviation from a directive, standard, or guideline, the Designer of Record will submit a request for a waiver to the MBTA Project Manager in line with the following process:

- The Designer of Record will notify the MBTA Project Manager in writing of a suspected or planned deviation and submit the waiver request within one week of the original notification unless otherwise approved by the MBTA Project Manager. The waiver will be submitted in line with MBTA Project communication protocols (e.g., eBuilder).
- The MBTA Project Manager will forward the waiver request for review and approval to the Office of the Chief Engineer, Attention to Joseph A. Pavao, P.E.
- The Office of the Chief Engineer is responsible for performing a preliminary evaluation of the waiver request and identify additional required reviewers as needed, including the BFMP Director (who would coordinate review by other members of the Office of the Chief Engineer as needed) and other stakeholder departments.
- All waivers will be approved by the Chief Engineer or designee.

2.2.2.7 Waiver Request Submittal

- The waiver request will be a maximum of two pages (not including supplemental drawings, plans, pictures, etc.) in a format agreed to by the Office of the Chief Engineer and will include the following:
  - Waiver request number (to be established with Office of the Chief Engineer)
  - A detailed narrative that identifies the following:
    - Impacted design element or system (e.g., location, application)
    - Relevant requirement, directive, or code that will be deviated
    - Why the waiver is being requested (e.g., technical feasibility, space constraints, cost)
    - An overview of the proposed deviation and impact to the design, including quantitative analysis of life-cycle performance and cost, and potential impact to the Project’s sustainability and/or resilience requirements
    - Associated engineering drawings including plans, elevations, pictures, and sections as necessary to detail the relevant design elements (not included in two-page limit)
    - Evidence that no other alternative is available that meets current directives, standards, and guidelines

2.2.2.8 Tracking

The Designer of Record will record all deviation waiver requests (even if not approved) and MBTA decisions in the Project change log.

3 SITE AND BUILDING REQUIREMENTS

3.1 Civil and Landscaping

Civil and landscaping elements will be designed to meet the requirements outlined in the following subsections. The designer will consider health, safety, resilience, and resource efficiency when making final decisions that are not dictated by code.

3.1.1 Codes, Standards, and Regulations

The designer will use the latest versions of the following Massachusetts Department of Transportation (MassDOT) and MassHighway codes, standards, and regulations as applicable:

- *Construction and Traffic Standard Details*
- *Engineering & Policy Directives*
- *Load and Resistance Factor Design Bridge Manual Design Guidelines*
- *Project Development and Design Guide*
- *Right-of-Way Manual*
- *Subsurface Utility Engineering*
- *Survey Manual*
- *Standard and Supplemental Specifications for Highways and Bridges*
- *Storm Water Handbook for Highways and Bridges*

The designer will use the latest versions of the following Massachusetts Department of Environmental Protection (MassDEP) and U.S. Environmental Protection Agency (EPA) codes, standards, and regulations:

- *Erosion and Sediment Control Guidelines for Urban and Suburban Areas*
- *Massachusetts Clean Water Toolkit Fact Sheets*
- *Protocol for Stormwater Best Management Practice Demonstrations*
- *Stormwater Policy, Standards and Handbook*
- EPA *National Pollutant Discharge Elimination System Stormwater Discharges from Municipal Sources (MS4) Guidelines*
- EPA *National Pollutant Discharge Elimination System Stormwater Management Plan for MassDOT Owned and Operated Highways*

The latest versions of the following codes, standards, and regulations will also be used:

- American Association of State Highway and Transportation Officials (AASHTO) *A Policy of Geometric Design of Highways and Streets*
- FHWA *Manual on Uniform Traffic Control Devices Guidelines*
- AASHTO *Guide for the Development of Bicycle Facilities, latest edition*
- American Nursery and Landscape Association *American Standard for Nursery Stock ANSI Z60.1*
- Commonwealth of Massachusetts *General Law, Chapter 87: Shade Trees*
- Commonwealth of Massachusetts, Architectural Access Board CMR 521
- MBTA's Engineering Directives

- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals
- U.S. Access Board *Guidance on the Americans with Disabilities Act Accessibility Standards and relevant supplemental guidance or standards*
- Design criteria for utilities
- Municipal specifications and Department of Public Works permit requirements

The civil engineer is responsible for coordinating with the Project Team to help ensure compliance with the following LEED requirements as applicable to each project:

- IP Credit *Integrative Process*
- LT Credit *Sensitive Land Protection*
- LT Credit *Bicycle Facilities*
- LT Credit *Reduced Parking Footprint*
- LT Credit *Green Vehicles*
- SS Prerequisite *Construction Activity Pollution Prevention*
- SS Credit *Site Development – Protect or Restore Habitat*
- SS Credit *Open Space*
- SS Credit *Rainwater Management*
- SS Credit *Heat Island Reduction*
- SS Credit *Heat Island Reduction*
- WE Prerequisite and Credit *Outdoor Water Use Reduction*
- MR Credit *Building Life-Cycle Impact Reduction*
- MR Credit *Building Product Disclosure & Optimization*
- Pilot Credit *Inclusive Design*

3.1.2 Resilient Design Considerations

Site design is a key component of designing for resilience, especially for prevention of flooding from extreme precipitation, effects related to sea-level rise, nearby natural streams, or the capacities of existing storm conveyance systems upstream and downstream of the site.

Civil and landscaping design will consider the resilience performance goals included in **Appendix A, Section A.3, General Resilience Requirements,** under the conditions for the disruptors outlined in **Section A.3.3, Resilience Performance Requirements and Goals** (i.e., extreme storms, coastal flooding, extreme precipitation, extreme heat, and pandemic/disease). The performance goals include design thresholds to build assets/infrastructure such that there are no damages and no disruption in critical functionality under specified conditions for each disruptor. If those conditions are exceeded, there are secondary performance goals to manage and minimize disruptions such that critical functionality is restored in a quick and safe manner to minimize risk to the bus maintenance facilities and MBTA workforce.

Strategies to meet these performance goals in design and operations/maintenance planning will vary based on the Project site and conditions. Several strategies specific to civil and landscaping elements are included in the following subsections by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

3.1.2.1 Extreme Storms

Exposure of non-resilient designs to extreme storms (e.g., snow, ice, nor'easters, extreme wind, and hurricanes) could result in the following consequences:

- Accelerated deterioration of pavement design, sidewalks and employee pathways, and other traffic networks
- Physical obstruction to paths of travel such as roadways, sidewalks, and parking lots
- Damages to aboveground utility connections that service the bus maintenance facilities
- Potential for insufficient capacity of stormwater drainage infrastructure if storm is too intense or if network is not maintained or serviced appropriately, such as localized flooding
- Potential for erosion of slopes

Possible civil and landscaping design strategies include the following:

- Secure elements that could erode or become debris and damage other assets or impact operations during an extreme storm event.
- Design green infrastructure features resilient to deterioration from natural hazards over time
- Design landscaping for synergy with storm resistance (e.g., depressed landscaping areas and vegetated species resistant to wind and temporary inundation).
- Use preferred design of subsurface utilities.
- Develop operation and maintenance plan for site infrastructure like the stormwater management systems to maintain proper working conditions.
- Provide pavement sections that will adequately withstand adverse weather impacts.

3.1.2.2 Coastal Flooding

Exposure of non-resilient designs to coastal flooding could result in the following consequences:

- Accelerated deterioration of civil/site features due to flooding and exposure to salt-water inundation
- Physical obstruction to paths of travel such as roadways, sidewalks, and parking lots
- Damages to aboveground utility connections that service the bus maintenance facilities
- Site flooding from tailwater elevations exceeding design criteria

If the site is exposed to current and/or future coastal flooding, civil and landscaping design will meet the resilience performance goals under the coastal flooding conditions outlined in **Appendix A**. Possible civil and landscaping design strategies include the following:

- Elevate or adjust site grading/design to raise above design flood elevations (best option if feasible).
- Implement backflow preventer valves and sump pumps with water level sensors.
- Design for overland relief away from critical civil/site features for extreme flows in excess of storm conveyance system capacity.
- Design green infrastructure with salt-tolerant vegetated species; consider coastal wetlands or marshes.
- Allow for coastal vegetation migration upslope with sea-level rise.

3.1.2.3 Extreme Precipitation

Exposure of non-resilient designs to extreme precipitation and associated flooding from stormwater and/or riverine conditions could result in the following consequences:

- Accelerated deterioration of pavement design, sidewalks and employee pathways, and other traffic networks
- Physical obstruction to paths of travel such as roadways, sidewalks, and parking lots
- Potential for insufficient capacity of stormwater drainage infrastructure if storm is too intense or if network is not maintained or serviced appropriately, such as localized flooding
- Potential for erosion

Possible civil and landscaping design strategies include the following:

- Elevate or adjust site grading/design to raise above design flood elevations (while mitigating stormwater impacts to offsite or adjacent features as a result of grade changes).
- Secure elements that could erode or become debris and damage other assets or impact operations during a storm event.
- Design green infrastructure features that are more resilient to deterioration from natural hazards over time.
- Design landscaping for synergy with storm resistance (e.g., depressed landscaping areas and vegetated species resistant to wind and temporary inundation).
- Use preferred design of subsurface utilities.
- Design for overland relief away from critical civil/site features to extreme flows in excess of storm conveyance system capacity.
- Follow operation and maintenance plan for site infrastructure like the stormwater management systems to maintain proper working conditions.
- Provide pavement sections that will adequately withstand adverse weather impacts.
- Implement backflow preventer valves and sump pumps with water level sensors.

3.1.2.4 Extreme Temperatures

Exposure of non-resilient designs to extreme temperatures could result in the following consequences:

- Increased surface temperature of impervious surfaces: urban heat island effect
- Accelerated deterioration of civil/site features due to overheating, especially asphalt
- Human health impacts

Possible civil and landscaping design strategies include the following:

- Design civil/site features with reflective or non-absorptive materials.
- Provide adequate shade/shelter for workforce and site occupants.
- Design green infrastructure with vegetated species that are resistant to temperature extremes.

3.1.2.5 Diseases/Pandemic

Exposure of non-resilient designs to disease/pandemic increases the risk and vulnerability to MBTA workforce and site occupants at bus maintenance facilities. Possible civil and landscaping design strategies include designing site walkways for incorporation of sanitary stations and space for social distancing.

3.1.3 Survey and Mapping

Surveys will be conducted prior to the preparation of preliminary designs. The most current property survey information on file will be field checked and verified; any differences will be provided in writing to the MBTA or designee. All survey data will be collected electronically and show the base points and points of reference for establishing the control used, up to and including back sight information, sufficient to be replicated by another surveying firm. Surveys will include a point file and break-line file in addition to the digital elevation model or contour lines. Survey will be conducted in accordance with the MassDOT's *Survey Manual* and *General Survey Guidelines*.

Survey and mapping will include the following:

- Investigation and survey of property boundaries and property owners' names as obtained from records filed at the Registry of Deeds
- Base plans including soil, topography, utility, and base maps for the site
- A grid to indicate soil boring locations on the survey drawings
- Wetland delineations
- Locations and sources of power, water, communications, and other utilities, such as existing storm water, wastewater, and natural gas lines
- Areas of tie in, such as curb ramps, storm sewer connection inverts, sewer system connection inverts, roadway entrance and exit connections will provide spot elevations and detail sufficient to allow for design and construction without grade bust or revisiting the site
- Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map and/or Coastal Flood Risk Model overlaid on the site

3.1.4 Traffic Impact Analysis

A Traffic Impact Analysis (TIA) will be conducted for all new facilities during the preliminary design phase. The TIA will identify level of service impacts of the proposed development and will be used to determine necessary improvements to support the development. The analysis will be conducted for the morning and evening peak commute hours, as well as for other peak hours applicable to the Project (e.g., peak bus service). The designer will follow the requirements of the local jurisdiction for traffic impact analyses; if none exist, designer will use MassDOT requirements. At a minimum, the impact analysis will address the following:

- Definition of pedestrian, bicycle, and motor vehicle access
- Turn lane and access improvements
- Internal site circulation
- Shared access/access to adjacent sites
- Impacts to intersections and median crossovers
- Potential need for signage, signalization, or roundabouts
- Bus operations schedules

3.1.5 Right-of-way

Any additional right-of-way necessary to properly fit the design will be identified early in the design process. If the need will arise for additional temporary or permanent easements, the designer will prepare easement plans on behalf of the MBTA. These plans will be in compliance with MBTA right-of-way plan guidelines. Work performed within a municipal right-of-way will require easements from said municipality in the form of agreement or memorandum of understanding which will allow the work to be performed, reviewed, and approved by the municipality and then turned back over to the municipality.

3.1.6 Site Design Requirements

Overall site design is governed by the amount of available land, the size of the assigned bus fleet and bus type, and the specific maintenance operations at the facility. Bus storage and queue areas will be evaluated to prioritize safety and ensure travel path conflicts are minimized between buses, employee vehicles, and pedestrians coming in and out of the facility.

3.1.6.1 Accessibility

The design will be accessible for people of all ages and abilities in compliance with the MBTA *Accessibility Design Directive* and *System-Wide Accessibility Design Guideline*. If the site is existing and being redeveloped, all features will be updated to allow such access.

Considerations of universal design standards for public access should be included to pursue LEED Credits (LEED Pilot Credit *Inclusive Design)*. The civil engineer will develop design strategies to best address requirements.

3.1.6.2 Heat Island Reduction

The designer will incorporate strategies to reduce heat islands, such as through proper treatments to roofs, parking lots, and other hardscape surfaces, as well as incorporating vegetation into the site. LEED Credits require that following design shading performance be met by providing tree canopy, awnings, or other structures, unless restricted by non-negotiable site constraints:

- At least 50% of pedestrian pathways and building entrances
- At least 25% of parking spaces
- Between 25% and 75% of all plazas, seating areas, and other outdoor areas of congregation

The architect, civil engineer, and landscape architect will coordinate their design efforts to incorporate the requirements of the LEED SS Credit *Heat Island Reduction*.

3.1.6.3 Snow Management

The designer will identify locations onsite for snow storage in accordance with resilient performance thresholds developed in alignment with the resilience performance requirements and goals described in **Appendix A**. For constrained sites with no or limited space for storage, the designer will evaluate the cost effectiveness of using heated surfaces in targeted location and coordinate with the MBTA to include the appropriate requirements for removal within the snow management contract for the facility.

3.1.6.4 Site Circulation

The designer will accommodate 360-degree coverage around the building for emergency vehicle access. Public right-of-way may be used to achieve emergency access needs where it is sufficiently proximate to the building. The site design will also provide safe walking and biking connections within the site. Site circulation for pedestrian, vehicular, and bus movements will be separately delineated to maximize safety. Locations where circulation modes cross or interface will be well identified, and sight lines maximized.

<u>Design Vehicles</u>

The designer will confirm the dimensions of buses and maintenance vehicles accessing the facility and ensure the site design can accommodate the appropriate vehicle turning movements. Operating space requirements will be verified utilizing AutoTURN software. At a minimum, the following design vehicles will be accommodated in the site design process:

- MBTA bus (40-foot, 60-foot)
- MBTA wrecker
- MBTA tug
- Loading trucks (SU-30, WB-40, WB-50)
- Firetruck

<u>Vehicle Circulation</u>

Following are principles the designer will incorporate into the design to facilitate safe vehicle circulation around the site:

- All site driveway used by buses, maintenance vehicles or loading will be a minimum of 30 feet wide. All other site circulation drives will be a minimum of 24 feet.
- The minimum turning radius of site driveways will be 28 feet.
- Bus vehicle movements will be one-way, forward movements, in a counterclockwise direction (required for 60-foot buses, preferred for 40-foot buses).
- Provide the most direct roadway access possible between the site entrance and the facility.

<u>Pedestrian Circulation and Safety</u>

The site design will include safe, convenient, and accessible pedestrian access within the site that accommodate travel of pedestrians on bicycles. The site designer will evaluate pedestrian safety by identifying pedestrian and vehicle conflict points (especially bus vehicles). Pedestrian facilities will provide convenient pedestrian connections within the site that avoid conflict points as feasible. Where there are conflicts, adequate warning for both pedestrians and vehicles will be provided. Additional warning and safety features such as pavement markings, bollards, in-pavement lighting, additional overhead lighting, and clear sight lines, will be considered.

3.1.6.5 Reducing Embodied Carbon

The civil engineer and landscape architect will work together starting in early design and into construction to develop the best mix of materials needed to maximize reduction of embodied carbon in the site elements. An embodied carbon reduction of 10% from the baseline building will be achieved; concrete and steel are the primary materials of greatest impact while vegetation provides ideal opportunities for sequestration. The civil engineer will explore site material options capable of sequestering carbon for applications that have no conflicting performance requirements. Results may be generated in a holistic manner in conjunction with the completion of a life-cycle assessment exercise, as identified in the LEED rating system, though it is noted that the LEED Credit, itself, does not directly include site elements in the Credit work. Refer to **Appendix A** for additional information on the coordination of carbon reduction strategies.

Refer to LEED MR Credits *Building Life-Cycle Impact Reduction and Building Product Disclosure & Optimization*.

3.1.7 Roadways and Intersections

The facility design will provide vehicle access and integration to the surrounding roadway network, including any roadway or intersection improvements associated with the Project. The designer will coordinate with the local jurisdiction and adjacent private property owners to ensure roadway and intersection designs match elevations of adjacent private properties and adjoining infrastructure. The designer will also obtain all required agreements and exemptions necessary to complete the design of the Project.

Roadway design will also consider sidewalk replacement, curb cuts, wheelchair ramps, granite curbing, asphalt pavement, cement concrete curbs and gutters, backfill, signage, striping, utility relocation, full depth and micro milling and overlay pavement, traffic control systems, maintenance of traffic, temporary traffic staging, or any other action as a result of the site development needs of each facility. Roadways in public rights-of-way that are to be relocated or improved will be designed to current standards set forth by MassDOT and as required by local codes.

The design will account for new or modified traffic control systems, including traffic signal equipment, dual displays, signal posts, pull boxes, signal timing adjustments, new/modified signal controllers and equipment, and maintenance of traffic with possible temporary traffic staging, as required.

3.1.7.1 Standard Roadway Dimensions and Gradients

The recommended roadway dimensions and gradients shown in **Table 3.1-1** as sourced from MassDOT, *Project Development and Design Guide* and AASHTO, *A Policy of Geometric Design of Highways and Streets.*

Table 3.1-1. Standard Roadway Dimensions and Gradients

Standard	Dimension or Gradient
Roadway Lane Widths	12 feet preferred 10 feet minimum 11 feet minimum for bus lanes 16 feet for minimum for one-way roadways
Roadway Cross-Slopes (roadways will be crowned in the middle and drain to edges where possible)	2% (1/4-inch per foot) preferred 1% (1/8-inch per foot) minimum 3% (3/8-inch per foot) maximum
Accessible Route Crossing Slopes	5% maximum 2% maximum cross-slope
Roadway Gradient Maximums – Vehicle	Ramps and driveways - 10% Safe operations – 6% Weather permitting – 5%
Roadway Gradient Maximums – Bus	Operating grade – 10% Design grade – 6.5%

3.1.7.2 Vehicle Entrances and Exits

The number and location of vehicle entrances and exits at each facility are determined by many factors, including parking lot size, volume of entrances/exits, site topography, traffic volumes on adjacent streets, and adjacent land uses. Driveway standards and dimensions are outlined in **Table 3.1-2**. Access to/from the facility for bus operations will be separate from employee or visitor access. Buses and employee/visitor vehicles may share interior circulation ramps. Site access control will be coordinated with safety and security requirements in **Section 3.9, Communications and Security Systems**.

Table 3.1-2. Driveway Standards and Dimensions

Standard	Dimension
Number of Driveways	Minimum - 2 Maximum - 4
Driveway Width for Bus Entrances/Exits	Minimum – 30 feet Maximum – 60 feet
Driveway Length	Minimum – 50 feet (unless requested otherwise by MBTA)
Driveway Radius	Minimum – 28 feet

The recommended distance between site entrances/exits and adjacent street intersections along various types of roadways is presented in AASHTO and FHWA guidelines and requirements. The designer will make the determination as to which is more stringent and follow as required.

At exits where a moderate number of left-hand turns is anticipated or there may be sight distance concerns, a second auxiliary exit lane will be considered to separate left- and right-hand turns. The width of auxiliary lanes will align with **Table 3.1-2** (refer to Error! Reference source not found. for more detail).

Additional vehicle storage length may be required to accommodate vehicles entering or exiting the site to avoid interference with vehicles in the public right-of-way or internal facility site circulation. As vehicles queue to enter or exit the facility, this storage length will be designed to prevent facility vehicles from interfering with other vehicles circulating the site, maintenance, employee or otherwise. For further information on the design of intersections, auxiliary lanes, and deceleration lanes, refer to *A Policy on the Geometric Design of Highways and Streets*, published by AASHTO.

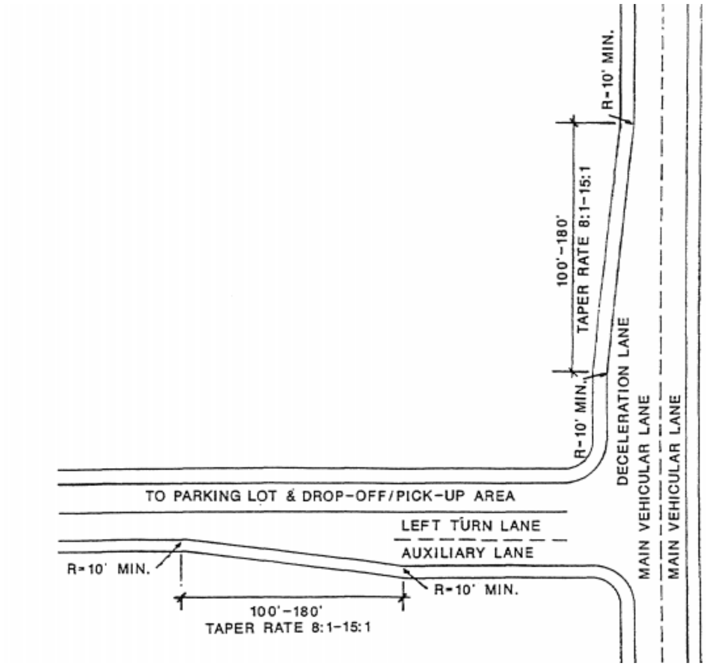


Figure 3.1-1. Layout of Auxiliary and Deceleration Lanes

3.1.7.3 Pavement Design

The pavement for drive aisles, employee parking, and other general-purpose roadways will at a minimum meet the pavement design requirements in the MBTA Directive *Busway Design Criteria*. Refer to current AASHTO guidance, which discusses flexible, rigid, and composite pavements.

Areas used by buses for parking, queuing, and building approach and departure will require heavy-duty concrete with minimum epoxy coated reinforcing.

Additional consideration will be given to subsurface conditions, variability in use (e.g., excessive heavy vehicle loading/usage), and flexibility with current and future pavement material design characteristics. Subgrades identified to be at risk will be mitigated. Refer to Chapter 9 of the MassDOT *Project Development and Design Guide* for guidance on how to evaluate and design for subsurface conditions to prevent subgrade problems from shortening the service life.

3.1.7.4 Maintenance of Traffic

The designer will develop a Maintenance of Traffic Plan that includes traffic staging and detours necessary to assure proper maintenance of traffic for all modes of travel, including pedestrians, bicycle, transit, and vehicular traffic during the construction of the facility. This Plan will ensure that existing bus routes served by the facility and bus maintenance facility vehicles movements can be maintained. Traffic maintenance within the public right-of-way will be coordinated with and approved by state or local authorities. The designer will follow all *Manual on Uniform Traffic Control Devices Guidelines* for the development of the Maintenance of Traffic Plan.

3.1.8 Sidewalks

Sidewalks will be incorporated into the design of the facility to provide pedestrian pathways to the facility from the main site entrance, parking areas, and public transit locations. Sidewalks will be provided such that site buildings may be reached safely on foot and adhere to the following principles:

- Pedestrian pathways will meet current Americans with Disabilities Act (ADA)/Architectural Access Board requirements as well as any engineering directives as provided by MassDOT or the MBTA.
- Pedestrian pathways will be direct, well defined, and provide a clear indication of where they lead.
- Pedestrian access from the surrounding community will be encouraged by providing a direct, paved walkway to the facility.
- An accessible route of travel, free from steps, will link the building accessible entrance with public sidewalks, bus stops, parking, and passenger drop-off areas.
- The MBTA *System-wide Accessibility Design Guideline* and relevant codes provide additional information on sidewalk width, travel-slope, and cross-slope.
- No level change greater than 0.5 inch is permitted unless a ramp is provided. Level changes between 0.25 inch and 0.5 inch will be beveled with a maximum slope of 1:2.
- Walkway surfaces will be slip-resistant (minimum static coefficient of friction of 0.6) with all joints finished flush.
- Walkways adjacent to roadways will be physically separated by curbing, guardrail, or bollards for safety and to prevent encroachment by vehicles (use of bollards will be minimized as they may interfere with snow removal).
- Where sidewalks are located immediately adjacent to parking areas, vehicle overhang from 90 degrees or angle parking will be accounted for in the layout of walkways to ensure that the required sidewalk width is maintained.
- Snow removal and storage will be considered in the location and design of sidewalks as to not obstruct the path of travel.

3.1.9 Bicycle Facilities

The design will provide connections to a local bicycle network if such network is present in proximity to the site. Protected bicycle parking will be provided, preferably close to the main entrance(s) to the building. Bicycle facilities should be designed in accordance with applicable code and MBTA Directive *Bicycle Parking*. The civil engineer and architect will coordinate design efforts to incorporate the requirements of the LEED LT Credit *Bicycle Facilities*.

3.1.10 Parking

Onsite employee parking will be provided. The number of parking spaces will be determined based on the fleet size and number of personnel assigned to each facility as determined by MBTA. It will be defined in the Project brief for each facility.

The number, location, dimensions, and vertical clearance of accessible parking spaces will meet ADA requirements. Where accessible parking is more than 200 feet from a building entrance, an accessible drop-off area will be provided. Refer to *521 CMR* and *ADA Accessibility Guidelines* for specific parking standards. Refer to the AASHTO *Guide for the Design of Park-and-Ride Facilities* for guidance in parking layout and recommendations for parking stall dimensions based upon the angle of parking.

Best practice calls for right-angle parking with sufficient aisle width for two-way travel. However, where space is limited, angle parking with one-way travel may be acceptable.

Parking regulatory signs such as “No Overnight Parking,” “No Parking” Signs, “Electric Vehicle Parking”, and “Inspector or Manager Parking” will be provided at the direction of MBTA.

Refer to LEED LT Credit *Reduced Parking Footprint.*

3.1.10.1 Green Vehicles

The Project design will encourage the use of alternative vehicle technologies by designating a minimum number of preferred parking spaces for such vehicles, as determined by the MBTA. The civil engineer and electrical engineer will coordinate their design efforts to incorporate the requirements of LEED LT Credit *Green Vehicles*.

3.1.11 Utilities

The design will include provisions for utility connections to service the bus maintenance facility including sanitary sewer, domestic water service, fire protection water service, electrical service, telecommunication service, cable service, and gas service that use existing connection points where possible. Internal and external charging stations, operational standby generators, and switchgear for BEBs will also require special power supply and structural support in the delivery and distribution throughout the site.

The MBTA will coordinate with the various utility companies whose facilities or services may be affected by the proposed Project, including the design team early in the design process. Coordination efforts should identify if utility providers require additional infrastructure on the site as early as practicable so they can be incorporated into the site plan.

The designer will design alterations of publicly or privately owned utilities, as necessary, except where the utility owner carries out the design of alterations themselves. Designs alterations will conform to the requirements and design standards of each utility service provider.

The designer will furnish anticipated utility demands for the Project; data gathered and used for the design of utility alterations, maintenance and improvements; or any interference that may be caused during the construction process to the utility service providers involved. The designer will review designs prepared by other agencies in connection with the Project work under this contract and will coordinate all alterations.

The designer will maintain existing utility easements within the site as feasible; however, relocation may be required as part of the site redevelopment. The relocation of utilities and associated easements will need to be coordinated with the individual utility companies and/or the local municipality. Utility work will be coordinated with the survey team, local municipality, or utility company to provide updated mapping and to verify any available utility as-builts.

3.1.12 Stormwater Drainage

The designer is responsible for the modeling, design, and permitting of all drainage infrastructure for the Project, including the bus maintenance facility, driveways, roadways and intersections, parking areas, access/egress paths, landscape areas and construction areas abutting the Project.

The design of surface drainage, underground drainage systems, stormwater management facilities, and erosion and sediment control will be in conformance with the applicable requirements of the local regulatory authority and follow the MassDEP *Stormwater Handbook and Stormwater Standards* and the MBTA Design Directives *Flood Resiliency* and *Drainage.*

The designer will develop a Stormwater Management Plan as part of the final design in compliance with federal, state, and local regulatory requirements, including regional or site-specific stormwater management agreements, as well as sustainability and resilience requirements specific to the Project.

The contractor will use the Stormwater Management Plan to obtain discharge authorization under the appropriate National Pollution Discharge Elimination System construction general permit and develop a Stormwater Pollution Prevention Plan prior to construction start. Temporary and permanent erosion and sediment control practices will be provided in accordance with local regulatory requirements during both the construction and operational phases of the Project.

3.1.12.1 Site Grading

Site grading is critical to prevent flooding of the building during extreme precipitation events. Refer to MBTA Design Directive *Flood Resiliency* for requirements for the minimum building floor elevation and for requirements for rainfall intensity to use in site overland relief drainage calculations. Site grading will complement the features and functions of the natural drainage system and the existing contours. Also consider the high and seasonal groundwater table elevations in the siting and sizing of stormwater management facilities. Refer to MBTA Design Directive *Drainage.*

Impervious Surface Grading

Determine the appropriate requirements for site grading and accessibility. Ensure that the grading and associated stormwater runoff do not adversely affect surrounding sites. Acceptable ranges of this criteria are as indicated in the MassDOT *Project Development and Design Guide* (Chapters 4 and 5), ADA/Architectural Access Board as well as the current version of AASHTO's *A Policy on Geometric Design of Highways and Streets*. Designer will use whichever requirement is more stringent.

Pervious Surface Grading

The designer will use **Table 3.1-3** to determine the appropriate requirements for pervious surface grading around the Project site.

Table 3.1-3. Pervious Surface Grading Requirements

Description	Requirement	Best Practice
Landscape Islands	Minimum of 1.0%	Not applicable
Landscape Areas	Minimum Slope of 2:1	Minimum slope of 3:1
Surface Detention Ponds	Minimum Slope of 2:1	Minimum slope of 3:1
Gravel Areas	Minimum Slope of 2:1	Not applicable
Existing Woods/Landscape Areas	Not applicable	Protect and maintain

3.1.12.2 Surface Drainage

Surface storage systems will be provided with a 3:1 slope and adequate storage based on stormwater design. If infiltration is used, test holes and percolation tests are required as proof of effectiveness. Data detailing underground water table elevations will be provided.

If site capacity constraints render surface storage systems infeasible, a waiver for deviation will be submitted to MBTA for alternate underground solutions. Subsurface storage systems will be designed with the ability to contain and attenuate flows as required. Following is a list of subsurface storage systems that may be used to fulfill this requirement:

- Advanced Drainage Systems
- CONTECH, Engineered Solutions
- CULTEC, Inc.

Any underground detention will accommodate HS-25 loading in areas of heavy vehicle traffic, including bus queue, bus storage, and loading bays.

3.1.12.3 Stormwater Structures

Storm structures for roads and site drainage will be in accordance with MassDOT's *Standards and Specifications*, MBTA's Design Directive *Drainage* or the requirements of the applicable local regulatory agency that governs stormwater management, whichever is more stringent. Structures will provide access for maintenance. Internal dimensions will not be less than 2 feet in any one direction. Ensure that catch basins, curb inlets, and maintenance holes are of adequate size to accommodate inlet and outlet pipes. Provide structures of cast-in-place or precast concrete. Masonry structures may be used for shallow installations less than 5 feet in depth. Design structure frames, covers and grates to withstand traffic loadings (HS-25) and meet any additional requirements set forth in the most recent MassDOT construction standard. Grate type will be selected based on such factors as hydraulic efficiency, debris-handling characteristics, pedestrian and bicycle safety, and loading conditions. Fixed ladders are required on all structures over 12 feet in depth.

3.1.12.4 Stormwater Piping

Straight alignments are required for piping between storm drainage structures. Deflection at structures will not be less than 90 degrees for main line flows and not less than 60 degrees for contributory flows as measured from the centerline of the mainline discharge and indicated in the MassDOT *Stormwater Handbook* and *Stormwater Standards*.

Storm drainage piping will not pass under buildings and the designer will try to maintain a parallel distance of at least 10 feet from building foundations. Care will be taken to avoid conflicts with other utilities. The design will comply with state or applicable regulatory agency requirements for separation distances between utilities and other public health and safety issues.

Use a minimum inside diameter of 12 inches for storm drainage piping (not including roof drainage piping) for runs 50 feet or less and where the existing downstream pipe is a 12-inch inside diameter with sufficient capacity; otherwise, use a minimum inside diameter of 15 inches. Refer to the MassDEP *Stormwater Handbook* and *Stormwater Standards* and MBTA's Design Directive *Drainage* for more information.

3.1.12.5 Roof Drainage

Where roof drainage is discharged to grade, provide splash pads to direct the flow away from the structure and to eliminate safety hazards such as ice, ponding, and flooding in pedestrian and vehicular traffic areas.

Where underground collection of roof drainage is used, provide an air break between the downspouts and underground piping. Size underground piping in accordance with the latest edition of the International Plumbing Code or a minimum of 6 inches interior diameter, whichever is greater.
No more than three downspouts will be collected in a single outlet before connecting to a storm

drainage structure, and the length of pipe from the most distant downspout to a drainage structure will not exceed 150 feet. Provide a clean out for each downspout connection and collection header; provide distances between cleanouts not greater than 100 feet; and provide cleanouts at changes in direction.

3.1.12.6 Stormwater and Sustainability

The civil engineer and landscape architect will coordinate their design efforts to best address the Credit requirements for LEED SS Credit *Rainwater Management.* Strategies to achieve these goals can include the following:

- Reduce stormwater runoff and improve water quality by using nature-based solutions or low-impact development and green infrastructure, or by managing runoff entirely onsite.
- Use pervious surfaces, avoid soil compaction and loss of vegetation, and restore or maintain natural drainage patterns.
- Increase infiltration, evapotranspiration, or rainwater harvesting onsite for stormwater volume control above the minimum regulatory requirements.
- Consider a stormwater management system that more closely replicate the historical undeveloped hydrology.
- Maintain or increase the initial abstraction and soil infiltration rates of areas intended to absorb precipitation.
- Increase the stormwater temporary detention volume available onsite in areas where the design depth will not cause a risk to infrastructure or operations.
- Upstream and downstream stormwater conveyance system capacities to identify riverine and coastal flooding vulnerabilities that could be mitigated onsite.
- If participation in a partnership for restoration of offsite, previously impacted streams, wetlands, or shorelines provide additional flood resiliency or ecosystem benefits instead of, or in addition to, onsite integrated stormwater management requirements.

In general, MBTA bus maintenance facilities are likely to be in areas where the natural receiving streams and wetlands have been impacted by uncontrolled runoff from prior development. If impacted streams, wetlands, or shorelines occur onsite, the site design is encouraged to restore these features using reinforced vegetated practices.

Material Pollutants

Avoid or minimize the use of materials in the building exterior and site work that can be a source of pollutants. Develop an integrated plan to minimize the use of deicing salt for sidewalks and site driveways and document in the Stormwater Management Plan.

3.1.13 Site Lighting

Security, visual comfort, compatibility with surrounding uses, energy efficiency, and attractiveness will be addressed in the design of maintenance facility lighting. The primary function of lighting is to make the maintenance facility site safe and secure, as well as visible from surrounding areas. All pedestrian pathways, bicycle facilities, parking areas and roadways will be provided with suitable lighting.
The lighting design will be applied such that economical usage of equipment and energy efficient products are used to meet all requirements. Refer to **Section 3.5, Electrical**, for complete exterior and site lighting requirements.

3.1.13.1 Light Pollution Reduction

To achieve LEED Credits, the designer will contain light within the Project's lighting boundary to avoid light trespass. Fixtures will comply with uplight requirements and be selected to respond to ambient lighting and increasing or decreasing light levels as required. LED fixtures are recommended to reduce the demand for electricity. The civil engineer and electrical engineer will coordinate their design efforts to incorporate the requirements of the LEED SS Credit *Light Pollution Reduction.*

3.1.14 Security

Security for each facility will be considered. At a minimum, the site will be fenced with gates to prevent unauthorized access, damage, and vandalism. Lighting, closed-circuit television (CCTV), and other forms of security will be provided in accordance with requirements outlined in **Sections 3.5, Electrical,** and **3.9, Communications and Security Systems.**

3.1.14.1 Fencing Requirements

- Install fence foundations to the minimum regional frost depth stated in the Massachusetts Building Code.
- The fencing will be minimum 6-foot-tall fusion bonded black vinyl coated chain link unless otherwise required.
- "No Trespassing" signs and video surveillance will be attached.
- Include personnel and vehicle gates at all driveway entrances and pathways leading to facility.
  - Personnel gates and vehicle gates will be separate but in similar locations if possible.
  - Gates will be a minimum 6-foot-tall with width compatible with access needs.
  - Gates will be fusion bonded black vinyl coated galvanized steel and vertically hinged at 2-foot centers.
  - Gates will be lockable with card reader and Internet Protocol (IP) intercom to request access. Mount card reader and IP intercom to provide driver side access from within vehicles.
  - Vehicular access gates will be lift gates or slide gates depending on site constraints.
  - Vehicular gates will be motorized unless otherwise noted by MBTA personnel.
  - Each gate area will have a Security Ethernet Switch cabinet to house a hardened network aggregation switch, surge suppressors, and electronic access control panel. Provide communications facilities from Security Ethernet Switch cabinet communications room.
  - Each vehicle gate will have at least one video surveillance camera viewing the gate.
  - Provide a fire department lock box at the secure side of the gate(s).
  - Include loop detectors on the unsecure side to open the gates when vehicles are exiting the facility from within.
- Update MBTA Physical Security Information Management (PSIM) System, Electronic Access Control System, Video Surveillance System, and Voice over Internet Protocol (VoIP) server with new devices, alarms, and licenses.
- Designer will consider the surrounding area, especially when adjacent to residential zoning, and provide appropriate mitigation for screening and security.

3.1.15 Landscaping

Landscaping refers to the existing natural features of a facility, as well as additional natural (e.g., trees, shrubs, ground cover) and humanmade (e.g., fencing, special paving materials) elements that can be used to enhance the overall visual quality of the facility.

Vegetative landscaping for MBTA bus facilities will be hardy enough to survive cold winters and drought tolerant to survive hot summers yet require minimal maintenance and no on-going irrigation needs. The MBTA prefers the planting of native species which meet these requirements and benefit pollinators (bees, butterflies, insects, birds).

The landscape design will consider other potential uses of the vegetative landscape, such as:

- To help improve site compatibility with the surrounding area and/or act as a buffer providing a natural screening to the facility
- To reduce/slow stormwater runoff volumes/flow and/or provide water quality benefits
- To provide space for snow storage; plants will be tolerant to the maintenance of these snow storage areas and documented in the snow management plan
- To lower temperatures and reduce the impacts associated with heat islands

3.1.15.1 Landscape Requirements

- Refer to Massachusetts Highway Department *Project Development & Design Guide*, *Chapter 13: Landscape and Aesthetics* for standards on soil volume, soil quality, plant materials, recommended species lists, tree protection, strategies for planting in constrained areas near other infrastructure, and strategies for enhancement of vegetated buffer areas.
- Water will not drain across walkways. Sidewalks or paving will drain to adjacent planted areas.
- Coordinate landscape design around the facility and parking lots with the communications systems design to maintain sight lines of surveillance cameras, especially with respect to anticipated vegetation growth.
- The landscaping will not reduce the sight distance of drivers, bus operators, and the public with respect to other vehicular traffic.
- Design landscape in parking lots and around the facility to perform water quality and detention functions.
- Design a landscape that requires low life-cycle maintenance and considers the long-term growth and health of the plantings when selecting plant materials.
- Use appropriate hardy, non-invasive, and native plants.
- Plant material adjacent to paved surfaces will be salt-tolerant to withstand winter applications of ice melt. Identify snow storage areas on the landscape plans and parking lot. Provide plantings at snow storage areas to withstand winter snow piles.
- Designer will take into consideration the surrounding area, especially when adjacent to residential zoning, and provide appropriate mitigation for screening and noise pollution.
- Prioritize amendment of onsite soils previously impacted by prior development over importing topsoil from offsite. Compost materials will be used as the preferred soil amendment in all maintenance and construction projects. Amendment will include organic content, mitigation of compaction, and testing of either the soil chemical characteristics or biological function.
  Soil amendments will be in accordance with the guidance of Massachusetts Clean Water Toolkit Best Management Practice Fact Sheet *Soil Amendments*. Consider the potential carbon sequestering and stormwater management benefits of increasing soil organic content beyond the

minimum required percentage by amending with compost. Specialized planting soils for trees and shrubs; engineered soils for bioretention, or green roofs; and structural fill soils for beneath foundations are allowed to be imported from offsite.

- Excess soil materials from the Project will be used as horticultural subsoil, where appropriate for planting, based upon soil testing to be performed by the landscape installer.
- Commercial topsoil will be certified as free from noxious and invasive species before use.
- Use fertilizers only if indicated by topsoil analysis by the University of Massachusetts Extension or commercial laboratory. No fertilizers will be used after the initial ninety-day maintenance period. No chemical fertilizers will be used. Ensure that fertilization use is effective and prevents harm to environment and human health. Use integrated pest management strategies to control pests, diseases, and invasive species.

  Refer to LEED SS Credits *Site Development – Protect or Restore Habitat, Open Space*, and *Outdoor Water Use Reduction*.

3.1.15.2 Operational Water Consumption Efficiency

Where feasible, reduce potable water use by making use of greywater, recycled water, and stormwater. Similarly, select appropriate landscaping materials to eliminate or reduce irrigation needs to reduce outdoor water consumption. The landscape architect and civil engineer will coordinate their design efforts to best address the requirements of LEED WE Prerequisite and Credit *Outdoor Water Use Reduction.*

3.2 Architectural

Architectural elements will be designed to meet the requirements outlined in the following subsections. MBTA needs in terms of future adaptability of the spaces and current flexibility of use will be carefully considered and the level of user comfort, as determined by the availability and adequacy, seismic, and sustainability will be addressed.

3.2.1 Codes, Standards, and Regulations

The design will adhere to the latest versions of the following codes, standards, and regulations as applicable:

- Massachusetts State Building Code (780 CMR)
- Massachusetts Comprehensive Fire Safety Code (527 CMR 1.00) (most current National Fire Protection Association [NFPA] 1, Fire Code, amended)
- NFPA 30A, *Motor Fuel Dispensing Facilities and Repair Garages*
- Massachusetts Architectural Access Board 521 CMR
- Massachusetts Electrical Code - 527 CMR 12.00 (most current NFPA 70 National Electric Code, amended)
- International Mechanical Code
- Massachusetts State Plumbing Code (248 CMR)
- IECC, as amended by 780 CMR 13.00
- Massachusetts Board of Elevator Regulations 524 CMR (2013 ASME-17.1, amended)
- Owner's Insurance Underwriter
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals
- ADA Standards for Accessible Design, 2010
- ADA Standards for Transportation Facilities, U.S. Department of Transportation (USDOT)
- Architectural Barriers Act
- Crime Prevention Through Environmental Design
- Massachusetts General Law Part I, Title XX, Chapter 148, Section 26G

The architect is responsible for coordinating with the Project Team to help ensure compliance with the following LEED requirements as applicable to each project:

- IP Credit *Integrative Process*
- LT Credit *Bicycle Facilities*
- SS Credit *Heat Island Reduction*
- EA Prerequisite *Fundamental Commissioning and Verification*
- EA Credit *Enhanced Commissioning*
- EA Prerequisite *Minimum Energy Performance*
- EA Credit *Optimize Energy Performance*
- MR Prerequisite *Storage and Collection of Recyclables*
- MR Credit *Building Life-Cycle Impact Reduction*

- MR Credit *Building Product Disclosure & Optimization* (three Credits)
- EQ Prerequisite *Environmental Tobacco Smoke Control*
- EQ Credit *Enhanced Indoor Air Quality Strategies*
- EQ Credit *Low Emitting Materials*
- EQ Credit *Interior Lighting*
- EQ Credits *Daylight*
- EQ Credit *Quality Views*
- EQ Credit *Acoustic Performance*
- Pilot Credit *Inclusive Design*

3.2.2 Dimensions and Clearances

The design of the fully enclosed maintenance facility will allow safe and efficient movement of personnel, equipment, and vehicles. The minimum overhead unobstructed clearances, door openings, bay sizes, parking space sizes, and work area dimensions listed in **Table 3.2-1** will be utilized during the design process.

Table 3.2-1. Minimum Dimensions and Clearances

Facility Spaces	Dimensions
Overhead unobstructed clearance in office areas	8 feet
Overhead unobstructed clearance in parts storage room	18 feet for first floor provides high bay storage and inventory retravel systems 12 feet for second floor as required for storage use and structural floor capacity
Overhead unobstructed clearance in fluid distribution, waste storage, and compressor room	12 feet
Overhead unobstructed clearance in shops with no overhead hoist	12 feet
Overhead unobstructed clearance in shops with overhead hoist	18 feet
Overhead unobstructed clearance in bus exterior wash bay and fueling	16 feet
Overhead unobstructed clearance in maintenance bay with lifts	21 feet
Overhead unobstructed clearance in maintenance bay with roof access and monorail or crane	24 feet
Overhead unobstructed clearance in inspection bay	16 feet
Overhead unobstructed clearance in bus chassis wash bay with platform lift	20 feet; 25 feet preferred
Overhead unobstructed clearance in bus storage (required for BEB fleet)	20 feet minimum below primary roof framing members
Shipping and receiving area door opening	12 feet by 12 feet (width by height)
Fueling bay door openings	14 feet by 14 feet (width by height)
Bus exterior wash bay door opening	14 feet by 14 feet (width by height)
Front of vehicle work area clearance	7 feet minimum clearance between vehicle and any obstruction

Facility Spaces	Dimensions
Back of vehicle work area clearance	10 feet minimum clearance between vehicle and any obstruction
Bus maintenance bay work area width	18-foot minimum clear center bay, 20-foot preferred 25 feet for end bays or bays with roof access (adjust upward for columns and other obstructions between bays)
Maintenance bay length for 40-foot vehicle	57 feet; 60 feet recommended
Maintenance bay length for 60-foot vehicle	77 feet; 80 feet recommended
Circulation of pedestrian corridors Pedestrian walkway (in open work/storage areas)	Refer to building codes for corridors 5 feet preferred for walkways in open work/storage areas
Circulation in the bay access aisle (not vehicle drive aisle)	8 feet minimum; 10 feet recommended
Corridor for forklift traffic	10 feet minimum; 12 feet + recommended (check forklift turning radius)
Street or yard tightest turning radius (90-degree turn) for a 40-foot bus	Designer must use MBTA-approved template for AutoTURN analysis; preferred radius provides 5-foot buffer from minimum dimensions, as determined from AutoTURN analysis. Buses must be straight to clear entrance openings; additional space may be required.
Street or yard tightest turning radius (90-degree turn) for a 60-foot bus	Designer must use MBTA-approved template for AutoTURN analysis; preferred radius provides 5-foot buffer from minimum dimensions, as determined from AutoTURN analysis. Buses must be straight to clear entrance openings; additional space may be required.

3.2.3 Exterior Finishes

Exterior envelope systems will be designed to be cost efficient, mitigate life-cycle costs and prioritize durability and reduced maintenance requirements. The selection of exterior finishes should consider the following: length and coverage of warranty; maintenance (cost of maintenance, frequency of maintenance, ease of maintenance), durability (impact resistance, traffic and vandal resistance, corrosion resistance, ease of repair); constructability (quality control, contractor pool, ease of transport, ease of assembly; availability and lead time); consistency with MBTA standards; risk/insurance considerations; and environmental impact, including ease of disassembly and reuse or recycling.

Rainscreen systems are preferred for enhanced thermal and moisture management. Wet sealant joints will be limited to the greatest extent possible.

Abrasion and impact-resistant materials will be provided at least 8 feet above the finished floor level on the interior and exterior.

The preferred roofing material should be durable and safe for staff to walk on to maintain rooftop equipment; should be designed for thermal expansion and contraction; and should be a product that offers a 30-to-40-year warranty.

Exterior thermal, envelope, and other characteristics will comply with the requirements in the following subsections and will be coordinated with the sustainable design criteria set out in Appendix A and with Envelope Building E Technology and Environmental Council.

3.2.3.1 Reflective Roofing and Heat Island Effect

Where there are exposed roof surfaces, a minimum solar reflective index of 82 or above will be provided to reduce heat island in the roofing system. The architect will work with the civil engineer and landscape architect to achieve overall reduction of heat island effect.

Refer to LEED SS Credit *Heat Island Reduction.*

3.2.4 Doors and Windows

Exterior glazing will be high thermal performance, such as multi-paned, insulated low E coated glass, set in aluminum with thermally broken frames or curtain wall system.

Interior glazing will be tempered and safety laminated if the glass is lower than 18 inches above the finish floor, per code. If no tempered and safety laminated glass is not used, recommended height from finish floor is 30 inches. Interior glazing systems will meet acoustical criteria to reduce noise transmission between program spaces and work areas.

Door thresholds will be avoided in maintenance and shop areas unless necessary. If thresholds are required, they will be of industrial grade.

Exterior personnel doors will adhere to the standards defined in MBTA's *Doors, Frames, and Hardware Design Directive*. Doors will be thermally insulated, and thermally gasketed fitted with industrial-grade hardware and closers, including kick plates.

Exterior overhead doors will be high-speed, insulated, equipped with camera sensors to automatically detect obstructions and open and close doors, hands-free based on approach of vehicles, equipped with audible alerts, and equipped with individual override capabilities with individual controls.

Interior overhead doors will be high-speed, and fire rated as required.

Exterior personnel doors and interior locked doors will have security access compatible with MBTA access control systems.

3.2.4.1 Control Solar Glare

All exterior envelope glazing will have shading. Atria or lobbies may be excluded. The shading will be controllable by the occupants or set to automatically prevent glare. Perform glare calculations and ensure an annual sunlight exposure of $ASE_{1000,250}$ is achieved for no more than 10% of all regularly occupied space.

Refer to LEED EQ Credit *Daylight.*

3.2.4.2 Daylight and Views

For optimal daylighting, regularly occupied spaces (as defined by LEED) will meet a spatial daylight autonomy of a minimum of 55%, and the annual sunlight exposure $ASE_{1000,250}$ of no more than 10% is achieved. This can be demonstrated through computer simulation.

These daylighting goals can be achieved in conjunction with those for quality views, providing a direct line of sight through vision glazing to the exterior for a minimum of 75% of the regularly occupied floor area.

At least two of the following criteria need to be met to qualify as quality views:

- Multiple lines of sight at least 90 degrees apart
- Views containing flora, fauna, or objects 25 feet away from the vision glass
- Unobstructed views at a distance equal to least 3 times the head height of the vision glazing
- Views with a view factor of 3 or greater, as defined by "Windows and Offices: A Study of Office Worker Performance and the Indoor Environment"

Views of interior atria may be used to satisfy the indicated requirements for up to 30% of the floor area. The architecture team is responsible for achievement of these priorities.

Refer to LEED EQ Credits *Daylight, and Quality Views.*

3.2.5 Floors and Interior Surfaces

All floors will include the following characteristics:

- Consistent materials throughout bodies
- Slip-resistant, ADA-compliant, and non-stainable finish
- Integral light color floor hardener and sealer in maintenance areas; sealer with no epoxy in other bus areas
- Floor will have no ponding
- Long-term cracking control of concrete using reinforcement compatible with the building design life
- Liquid proof floor slabs in vehicular areas (per code)

3.2.5.1 Reflectivity of Interior Surfaces and Materials

Select interior finishes and furniture materials to meet the following at a minimum:

- For at least 90% of regularly occupied spaces, select finishes with an area-weighted average surface reflectance of 85% for ceilings, 60% for walls, and 25% for floors.
- Any furniture in the Project scope will meet an area-weighted average surface reflectance of 45% for work surfaces and 50% for movable partitions.
- For at least 75% of regularly occupied spaces, and excluding fenestration, average wall surface illuminance to average work surface illuminance ratio of 1:10 (with previously described criteria).
- For at least 75% of regularly occupied spaces, and excluding fenestration, average ceiling surface illuminance to average work surface illuminance ratio of 1:10 (with previously described criteria).

The architect will coordinate with the electrical engineer on light fixture selection and placement.
All light sources on the Project, excluding specialty lighting providing color or specific site functions, are to have a Color Rendering Index of 80 or higher.

Refer to LEED EQ Credit *Interior Lighting Quality, Option 2: Reflectivity of Surfaces and Daylight.*

3.2.6 Vibration and Acoustics

Follow guidelines for Sound Transmission Class ratings for materials and finishes that comply with ASHRAE's Performance Measurement Protocols for Commercial Buildings; additionally, meet the reverberation time requirements in Table 9.1 in the Performance Measurement Protocols for Commercial Buildings. The architect and/or acoustician is responsible for compliance with this aspect.

Vibration and noise-generating equipment, including air compressors and pumps, will be located away from office areas and acoustically isolated. Vibrating equipment, including HVAC mechanical units, will similarly be located and specified with isolation or mass strategies so that noise and vibration transmission is minimized. Interior view windows, walls, ceiling, and floors in these spaces will be rated to further reduce noise transmission to other parts of the facility.

Refer to LEED EQ Credit *Acoustic Performance.*

3.2.7 Housekeeping Pads

Housekeeping and isolation pads will be provided for appropriate electrical equipment and mechanical equipment. Other housekeeping pads may be functionally necessary for some types of shop equipment.

Housekeeping and isolation pads will extend a minimum of 6-inches beyond the perimeter of the equipment to prevent water damage (or more to meet resilience performance thresholds), will be cast-in place concrete, and will be anchored into the floor slab. Design will be coordinated with structural engineers to ensure pad strength and uniformity throughout the facility.

3.2.8 Safety Issues

A comprehensive plan for safety markings, signage, and warnings will be developed in coordination with MBTA staff (e.g., Signage & System Wide Accessibility); plans will be included in the final 100% construction documents (refer to **Section 2.2.2, MBTA-specific Processes,** for more information). Avoid having internal pedestrian paths and desire lines cross vehicular circulation paths whenever possible. Use guards or barriers to direct pedestrians to clearly marked paths when circulation paths will intersect. Include floor markings for pedestrian egress in case of an evacuation event to ensure no equipment or materials are stored along the path and that the paths clearly lead to exit doors. Install parabolic mirrors to improve visibility around corners and at intersections.

Roofs will be provided with fall protection tie-offs that meet Occupational Safety and Health Administration requirements for all roofs requiring maintenance. Any safety protocols for eliminating fall/drop risks will be included in the manufacturer equipment manuals.

3.2.8.1 Bollards

Protective bollards will be provided at the exterior of all overhead doors and around interior or exterior equipment vehicle circulation paths. Bollards or guardrail will be installed adjacent to interior doorways that open onto internal vehicle circulation paths for protection of personnel and structures and at other locations with potentially hazardous conditions. Location of bollards and guardrails will be coordinated with the overall safety plan for the facility.

3.2.9 Signage and Graphics

Specific signage and graphics requirements, including safety, directional, guidance, informational, traffic signs, and pavement markings, will be developed with MBTA during detailed design. In alignment with both accessibility and inclusive design, considerations for those with limiting needs, specialized wayfinding and assistive technologies will be included.

Refer to LEED EQ Prerequisite *Environmental Tobacco Smoke Control*

3.2.10 Refuse/Recycling Collection

Containers will be provided and designated for recycling purposes, including metal, paper, cardboard, plastic, and glass in alignment with MBTA requirements and site-specific direction.

Containers will be provided for oil and hydraulic fluid recycling and hazardous waste.

Refuse collection, recycle bins, and dumpsters will be provided at locations convenient to work areas, as well as to collection vehicles, while not infringing on operations or clearances for bus maintenance.

Refer to LEED MR Prerequisite *Storage and Collection of Recyclables*

3.2.11 Product Selection and Commissioning

3.2.11.1 Responsible Materials and Product Transparency

Specify products that are salvaged, reused, or contain recycled content. Prioritize products from companies that use sustainable procurement and manufacturing practices, and can provide documentation outlining their carbon footprint, minimum cradle to gate scope, environmental product declarations, or other proofs of their transparency of process. The entire Project Team is responsible for selecting compliant products, though a larger role rests with the architecture team for achievement.

Refer to LEED MR Credits *Building Product Disclosure Information,* and EQ Credit *Low Emitting Materials.*

3.2.11.2 Commissioning

The purpose of commissioning services is to ensure that the equipment and systems are installed properly and are functioning as intended, in accordance with ASHRAE Guideline 0 and ASHRAE Guideline 1.1. Additional services expand the roles and responsibilities of the commissioning authority, to ensure that the design and its execution are in compliance with the Owner's Project Requirements and/or with the basis of design (BOD), the Operating Personnel are trained in the use of the equipment, and that the equipment is tested and is operating in accordance with the design in different seasons.

The building envelope will be commissioned in addition to the mechanical and electrical systems. This is required due to the importance of the correct installation of the weather-resistive barrier, the air barrier, the insulation, the sheathing, the façade, and the flashing to building energy consumption, durability, and occupant comfort. The building envelope commissioning will be performed by a Building Enclosure Commissioning Specialist. The architect will work with the commissioning authority throughout the design process to maximize efficient and effective design of these components.

Refer to LEED EA Prerequisite *Fundamental Commissioning and Verification* and LEED EA Credit *Enhanced Commissioning.*

3.2.12 Other Sustainability Design Requirements

3.2.12.1 Reducing Embodied Carbon

The architect will work with the structural engineer starting in early design and into construction to develop the best mix of materials needed to maximize reduction of embodied carbon in the site elements. An embodied carbon reduction of 10% from the baseline building will be achieved. Concrete and steel are the primary materials of greatest impact; however, the complete building envelope and structural elements, including the material components of footings and foundations, structural wall assembly (from cladding to interior finishes), structural floors and ceilings (not including finishes), and roof assemblies will be included as additional foci. Results may be generated in a holistic manner in conjunction with the completion of a life-cycle assessment exercise, as identified in the LEED rating system.

Refer to LEED MR Credit *Building Life-Cycle Impact Reduction*.

3.2.12.2 Reducing Operational Carbon

The architect will coordinate with the civil, mechanical, and electrical engineers to address the goal to move toward net-zero carbon in a holistic manner. In addition to other design aspects, architecturally focused required considerations include the following:

- Orientation and massing
- Building envelope
- Assembly U-values
- Envelope airtightness
- Windows and glazing
- Building assembly analysis
- Lighting and controls

Refer to LEED EA Prerequisite *Minimum Energy Performance* and Credit *Optimize Energy Performance*.

3.2.12.3 Energy Consumption and Performance

Establish a baseline energy performance for the facility and reduce the energy requirements, prioritizing building design and efficient exterior envelope strategies. Use strategies such as building orientation and massing, natural or humanmade shading, material selection or other strategies as appropriate on a project-by-project basis. The architect will work with the electrical and mechanical engineers to coordinate energy efficiency measures and maximize savings.

Refer to LEED EA Credit *Optimize Energy Performance*.

3.2.12.4 Inclusive/Universal Design

Use a design process that prioritizes inclusive design that considers the full range of characteristics of human diversity such as ability, age, gender, language, and other characteristics in the context of place. Follow local zoning and code requirements for accessibility, inclusion, and engagement. The architect will work with the civil and electrical engineers to comply with these requirements.

Refer to LEED Pilot Credit *Inclusive Design*.

3.2.12.5 Enhanced Indoor Air Quality

Provide entryway systems, such as permanently installed recessed grate or grille systems or roll-out mats, at least 10 feet long, in the primary direction of travel. The architect will coordinate with the mechanical engineer for mechanical or natural ventilation strategies and prevention of interior cross-contamination prevention of hazardous spaces such as open garages, housekeeping spaces, and copy/print rooms.

Refer to LEED EQ Credit *Enhanced Indoor Air Quality Strategies*.

3.2.13 Resilient Design Considerations

Architectural design will consider the resilience performance goals included in **Appendix A, Section A.3, General Resilience Requirements**, under the conditions for the disruptors outlined in

Section A.3.3, Resilience Performance Requirements and Goals (i.e., extreme storms, coastal flooding, extreme precipitation, extreme heat, and pandemic/disease). The performance goals include design thresholds to build assets/infrastructure such that there are no damages and no disruption in critical functionality under specified conditions for each disruptor. If those conditions are exceeded, there are secondary performance goals to manage and minimize disruptions such that critical functionality is restored in a quick and safe manner to minimize risk to the bus maintenance facilities and MBTA workforce.

Strategies to meet these performance goals in design and operations/maintenance planning will vary based on the Project site and conditions. Several strategies specific to architectural elements are included in the following subsections by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

3.2.13.1 Extreme Storms

Exposure of non-resilient designs to extreme storms (e.g., snow, ice, nor'easters, extreme wind, and hurricanes) could result in the following consequences:

- Accelerated deterioration to architectural features (e.g., windows, doors, and overall building envelope) due to impact from extreme storm debris
- Possible architectural damages due to exceeded snow, ice, and wind loads
- Potential for impact damage from wind debris
- Accumulation of snow and ice may create direct hazards to site access

Possible architectural design strategies include the following:

- Secure elements that could become debris during an extreme storm event
- Storm shelter rooms per International Code Council: Standard for the Design and Construction of Storm Shelters (ICC 500)
- Federal Emergency Management Agency Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms (P-361)
- Resilient roofing design with heating pads to de-ice and remove snow
- Include redundancy in design to prevent further compromising critical functionality of mechanical, electrical, and communication systems

3.2.13.2 Coastal Flooding

Exposure of non-resilient designs to coastal flooding could result in the following consequences:

- Possible damages critical architectural features due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment
- Accelerated deterioration due to salt-water exposure

If the site is exposed to current and/or future coastal flooding, architectural design will meet the resilience performance goals under the coastal flooding conditions outlined in **Appendix A** Section A.2.1.3, Energy Efficiency Performance. Possible architectural design strategies include the following:

- Elevate critical architectural features above design flood elevation.
- Relocate critical architectural features out of flood zones as possible.
- Building features that are not located above the base flood elevation will be designed to withstand the corresponding hydrostatic pressure or protected from the flood hazard.

- Consider corrosive resistant materials.

3.2.13.3 Extreme Precipitation

Exposure of non-resilient designs to extreme precipitation and associated flooding from stormwater and/or riverine conditions could result in the following consequences:

- Accelerated deterioration of flood-born debris during extreme precipitation events
- Potential for mold, mildew, general air quality issues, and subsequent human health issues with exposure to water

Possible architectural design strategies include the following:

- Elevate critical entryways architectural features above flood zone
- Storm Shelter rooms per International Code Council (ICC 500)
- Federal Emergency Management Agency Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms (P-361)
- Consider enhanced sealing from for water entry (e.g., perimeter of doors, windows and other openings, control and expansion joints, plus drainage and utility connections)

3.2.13.4 Extreme Temperatures

Exposure of non-resilient designs to extreme temperatures could result in the following consequences:

- Increased indoor ambient air temperatures, extended temperature ranges throughout the year
- Increased surface temperature of impervious surfaces (urban heat island effect) with potential human health concerns

Possible architectural design strategies include the following:

- Seal and insulate elements common pathways for air entry (e.g., perimeter of doors, windows and other openings, control and expansion joints, plus drainage and utility connections).
- Install adequate exterior shading structures.
- Consider reflective materials and solar facades.
- Consider destratification fans-internal circulation to eliminate thermal stratification.
- Consider thermic barriers and zones to reduce building energy demand and provide safe zones during extended temperature extremes.
- Consider passive cooling techniques, such as enhanced natural ventilation, using solar energy and evaporative cooling to reduce building energy consumption and increase indoor thermal comfort.

3.2.13.5 Diseases/Pandemic

Exposure of non-resilient designs to disease/pandemic increases the risk and vulnerability to MBTA workforce and site occupants at bus maintenance facilities. Possible architectural design strategies include the following:

- Design mitigation for airborne pathogens as part of air flow and space usage strategy (improving health performance is allowed to take precedence over energy efficiency).
- Design easy to clean materials and surfaces; consider antimicrobial materials.

3.3 Structural

The structure will be designed to meet the requirements outlined in the following subsections. The structure will include complete lateral and vertical-force-resisting systems capable of providing adequate strength, stiffness, and energy dissipation capacity to withstand the applied loading within the prescribed limits of deformation and strength demand. The adequacy of the structural systems will be demonstrated through the construction of a mathematical model and the evaluation of this model for the applied force effects. Individual members will be provided with adequate strength at all sections to resist the shears, axial forces and moments determined in accordance with these provisions and connections will develop the strength of the connected members for the forces indicated previously. The deformation of the structure will not exceed prescribed limits. A continuous load path or paths, with adequate strength and stiffness will be provided for all forces from the point of application to the final point of resistance.

3.3.1 Codes, Standards, and Regulations

The design will adhere to the latest versions of the following codes, standards, and regulations as applicable:

- Massachusetts State Building Code (789 CMR)
- International Building Code
- ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*
- American Concrete Institute 318, *Building Code Requirements for Structural Concrete*
- American Concrete Institute 530/ASCE 5/TMS 402, *Building Code Requirements for Masonry Structures*
- AISC 360, *Specifications for Structural Steel Buildings*
- AISC *Steel Construction Manual*
- American Iron and Steel Institute S100, *North American Specification for Design of Cold-Formed Steel Structural Members*
- Steel Deck Institute *Design manual for Composite Decks, Form Decks, and Roof Decks*
- Steel Joist Institute *Standard Specifications, Load Tables, and Weight Tables for Steel Joists and Joist Girders*
- American Welding Society D1.1, *Structural Welding Code – Steel*
- AASHTO Load and Resistance Factor Design Bridge Design Specifications
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals

The structural engineer is responsible for coordinating with the Project Team to help ensure compliance with the following LEED requirements as applicable to each project:

- MR Credit *Building Life-Cycle Impact Reduction*
- MR Credit *Building Product Disclosure & Optimization*
- EQ Credit *Low Emitting Materials*

3.3.2 Design Requirements

3.3.2.1 Material Specifications

The structural design will adhere to the material specifications outlined in **Table 3.3-1**.

Table 3.3-1. Material Specifications

Material	Design Parameter
Concrete	F'c = 4,000 psi (minimum)
Masonry	F'm = 1,900 psi
Steel Reinforcing	Fy = 60,000 psi
Structural Steel (Wide Flange Members)	Fy = 50,000 psi
Rectangular/Round Hollow Steel Sections	Fy = 46,000 psi
Other Steel Shapes	Fy 36,000 psi

Note:
psi = pound(s) per square inch

3.3.2.2 Combination of Load Effects

The effects on the structure and its components due to gravity loads and seismic forces will be combined in accordance with the factored load combinations as presented in International Building Code Section 1605.2

3.3.2.3 Standard Design Loads

For the purposes of analysis and design, the weights of construction materials outlined in **Table 3.3-2** will be used. The Live Loads, Snow Loads, Wind Loads, and Seismic Loads will be as per International Building Code Sections 1607, 1608, 1609, and 1613.

Table 3.3-2. Standard Design Loads

Material	Design Unit Weight
Normal Weight Concrete	150 pounds per cubic foot (pcf)
Light Weight Concrete	115 pcf
Normal Weight CMU	90 pcf
Lightweight CMU	75 pcf
Brick Masonry	120 pcf
Structural Steel	490 pcf
Soil (saturated)	130 pcf
Soil (for buoyancy)	110 pcf
Water (fresh)	62.4 pcf
Bituminous Pavement	150 pcf

3.3.2.4 Serviceability Requirements

All the structural systems and members thereof will be designed to have adequate stiffness to limit deflection limits specified in International Building Code Section 1604.3 and ASCE 7 Section 12.12.

3.3.2.5 Foundations and Geotechnical

Each site will have a geotechnical exploration program completed and geotechnical report prepared. Shallow Foundations will bear on either native soils or compacted engineered fill. Deep Foundations will be used when recommended by the geotechnical report.

Supplemental foundation elements may be required to support equipment or tanks recessed within the slab. These foundation elements will be designed based using actual loads from the BOD manufacturer(s) with appropriate factors to account for "or equal" equipment alternatives.

3.3.2.6 Floor Slabs and Aprons

The ground floor slabs for vehicular traffic areas will be reinforced concrete slab-on-grade placed over a vapor retarder, bearing upon compacted granular material. These slabs will be designed for bending stresses due to uniform load and concentrated loads and for in-plane stresses due to drying shrinkage and subgrade drag resistance. The loading on the ground floor slabs will be a uniform loading of 250 pounds per square foot and a concentrated load of 20 Kips for HS-25 wheel load as per International Building Code Table 1607.1 and AASHTO Load and Resistance Factor Design Specifications. The ground-level floor slab in the office space portion of the facility will not need to be designed for the AASHTO Live Load.

Attention will also be given regarding the relationship between the base slab and the wall structure as it pertains to potential uplift due to high groundwater and flood events if site conditions indicate a high level of risk. Flood-proofing water stops and pressure relief openings will be included if conditions indicate legitimate risk. Floor slab design will align with resilience performance thresholds as referenced in **Section 3.3.3, Other Sustainability Design Requirements,** which includes guidelines for specific design parameters.

Ground floor slabs will extend to the exterior of the building along all vehicular circulation paths including areas adjacent to all overhead doors, queuing areas and loading docks. Ground floor slabs adjacent to overhead doors will be supported on the building side by the foundation of the adjacent building façade to prevent settlement of the pavement and maintain a smooth transition from interior to exterior surfaces.

Ground floor slabs in the bus-accessible portions of the facility, including any exterior apron areas, will contain an integral waterproofing admixture to prevent the intrusion of chlorides contained in de-icing salts, as well as other chemicals.

Elevated floor slabs will be designed using appropriate loading for the general use or using loading data for with appropriate factors to account for "or equal" equipment alternatives.

Electrical Switchgear and large mechanical equipment will be installed on 6-inch-high housekeeping pads.

Floor depressions and sloped slabs will be formed using a rapid-setting low permeability cementitious overlay which will be installed in a recess in the structural slab. Recess in the structural slab will allow for a minimum overlay material thickness of 4 inches.

3.3.2.7 Roof Structure

In addition to the standard International Building Code load requirements, the roof of the facility will be designed to support all required rooftop equipment and provisions for sustainable or resilient roof installations selected by MBTA (e.g., photovoltaic array, green or blue roof). There may also be additional loading due to overhead bus charging contacts, wiring, and conduits associated with future electrification of the fleet.

3.3.3 Other Sustainability Design Requirements

3.3.3.1 Material Sustainability Considerations

In order to create a sustainable structure and to minimize the life-cycle costs of the facility, the structural design will incorporate the following features as applicable:

- Eliminate thermal bridging to the maximum extent possible.
- Hot-dip galvanize and paint steel framing in areas exposed to water and/or road salt to provide a more durable finish and help prevent corrosion.
- Include integral waterproofing admixtures in the facility's floor slabs and concrete paving to prevent intrusion of chlorides and extend the life of the concrete.
- Coordinate with the mechanical engineer as appropriate to specify insulation under slab-on-grade components and footings.
- Investigate the use of stainless-steel structural members and fasteners in corrosion-prone areas as a means of extending the life of the structure.

Refer to LEED MR Credits *Building Product Disclosure Information*, and EQ Credit *Low Emitting Materials*.

3.3.3.2 Reducing Embodied Carbon

It is critical that the structural engineer work closely with the architect starting in early design and then optimizing structural design throughout the design and into construction to develop the building form and massing needed to maximize reduction of embodied carbon in the foundation and structural elements. An embodied carbon reduction of 10% from the baseline building will be achieved. Concrete and steel are the primary materials of greatest concern. Results may be generated in a holistic manner in conjunction with the completion of a life-cycle assessment exercise, as identified in the LEED rating system. Refer to **Appendix A, Section A.2, General Sustainability Requirements,** for additional information on the coordination of carbon reduction strategies.

Refer to LEED MR Credit *Building Life-Cycle Impact Reduction.*

3.3.4 Resilient Design Considerations

Structural design will consider the resilience performance goals included in **Appendix A, Section A.3, General Resilience Requirements,** under the conditions for the disruptors outlined in **Section A.3.3, Resilience Performance Requirements and Goals** (i.e., extreme storms, coastal flooding, extreme precipitation, extreme heat, and pandemic/disease). The performance goals include design thresholds to build assets/infrastructure such that there are no damages and no disruption in critical functionality under specified conditions for each disruptor. If those conditions are exceeded, there are secondary performance goals to manage and minimize disruptions such that critical functionality is restored in a quick and safe manner to minimize risk to the bus maintenance facilities and MBTA workforce.

Strategies to meet these performance goals in design and operations/maintenance planning will vary based on the Project site and conditions. Several strategies specific to structural elements are included in the following subsections by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

3.3.4.1 Extreme Storms

Exposure of non-resilient designs to extreme storms (e.g., snow, ice, nor'easters, extreme wind, and hurricanes) could result in accelerated deterioration of and damage to structural elements (e.g., roofing, building envelope, foundations) due to exceeded snow, ice, and wind loads.

Possible structural design strategies include the following:

- Secure elements that could become debris during an extreme storm event
- Resilient roofing design with heating pads to de-ice and remove snow
- Design breakaway walls in coastal flood areas for storm surge due to nor'easter events
- Select corrosion-resistant materials

3.3.4.2 Coastal Flooding

Exposure of non-resilient designs to coastal flooding could result in accelerated deterioration and possible structural damages due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment.

If the site is exposed to current and/or future coastal flooding, structural design will meet the resilience performance goals under the coastal flooding conditions outlined in **Appendix A Section A.3.3, Resilience Performance Requirements and Goals**. Possible structural design strategies include the following:

- Elevate critical structural features above design flood elevation.
- Relocate critical structural features out of flood zones as possible.
- Provide permanent site perimeter protection from floodwater.
- Reinforce exposed structural elements to resist direct flood action and hydrostatic pressures.
- Implement breakaway walls.
- Design and construct deep foundations in flood zone.

3.3.4.3 Extreme Precipitation

Exposure of non-resilient designs to extreme precipitation and associated flooding from stormwater and/or riverine conditions could result in flooding of basement facilities or accelerated deterioration (e.g., rot, buckling) and possible structural damages to building foundations, columns, trusses, beams, and other structural elements. Possible structural design strategies include the following:

- Elevate structural elements out of design flood elevations.
- Dry floodproof and reinforce walls.
- Install permanent flood barriers around site to mitigate flooding.
- Secure elements that could become debris during flooding.
- Design a resilient roofing option: blue roofs to temporarily store water, green roofs to mitigate stormwater flooding, white roofs to mitigate extreme heat.
- Select corrosion-resistant materials.

3.3.4.4 Extreme Temperatures

Exposure of non-resilient designs to extreme temperatures could result in thermal expansion of exposed columns, trusses, beams, and structural materials. Possible structural design strategies include the following:

- Install adequate exterior shading structures.
- Consider reflective materials and solar facades.
- Consider resilient green/white roof design to mitigate extreme heat and/or urban heat island effects for general building envelope and site.
- Identify structural members that are sensitive to thermal expansion and develop operations and maintenance plan for mitigating heat and cold impacts.

3.4 Mechanical

HVAC systems and equipment will be designed to meet the requirements outlined in the following subsections. The designer will consider health and safety, resilience, and energy efficiency when making final decisions that are not dictated by code.

3.4.1 Code, Standards, and Regulations

The design will adhere to the latest versions of the following codes, standards, and regulations as applicable:

- American Conference of Governmental Industrial Hygienists *Industrial Ventilation Handbook*
- Massachusetts State Building Code
- International Mechanical Code, edition referenced in the Massachusetts State Building Code
- IECC, edition referenced in Massachusetts Building Code
- ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential*
- ASHRAE Standard 55, *Thermal Environment Conditions for Human Occupancy*
- ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*
- Sheetmetal and Air Conditioning Contractors National Association Guidance
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals

The mechanical engineer is responsible for coordinating with the Project Team to help ensure compliance with the following LEED requirements as applicable to each project:

- IP Credit *Integrated Process*
- EA Prerequisite and Credit *Fundamental Commissioning and Verification*
- EA Prerequisite and Credit *Enhanced Commissioning*
- EA Prerequisite *Minimum Energy Performance*
- EA Credit *Optimize Energy Performance*
- EA Prerequisite *Fundamental Refrigerant Management*
- EA *Enhanced Refrigerant Management*
- IEQ Prerequisite *Minimum Indoor Air Quality*
- IEQ Credit *Enhanced Indoor Air Quality Strategies*
- EQ Credit *Low Emitting Materials*
- EQ Credit *Thermal Comfort*
- EQ Credit *Acoustic Performance*

3.4.3 Design Requirements

3.4.3.1 Set Points

Outdoor (ambient) conditions used for calculating the design (peak) load for HVAC systems will be based on weather data published in ASHRAE Handbook-Fundamentals (latest edition) for Climate Zone 5A (Logan Airport). Future climate conditions as stated in the resilience performance goals will be accounted for.

Indoor design conditions that are to be maintained within the building are outlined in **Table 3.4-1**.

Table 3.4-1. Indoor Design Conditions

Room Type	Summer Dry Bulb (˚F)	Summer Relative Humidity (percent)	Winter Dry Bulb (˚F)	Winter Relative Humidity (percent)
Administrative	75 ± 2	Not controlled	70 ± 2	Not controlled
Bus Storage	Not controlled	Not controlled	55 ± 4	Not controlled
Maintenance Area	80 ± 5	Not controlled	55 ± 4	Not controlled
Utility Rooms	Not controlled	Not controlled	55 ± 2	Not controlled
Parts/General Storage	Not controlled	Not controlled	55 ± 2	Not controlled
Fueling Bays	Not controlled	Not controlled	55 ± 4	Not controlled
Bus Wash	Not controlled	Not controlled	55 ± 4	Not controlled

Note:
˚F = degree(s) Fahrenheit

3.4.3.2 Thermal Comfort

Design regularly occupied spaces to meet ASHRAE 55 Thermal Comfort Conditions for Human Occupancy, with errata; all applicable office, conference, and congregation areas will meet these criteria, though it is noted that maintenance areas are not always able to comply in their entirety.

Additionally, provide individual thermal comfort controls for at least 50% of individual occupant spaces; provide group thermal comfort controls for all shared multi-occupant spaces. The controls will allow occupants to adjust at least one of the following in their local environment: air temperature, radiant temperature, air speed, and/or humidity.

Refer to LEED EQ Credit *Thermal Comfort.*

Display

Real-time display of dry-bulb temperature and relative humidity is made available to occupants through at least one monitor screen prominently positioned at the height of 3.6–5.6 feet per 10,000 square feet of regularly occupied space.

3.4.3.3 Indoor Air Quality

Maintain indoor conditions at a minimum level of quality, via compliance with ASHRAE Standard 62.1, Sections 4 through 7. In addition to the requirements of ASHRAE 62.1, include the use of minimum-efficiency reporting value (MERV) 13 (minimum) filtration for all equipment providing outside air to the Project building and the use of negative pressurization in spaces containing hazardous gases or chemicals (e.g., cleaning materials).

Refer to LEED IEQ Prerequisite *Minimum Indoor Air Quality* and LEED IEQ Credit *Enhanced Indoor Air Quality Strategies.*

3.4.4 Energy Source and Efficiency

The designer will strive to eliminate or minimize use of fossil fuel heating equipment and incorporate electric equipment to the extent possible in consideration of heating demands and electric loads of the facility, as per MA Executive Order 594. Where fossil fuel heating equipment is used, equipment will use natural gas. The designer will demonstrate due diligence on providing electric heating and present justification if not feasible. The designer will also incorporate hybrid-powered systems, provided they do not use oil, if electric heating alone cannot satisfy the building load.

3.4.4.1 Energy Performance

Efficiency of the building systems and equipment included in the design and installation will conform with the latest version of IECC, as amended by MA Energy Code and ASHRAE Standard 90.1 (which is a standard that has been adopted in Massachusetts state code) and with the Stretch Energy Code (which is required by the City of Boston and in most Boston-area municipalities).

The mechanical engineer will collaborate with the electrical and structural engineers and architect to provide for building systems and equipment that are more efficient than the baseline building systems and equipment, with verification via "…energy simulation of efficiency opportunities, past energy simulation analyses for similar buildings, or published data…from analyses for similar buildings."

In addition, general requirements include the following:

- Where spaces served do not have dedicated exhaust systems or high levels of moisture or contamination, air-handling systems will be provided with some form of heat recovery. Spaces that do have dedicated exhaust systems or high levels of moisture or contamination will strive to incorporate heat recovery without cross-contamination.
- All air-handling equipment that provides mechanical cooling will have an airside economizer.
- All spaces without 24/7 occupancy or ventilation loads will implement HVAC controls, such as timeclock controls or demand-controlled ventilation. All spaces with 24/7 occupancy or ventilation loads will implement HVAC controls where possible, such as occupancy sensors.
- Any equipment serving year-round cooling loads will have controls that provide for free cooling during the cooling season.
- All boilers will be condensing type.
- All-electric motors will be premium efficiency type.
- Energy metering for HVAC systems will be reported to the Enterprise Energy Management System and Building Automation System (BAS) in accordance with *LEED v4/4.1* EA Cr 3 Advanced Metering.
- Design solutions that mitigate airborne pathogens and increase health benefits are allowed to take precedence over energy efficiency when approved by MBTA.
- N+1 redundancy will be used where feasible or at the request of MBTA.

Refer to LEED EA Prerequisite *Minimum Energy Performance*, and *Credit Optimize Energy Performance*.

3.4.4.2 Reducing Operational Carbon

The mechanical engineer will coordinate with the civil, structural, and electrical engineers, and architecture team to address the goal to move toward net-zero carbon in a holistic manner. In addition to other design aspects, mechanically focused required considerations include the following (full descriptions are detailed in **Appendix A**):

- Envelope airtightness - Account for air barrier performance in system sizing

- High thermal performance of envelope assemblies, including slab/floors and glazing
- Energy recovery/ventilation - Provide required ventilation with efficient dedicated outside air units with energy recovery
- Efficient building systems - Collaborate with other disciplines to minimize loads to downsize HVAC equipment

Refer to LEED EA Prerequisite *Minimum Energy Performance* and Credit *Optimize Energy Performance*.

3.4.5 Building Space Requirements

The following sections detail requirements for spaces not covered in ASHRAE 62.1. The mechanical engineer will take into consideration the design condition requirements, energy source and efficiency requirements, and the following standards to identify strategies for review with the MBTA for providing heating, cooling, and ventilation in the different types of building spaces in a cost-effective and operationally beneficial manner. **Table 3.4-2** shows the building space requirement.

Table 3.4-2. Building Space Requirement

Space Type	HVAC Loads	Code CFM/sf	Other
Bus storage	HV	0.75	100% makeup air with energy recovery
Bus maintenance	HVAC	1.00	100% makeup air with energy recovery; direct exhaust source capture system for fossil fuel buses The bottom(s) of the exhaust openings in fuel dispensing areas will be located not more than 18 inches above the floor. Exhaust airflow will be provided with an equal quantity of makeup airflow, as recirculation is not allowed. Makeup airflow will be heated as required to maintain the indoor design.
Fueling and Bus Wash Bays	HV	1.5	The bottom(s) of the exhaust openings in fuel dispensing areas will be located not more than 18 inches above the floor. Exhaust airflow will be provided with an equal quantity of makeup airflow, as recirculation is not allowed. Makeup airflow will be heated as required to maintain the indoor design temperature.
Welding Operations	HV		Ventilation of welding operations will be in conformance with the American Conference of Governmental Industrial Hygienists *Industrial Ventilation Handbook*.

Notes:
CFM/sf = cubic feet per minute per square foot
HV = heating and ventilation
HVAC = heating, ventilation, and air conditioning

3.4.6 HVAC Equipment Standards

3.4.6.1 General Requirements

Refrigerant Management

The HVAC and refrigerant equipment will reduce stratospheric ozone depletion via the use of nonchlorofluorocarbon-based refrigerants in all new equipment. Ideal systems will use refrigerants with an ozone depletion potential of zero and a global warming potential of less than 50 when available.

Refer to LEED EA Prerequisite *Fundamental Refrigerant Management* and Credit *Enhanced Refrigerant Management*.

<u>Acoustics and HVAC Equipment</u>

For all occupied spaces, achieve maximum background noise levels from HVAC systems per 2011 ASHRAE Handbook, HVAC Applications, Chapter 48, Table 1 or Air Conditioning, Heating, and Refrigeration Institute Standard 885-2008, Table 15. Comply with design criteria for HVAC noise levels resulting from the sound transmission paths listed in ASHRAE 2011 Applications Handbook, Table 6. Engage an acoustician as needed.

Refer to LEED EQ Credit *Acoustic Performance*.

3.4.6.2 Air-handling Units

These units, including packaged rooftop units (RTUs), will be commercial-grade units with components selected for durability. Cooling coils (if included) will be provided with stainless-steel coil casings and drain pans. If gas-fired, heat exchangers will be stainless-steel. RTUs will be provided with variable frequency drives. Packaged RTUs will be provided with airside economizers with return/exhaust fans.

3.4.6.3 General Exhaust Fans

These units will be commercial-grade centrifugal fans with spun aluminum unit covers, with integral disconnects and will be provided with variable frequency drives.

3.4.6.4 Source Capture Exhaust Systems

These systems will be provided with industrial-grade fans with hose-reel kits with connections selected to properly connect to the buses in use.

3.4.6.5 Air Curtains

An air curtain with high thermal performance will be provided at each overhead door. These devices will be selected to provide for insect and wind control.

3.4.6.6 Boilers

If natural gas heating equipment is used, boiler(s) will be commercial-grade, high-efficiency condensing type with integral controls.

3.4.6.7 Unit Heaters

Where heaters are used to serve open spaces such as storage or loading docks, they will be horizontal propeller type, with one of the following heating sources:

- Hot water, where there is a boiler plant
- Electric, in moisture sensitive spaces
- Indirect gas-fired, where natural gas is available and there is no boiler plant

Where heaters are used to serve spaces such as stairwells, they will be wall- or floor-mounted type with hot-water coils where there is a boiler plant, or with electric heating elements if there is no boiler plant.

3.4.6.8 Ductwork

Ductwork systems will be suitable for the service and meet the following requirements:

- Galvanized, 2-inch pressure class for general supply and exhaust, SMACNA Duct Construction
- Aluminum, 2-inch pressure class for spaces with high moisture levels, such as toilet room exhaust, locker/shower exhaust, supply and exhaust to/from bus wash, SMACNA Duct Construction

- Galvanized, 3-inch pressure class in variable volume supply ducts upstream from variable air volume (VAV) terminal units, SMACNA Duct Construction
- Piping systems will be suitable for service with hot-water heating piping at 125 pounds per square inch gauge at 200˚F.

3.4.7 Building Automation System

The BAS will monitor and control all major equipment, including lighting and electrical system, plumbing system, HVAC and rooftop units, vents and exhaust fans, fire and emergency systems, elevators, and other mechanical systems. Alarms will be provided to ensure safe operation of all equipment and alert building personnel in the event of system failure. This system should enable both remote and local control over the building systems and allow for automated routines and setpoints to be established. The system should be a non-proprietary, open system able to push and pull data via an API. Refer to **Section 3.5.3.3, BEB Charge Management System,** for data transfer capabilities.

3.4.8 Commissioning

The purpose of commissioning services is to ensure that the equipment and systems are installed properly and are functioning as intended, in accordance with ASHRAE Guideline 0 and ASHRAE Guideline 1.1. Additional services expand the roles and responsibilities of the commissioning authority, to ensure that the design and its execution are in compliance with the Owner’s Project Requirements and/or with the BOD, the Operating Personnel are trained in the use of the equipment, and that the equipment is tested and is operating in accordance with the design in different seasons.

The mechanical contractor will be responsible for supporting the commissioning authority, via provision of the services of the subcontractors (including the controls contractor and the test/balance contractor) during the functional performance testing of the HVAC system/equipment.

The building envelope will be commissioned in addition to the mechanical, plumbing, and electrical systems. This is required due to the importance of the correct installation of the weather-resistive barrier, the air barrier, the insulation, the sheathing, the façade, and the flashing to building energy consumption, durability, and occupant comfort. The building envelope commissioning will be performed by a Building Enclosure Commissioning Specialist.

Refer to LEED EA Prerequisite and Credit *Fundamental Commissioning and Verification* and *Enhanced Commissioning*

3.4.9 Resilient Design Considerations

Mechanical design will consider the resilience performance goals included in **Appendix A, Section A.3, General Resilience Requirements,** under the conditions for the disruptors outlined in **Section A.3.3, Resilience Performance Requirements and Goals** (i.e., extreme storms, coastal flooding, extreme precipitation, extreme heat, and pandemic/disease). The performance goals include design thresholds to build assets/infrastructure such that there are no damages and no disruption in critical functionality under specified conditions for each disruptor. If those conditions are exceeded, there are secondary performance goals to manage and minimize disruptions such that critical functionality is restored in a quick and safe manner to minimize risk to the bus maintenance facilities and MBTA workforce.

Strategies to meet these performance goals in design and operations/maintenance planning will vary based on the Project site and conditions. Several strategies specific to mechanical elements are included in the following subsections by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

3.4.9.1 Extreme Storms

Exposure of non-resilient designs to extreme storms (e.g., snow, ice, nor'easters, extreme wind, and hurricanes) could result in accelerated deterioration due to impact from extreme storm debris or system damages due to exceeded snow, ice, and wind loads. Possible mechanical design strategies include the following:

- Seal, insulate, and secure elements (e.g., intake and exhaust louvers and dampers, exposed ductwork)
- Select corrosion-resistant materials
- Provide redundancy in mechanical systems through standby units as needed

3.4.9.2 Coastal Flooding

Exposure of non-resilient designs to coastal flooding could result in accelerated deterioration and possible damages to HVAC and mechanical systems due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment. If the site is exposed to current and/or future coastal flooding, mechanical design will meet the resilience performance goals under the coastal flooding conditions outlined in **Appendix A**. Possible mechanical design strategies include the following:

- Elevate mechanical systems above design flood elevation.
- Relocate critical mechanical systems out of flood zones as possible.
- Building features that are not located above the base flood elevation will be designed to withstand the corresponding hydrostatic pressure or protected from the flood hazard.
- Provide redundancy in mechanical systems through standby units as needed.
- Seal, insulate, and secure elements (e.g., intake and exhaust louvers and dampers, exposed ductwork).

3.4.9.3 Extreme Precipitation

Exposure of non-resilient designs to extreme precipitation flooding from stormwater and/or riverine conditions could inundate HVAC systems with water and cause short/long-term air quality issues, leakage into occupied spaces, and potential equipment failure. Possible mechanical design strategies include the following:

- Elevate mechanical rooms above design flood elevations.
- Dry floodproof entrances that lead to mechanical rooms.
- Install floor guard connections to floor drains and under slab drains in mechanical room to prevent backflow and flooding.
- Install an exterior duplex pump system to remove water in sub-floor trenches.
- Seal, insulate, and secure elements (e.g., intake and exhaust louvers and dampers, exposed ductwork) that could serve as pathways for excess runoff during flood events.
- Move outside air intakes and exhaust to roof.
- Wet floodproof critical systems with waterproof membranes or sealants.
- Provide redundancy in mechanical systems through standby units as needed.
- Consider backflow preventers.

3.4.9.4 Extreme Temperatures

Exposure of non-resilient designs to extreme temperatures could result in the following consequences:

- Accelerated deterioration of mechanical systems, leading to higher maintenance demands and shorter service life
- Evaporative-cooled systems will require greater amounts of water in heat extremes
- High ambient humidity will result in larger amounts of interior condensate and may stress drainage systems
- Reduced efficiency of cooling cycles and additional energy requirements to operate

Possible mechanical design strategies include the following:

- Design air-handling units with heat recovery.
- Install electrical condensate evaporation and/or supplemental evaporative cooling for HVAC systems.
- Provide redundancy in mechanical systems through standby units as needed.
- Consider dedicated outside air systems to directly address the outside environment entering the building.
- When designing to future anticipated higher climate temperatures, consider an incremental approach (splitting the design load between multiple pieces of equipment) to ensure equipment operates in its most efficient zones when temperatures are not elevated.

3.4.9.5 Diseases/Pandemic

Exposure of non-resilient designs to disease/pandemic could increase the consequence of air quality issues and inherent spread of diseases. Possible mechanical design strategies include the following:

- Design mitigation for airborne pathogens as part of HVAC design strategy (improving health performance is allowed to take precedence over energy efficiency).
- Consider emergency alternatives and shut-off pathways for air flow.
- Consider sanitation and cleaning requirements in mechanical system design.
- Provide a holistic plan for air movement paying attention to air migration and space pressurization.
- Consider disinfection alternatives such as ultraviolet and bipolar ionization.

3.5 Electrical

Electrical systems will be designed to meet the requirements outlined in the following subsections. The electrical distribution will be designed for the maximum level of safety and convenience. Electrical design will provide an electrical system integrated with the requirements for mechanical, plumbing, fire protection, industrial equipment, architectural design intent, and the facility service needs. MBTA needs in terms of future adaptability of the spaces and current flexibility of use will be carefully considered as well as the level of user comfort, as determined by the availability and adequacy, seismic, and sustainability requirements. The designer will also consider resilience criteria as described in more detail in **Appendix A.**

3.5.1 Codes, Standards, and Regulations

The design will adhere to the latest versions of following codes, standards, and regulations as applicable:

- MBTA Design Directive *Design Lighting Levels and Fixtures*
- NFPA 70
- National Electrical Code (NEC) with 527 CMR 12, *Massachusetts Electrical Code (amendments)*
- NFPA 70E, *Electrical Safety Requirements for Employee Workplaces*
- NFPA 780, *Lightning Protection System*
- NFPA 79, *Electrical Standard for Industrial Machinery*
- NFPA 101, *Life Safety Code*
- NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations*
- ASME-17.1 Massachusetts Board of Elevator Regulations – 524 CMR
- ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential*
- IECC
- AASHTO Standard Specifications for Structural Supports
- Energy Executive Order 484, *Leading by Example – Clean Energy and Efficient Buildings*
- Energy Executive Order 569, *Establishing an Integrated Climate Change Strategy for the Commonwealth*
- Executive Order 594, *Leading by Example: Decarbonizing and Minimizing Environmental Impacts of State Government*
- Massachusetts Base Energy Code
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals

The electrical engineer is responsible for coordinating with the Project Team to help ensure compliance with the following LEED requirements as applicable to each project :

- IP Credit *Integrated Process*
- SS Credit *Light Pollution Reduction*
- EA Prerequisite and Credit *Fundamental Commissioning and Verification and Enhanced Commissioning*
- EA Prerequisite *Minimum Energy Performance*

- EA Credit *Optimize Energy Performance*
- EA Prerequisite and Credit *Advanced Energy Metering*
- EA Credit *Renewable Energy*
- MR Credits *Building Product Disclosure Information*
- EQ Credit *Low Emitting Materials*
- EQ Credit *Interior Lighting*
- Pilot Credit *Inclusive Design*

3.5.2 Electrical System

3.5.2.1 Incoming Electrical Service Requirement

Each facility will be supplied from local utility power at medium voltage.

The power interface will be via utility "Outdoor Customer" substations which will be located exterior to the facility and the MBTA medium-voltage switching station or electrical room. A minimum of two independent incoming utility lines will be provided sized and rated based on facility demands.

Each utility "Outdoor Customer" substation will include utility switching and metering equipment and will provide power to the MBTA switching station or medium-voltage electrical room for the facility.

The external "Outdoor Customer" substation will meet local power utility standards and requirements and at minimum be enclosed within a fenced compound complete with ground grid, lighting, full access, foundations, duct banks and any remote monitoring equipment needed.

Design requirements will be coordinated between the MBTA, local power utility and final designer.

Designer will provide the expected facility demand and peak loads to the utility in consultation with the MBTA. The loads will be provided for the electrical fleet charging systems considering plans for expansion plus the facility expected loads. Exact quantity of BEBs that can be charged will be based on MBTA operations requirements and power systems that can be provided to each site and the building. Careful consideration will be made for building demand, diversity of electrical systems, building operations, and the Project program.

Final designer will ensure the power factor is greater than 90%, or as dictated by the local utility.

3.5.2.2 MBTA Switching Station or Medium-voltage Electrical Room

An MBTA switching station or switching station electrical room will be provided at each facility. The switching station will power the overall facility (**Section 3.5.2.3, Maintenance Facility Power**) as well as the BEB charging systems (**Section 3.5.3, Bus Charging System**).

The switching station room can be integrated into the facility building as its own medium-voltage electrical room or may be a separate external facility, prefabricated or built-in-place.

The switching station will house withdrawable medium-voltage switchgear per MBTA standards, controls, control power, and supervisory control and data acquisition (SCADA), as required for each facility. The equipment will be grounded in accordance with MBTA requirements to the building facility ground or independent switching station ground grid.

The switchgear will comprise of all circuit breakers, relaying, protection, and controls per MBTA power department requirements. Spare breakers will be provided for future expansion. The switchgear will be arranged to be controlled by a local substation automation system which will provide interface to the SCADA system for remote monitoring and controls. The local automation control system will be located adjacent to the switching station entry doorway. Safe means of egress will be provided via a minimum of two exits or as required by relevant standards and codes. Additionally, the switching station will be provided with a roll up door to provide equipment delivery and removal. Roll up door will have a clear access path to an external loading/delivery area.

The incoming power lines will be connected to separate medium-voltage buses within the medium-voltage switchgear. The switchgear will be provided in a tie breaker in a Main-Tie-Main configuration with automatic closure of the bus tie breaker in the event of loss of either incoming line. Each incoming line will provide full redundancy for meeting the normal power demands of the facility.

The electrical room or switching station house will be provided with a direct-current (DC) stationary battery system which will be used to control, monitor, and operate all power equipment. An auxiliary transformer or facility low-voltage power system will provide low-voltage alternating-current (AC) power for heaters, lighting, and other auxiliary power.

The DC battery system will provide the substation equipment to operate for a minimum of 8 hours of normal operation. A battery system emergency eye wash station will be provided. For a switching station within the facility the eye wash station will be interconnected to the facility plumbing system. For separate prefabricated switching stations these may be plumbed or comprise of a stationary self-contained unit subject to acceptance by the MBTA. The designer will accommodate the requirements for providing tempered water for the eye wash unit. Continuous exhaust fans will be provided in the battery areas to avoid accumulation of any potential battery charging gases and to avoid classification as a hazardous location. An air collection hood may be located over the batteries as needed to satisfy requirements.

Each switching station will be provided with a backup source of power. This may comprise use of the facility backup generators or may be facilitated by the provision for connecting a portable generator located in an accessible area.

The designer will provide equipment layouts of all rooms related to the switching station equipment. Design will accommodate all necessary access paths, maintainer parking areas, working clearances in addition to a minimum of 8-foot operating clearance in front of the switchgear, grounding, and safety provisions. Additionally, for medium-voltage electrical rooms within the facility, the designer will coordinate all lighting, access/egress, heating and ventilation, equipment weights, cable distribution with the architect, MEP, fire alarm and structural design teams.

Switching station access doors will also be provided with MBTA security system controls.

The switching station will be provided with an energy management system per the MBTA requirements.

For switching station buildings separate from the main maintenance facility will be designed to be resilient from potential environmental incidents including earthquakes, floods, and other natural and manmade issues.

3.5.2.3 Maintenance Facility Power

Circuit breakers at the switching station will provide power to double-ended unit substations to power the facility. Each double-ended unit substation will receive power from two separate medium-voltage buses.

Double-ended substations will be provided per MBTA standard specifications. The unit substations will be configured in a Main-Tie-Main configuration to afford redundancy for MBTA operations with automatic closure of the bus tie breaker in the event of loss of either incoming line. Secondary main breakers, the tie breaker, and feeder breakers will be power circuit breakers.

The double-ended substations will comprise incoming load break fused disconnect switches, step-down transformers (dry-type cast coil) and 480-volt (V) distribution circuit breakers. Spare breakers will be provided for future expansion.

The double-ended substations will be located indoors within the facility within dedicated electrical rooms. Designer will locate the electrical rooms with consideration of proximity to the electrical loads, consideration of minimizing cabling requirements and affording the necessary normal and emergency access.

The quantity and rating for the unit substation(s) will be developed by the designer in accordance with the connected loads and system redundancy requirements. Where possible a standard rating will be used through the facility. Designer will identify the expect fault ratings of the equipment to ensure adequate dimensions are utilized within the design.

The double-ended unit substations will service all the facility power requirements and be integrated with the emergency and standby power systems required for the facility.

The unit substations will be configured for remote monitoring and control by the MBTA SCADA system. The unit substation will be controlled via a local monitoring and control station. The local automation control system panel will be located adjacent to the switching station entry doorway. Safe means of egress will be provided via a minimum of two exits or as required by relevant standards and codes. Additionally, the switching station will be provided with a roll up door to provide equipment delivery and removal. Roll up door will have a clear access path to an external loading/delivery area.

The equipment control power will be 120-V AC, 60 hertz (Hz), or 125-V DC. If designer elects to use 125-V DC power, then a DC battery system will be provided similar to that identified for the medium-voltage switching station.

The designer will provide equipment layouts of each and all dedicated electrical rooms. Design will accommodate all necessary access paths, maintainer parking areas, working clearances, grounding and safety provisions. Additionally, for facility electrical rooms within the facility designer will coordinate all lighting, access/egress, heating and ventilation, equipment weights, cable distribution with the architect, MEP, fire alarm and structural design teams.

The size of the electrical room(s) will be designed according to the NEC and Massachusetts amendments to meet the low-voltage switchgears size and capacity layout, facility requirement, need, and flexibility. Submeters will be required to monitor different floors and practices (lighting, chillers, etc.) for sustainability consideration. The number of submeters will be further discussed per each site with MBTA.

The electrical system will be distributed at the necessary voltage to supply the equipment throughout the facility. Automatic transfer switches, manual transfer switches, step-down transformers, distribution panels, conduits, raceways, and cabling will all be provided. Designer will tabulate all expected facility loads and size all cables, conduits, and raceway systems. Refer to **Section 3.5.4, Low-voltage Distribution**.

3.5.2.4 Medium-voltage Power Distribution

The medium-voltage distribution from the switching facility (if separate to the facility) to the bus maintenance facility will be routed via concrete encased reinforced duct banks and maintenance holes. Feeders will be routed independently from each medium-voltage bus to the facility to ensure redundancy is maintained. Conduits will be sized as required but will not be less than 5-inch conduits for medium-voltage circuits. Maintenance holes will be spaced at not more than 350 feet apart and will be suitably sized per electrical codes and MBTA standards. The switching station facility will be designed to be resilient from potential environmental incidents including earthquakes, floods, and other natural and manmade issues. Distribution to the facilities or the unit substations, will be separated where Side 1 will be in one set of maintenance holes and Side 2 will be in another set of maintenance holes, to provide complete redundancy during outages and maintenance.

All power cabling will be copper.

If directed by the MBTA, each low-voltage substation will be equipped with a high-resistance ground system. The benefit of the high-resistance ground is not having to trip on the first ground fault, which will avoid unplanned shutdowns. The low-voltage substations will be provided with ground-fault detection systems to allow a ground fault to be found and removed. An additional benefit of the high-resistance ground is the reduction of arc flash hazard caused by ground fault.

3.5.2.5 Metering Energy Systems

The Project will install new building-level energy meters, or submeters that can be aggregated to provide building-level data representing total building energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass, etc.) on a 15-minute interval. Utility-owned meters capable of aggregating building-level resource use are acceptable.

Additionally, the design will include advanced energy metering per the requirements outlined in LEED EA Prerequisite and Credit *Advanced Energy Metering.*

3.5.2.6 Emergency and Optional Standby Generators

Diesel-powered generators will be provided for emergency and standby power.

- An emergency generator will be provided as required by code to serve life safety and emergency systems.
- Hooks ups for mobile standby generators will be provided to serve selected general building electrical loads.
- Emergency and standby generators will either be Tier 2 or Tier 3 (depending on size) to meet EPA emissions standards. Assumes generators will not be used to participate in a demand/response program.

Standby power is intended to allow much of the facility to operate in case of loss of power. It is assumed that the maintenance functions would continue as feasible. However, the following elements are not planned to be on backup power:

- BEB charging, due to the high electrical loads
- Non-essential high-load functions such as welding equipment

Stationary generators will be monitored by the MBTA's SCADA system.

The emergency generator for life-safety equipment will be at the facility in a self-contained, weatherproof, sound attenuated walk-in enclosure and designed to comply with NEC Article 700 with Massachusetts amendments and NFPA 110 - Emergency & Standby Power. The designer will work with MBTA to determine the exact location and size of the generator at each site and comply with all current related MBTA specifications and Design Directives for final design approval.

The emergency generator will provide power during outages to enable evacuation of the facility during the temporary outage. In addition to the emergency generator, provisions will be made in the design for a portable generator with a quick power connection and manual transfer switch to connect to the life-safety emergency distribution system for additional system redundancy.

The emergency generator will feed power to the life-safety automatic transfer switch (ATS) to provide power to life-safety loads. When an ATS senses a loss of normal power, it will send a signal to start the generator. The ATS will then transfer the load from the normal source to the emergency source. When normal power has returned, the ATS will make a closed transition transfer from the emergency source to the normal source. The ATS will then send a signal to shut down the generator.

Electrical rooms housing life-safety equipment, electrical equipment for life-safety loads, and associated feeders will be installed according to NFPA fire rating requirements. The emergency distribution system will consist of a main distribution for each branch of protection. During a normal power outage, the loads will not experience power interruption longer than the duration specified by NEC.

The loads connected to the emergency generator include the following:

- Egress and emergency exit Lighting
- Fire alarm panel
- Fire pump and jockey pumps
- Fire elevators, if provided
- Automatic sprinkler system
- Smoke exhaust fans
- Fire suppression system

A mobile standby generator will provide power during outages to enable much of the facility to operate normally. Determination of the loads to be standby generator supplied will be developed by the designer for acceptance by the MBTA. Provisions will be made in the design for a portable generator with a quick power connection and manual transfer switch to connect to the facility electrical distribution system for additional system redundancy.

The loads connected to the mobile standby generator include the following:

Maintenance Service and Repair Equipment

- Fluid servicing lanes and support areas
- Maintenance bay vehicle lifts
- General machine shop and maintenance repair bays equipment
- Tire shop and storage

HVAC System

- As noted in Section 3.5.2.6, Emergency and Optional Standby Generators, the standby power is intended to allow much of the facility to operate in case of loss of power. It is assumed that the maintenance functions would continue as feasible. It is expected that the following assumptions will be reviewed and confirmed by the MBTA during the stakeholder review workshops:
  - HVAC systems will typically be on standby power, with the following exceptions:
    - Non-essential office area heating, cooling, and ventilation
    - Heating and exhaust at the wash and steam bays
    - Non-essential cooling
    - The bus storage area regular HVAC (however exhaust fans for smoke purge should be on standby power)

Plumbing Systems

- Emergency diesel generator fuel tank leak detection and heater
- Basement equipment including elevator sump pumps, sewer ejectors, and stormwater pumps
- Upper floor selected equipment to serve maintenance personnel, including selected water heaters.

General Lighting and Power (Beyond Emergency Lighting)

- Building Management System
- Charge Management System
- Data and communications systems
- Fluid servicing area and shifters' work area
- Inspectors' offices
- Transportation and maintenance management offices
- Bus storage
- Exterior and interior overhead door operators for bus vehicles
- Operations control rooms

Communication and Security Systems

- Uninterruptable power supply (UPS) systems
  - Server/data communications rooms and closets
  - Information technology (telephone/data equipment)
  - Building management system
  - Building electronic access control system
  - Building video surveillance system
  - Building bidirectional antenna and distributed antenna systems
  - SCADA systems
  - Information technology (IT) wide area network (WAN) node
  - Security wide area network (SWAN) node
  - Verizon demarcation equipment
  - Power equipment (power distribution units, panels, from UPS system)

Per MBTA Design Directives, all generators will be sized with a future capacity of 30% over the base calculated values unless a waiver is requested and granted.

In addition, the generator fuel supply systems will be sized to allow for a minimum run time of 24 hours under full load.

Generator installations will be designed to be resilient from potential environmental incidents including earthquakes, floods, and other natural and manmade issues.

3.5.2.7 Uninterruptable Power Supply

Rack-mounted UPS' will provide backup power for critical and other non-motor loads, such as IT equipment and security systems, that cannot tolerate a power interruption. Separate UPS units will be provided to power the following loads without interruption when normal power is lost:

- Server/data communications rooms
- IT (telephone/data) equipment
- Building Management System

Battery capacity will be a minimum of 30 minutes and battery monitoring will be provided.

Each UPS will be supplied by the generator backed power system as identified previously using a separate ATS.

Each UPS will be located in a climate-controlled room and will be designed to be resilient from potential environmental incidents including earthquakes, floods, and other natural and manmade issues.

3.5.3 Bus Charging System

3.5.3.1 BEB Unit Substations

Circuit breakers at the switching station will provide power to double-ended unit substations to power the BEB charging systems (double ended is preferred, unless otherwise directed by MBTA). Transformer capacity will be standardized at 3MW; however, will be subject to review and evaluation by the designer to justify alternative capacities, citing the benefits to the MBTA. The designer will selectively distribute the bus charging circuits and load evenly across the separate medium-voltage buses of the switching station.

Each substation or substations will be configured similar to the facility double-ended substations and will be provided per MBTA standard specifications. Secondary main breakers, the tie breaker, and feeder breakers will be power circuit breakers.

The unit substations will comprise incoming load break fused disconnect switches, step-down transformers (dry-type cast coil) and 480-V distribution circuit breakers. Spare breakers will be provided for future expansion. Each bus battery charger will be supplied by a 480-V circuit breaker.

The unit substations will be located indoors within the facility within dedicated electrical rooms. Designer will locate the electrical rooms with consideration of proximity to the electrical bus charging loads, consideration of minimizing cabling requirements and affording the necessary normal and emergency access.

The quantity and rating for the unit substation(s) will be developed by the designer in accordance with the connected loads and system redundancy requirements. Where possible a standard rating will be used through the facility and also be similar to capacities used at other facilities, i.e., 3-megavolt-ampere transformers supplying up to 10 charging circuits per transformer, the redundant condition where the loss of one side will still provide enough power for both sides of the unit substation. Other configurations of transformers can be developed but must be approved by the MBTA. Designer will identify the expect fault ratings of the equipment to ensure adequate dimensions are utilized within the design.

The BEB unit substations will service all the BEB charging power requirements and have facility to be supplied via a portable generator in the event of loss of the incoming power supply.

The unit substations will be configured for remote monitoring and control by an MBTA SCADA system. The unit substation will be controlled via a local monitoring and control station. The local automation control system panel will be located adjacent to the switching station entry doorway. Safe means of egress will be provided via a minimum of two exits or as required by relevant standards and codes. Additionally, the switching station will be provided with a roll up door to provide equipment delivery and removal. Roll up door will have a clear access path to an external loading/delivery area.

The equipment control power will be 120-V AC, 60 Hz, or 125-V DC. If designer elects to use 125-V DC power, then a DC battery system will be provided similar to that identified for the medium-voltage switching station.

The designer will provide equipment layouts of each and all dedicated electrical rooms. Design will accommodate all necessary access paths, maintainer parking areas, working clearances, grounding, and safety provisions. Additionally, for the BEB electrical rooms within the facility designer will coordinate all lighting, access/egress, heating and ventilation, equipment weights, cable distribution with the architect, MEP, fire alarm and structural design teams.

Designer will develop the 480-V distribution to each BEB charger. The cabling may be via overhead conduit and raceways systems or may be via embedded concrete encased conduits. Designer will provide conduit routing layouts and ensure that all supports and mounting systems are coordinated with structural and architectural disciplines including structural loading capacity calculations.

The size of the electrical room(s) will be designed according to the NEC and Massachusetts amendments to meet the low-voltage switchgears size and capacity layout, facility requirement, need, and flexibility. Submeters will be required to monitor different floors and practices (lighting, chillers, etc.) for sustainability consideration. The number of submeters will be further discussed per each site with MBTA.

3.5.3.2 BEB Charging Equipment

The BEB charging equipment will comprise of sets of 480-V disconnect switches, Bus DC charger, distribution cabling, bus charging dispensers (overhead pantograph or plug in).

Each set of equipment will be supplied 480-V, 60-Hz, three-phase power from a BEB unit substation.

The incoming 480-V power will be able to be isolated at each charger via an accessible fused disconnect switch.

Bus storage areas will utilize pantograph system charging systems (pantograph down configuration) which will be powered from 180-kW 3-to-1 battery chargers (flex configuration). The charging head will comply with standard Society of Automotive Engineers (SAE) J3105. The overall configuration, layout and required electrical capacity will be developed by the designer to meet MBTA operational requirements. The MBTA will provide the designer the number of buses that will utilize each facility.

Unless otherwise indicated by the MBTA, the designer will anticipate that primarily BEB charging will be completed during evening and nighttime hours and that a minimum of three full charging periods can occur within that period. As a result, the peak BEB loading cycle of the facility can be established based on the quantity of buses.

The designer will develop the charging dispenser and circuit layout based on the bus operations requirements of the MBTA. The three charging dispensers per charger will be grouped or dispersed based on functional and safety requirements. The designer will develop the cabling distribution from each BEB charger to the dispensing units. In the bus storage area, the cabling is expected to be via overhead conduit and raceways systems and will incorporate power as well as control and monitoring cabling as required by the manufacturer. Designer will provide conduit routing layouts and ensure that all supports and mounting systems are coordinated with structural and architectural disciplines including structural loading capacity calculations. Additionally, the designer will ensure that the HVAC systems of the facility include the heat generated from this equipment.

Chargers will be located near the charging heads within the distance recommended by the manufacturer and to minimize cable size and route lengths. Specific to each facility, the chargers may be located in a nearby area, separate nearby room or located in the bus storage area. If within the bus storage area, it is the MBTA's preference to avoid potential damage by not locating the chargers where they may be at risk of damage by moving buses. Designer will ensure that the electrical equipment will be protected from damage from vehicles.

An emergency trip system will be included in the facility to de-energize BEB equipment within a work area (e.g., section of bus storage or bus maintenance bays), subject to MBTA delineation of areas grouped together. All chargers have an off switch to control individual units.

Bus maintenance areas will be supplied with plug-in charging dispensers. The charging plug connections will comply with standard Society of Automotive Engineers (SAE) J1772. The quantity, rating, and configuration will be developed by the designer based on the size and use of the maintenance area and quantity of maintenance bays and the specific usage. At specific areas within each facility, where beneficial to the MBTA, high-capacity chargers may be installed. These chargers, expected to be rated at 360 kW are expected to be utilized for specific buses that have a short layover period at the facility or for buses that cannot otherwise be charged within the main storage area but are required to be placed back into service after a short period. The designer will develop the proposed location(s) for these types of chargers, e.g., fueling area, pass-through lane, head row of storage area, maintenance bay, etc. along with the benefit of each for MBTA consideration and include with the load calculations of the facility.

The guideline is primarily based upon the use of 480-V AC bus charging equipment in order to attempt to standardize facilities, allow for competitive manufacturer prices of alternate products, and facilitate future adaptation or modifications to newer or emerging technologies.

As a result, the MBTA is open to designers proposing alternate technologies and strategies to meet the required overall bus charging objectives to provide reliable services.

3.5.3.3 BEB Charge Management System (CMS)

The facility will be provided with a bus CMS that is compatible with all buses that will utilize the facility. The CMS will be a cloud-based subscription service that controls and manages the connected charger cabinets and dispensers, broadcasts charging information from the charging solution via the OCPP 2.0 or newer protocol and is capable of consuming and integrating all available vehicle, planning, scheduling, and utility information, as well as other data sources. Smart charging features will be included. The CMS will also provide data transfer capability with the BAS to obtain aggregate energy consumption and power demand for the entire charging system on a continuous basis. Refer to **Section 3.4.6, Building Automation System**.

Final design of the CMS will be by the manufacturer and will be presented as a fully coordinated complete design as specified by MBTA.

3.5.4 Low-voltage Distribution

The facility will be fed by low-voltage substations through duct banks, exposed and embedded conduits, and raceways systems distributed throughout the building at a nominal 480/277-V, 60 Hz, three-phase, four-wire with ground. Large loads, such as the chillers, will be fed directly from the double-ended unit substations and will be run in conduit. Normal, emergency and optional standby power feeders will be run in separate conduits.

The secondary power distribution system will be designed to limit voltage drop to a maximum of 2% on feeders and 3% on branch circuits. Power and safety switches will be provided and sized for mechanical equipment, plumbing equipment and fire protection equipment. Power will be provided for elevators, elevator pit receptacles and elevator pit pumps as a provision in the case that they are needed.

Emergency and optional standby power panels will be fed from independent ATS from the separate generators through separate duct banks and conduit systems. Loads with backup power from emergency and optional standby generator(s) will be fed through the respective panels. Normal and backup power feeders will be run in separate conduits.

The design and layout of the distribution panels will be as follows: The lighting circuits will be fed from dedicated lighting distribution panels at 480/277-V, three-phase, four-wire with ground. General convenience outlets and small appliances will be fed from power distribution panels supplied at 208/120-V, three-phase, four-wire with ground. Additional power distribution panels supplied at 480/277-V, three-phase, four-wire with ground will be provided for larger motor loads and equipment requiring 480-V, three phase. The design of this distribution system will be required to be sourced from different transformers and distribution panel boards.

All distribution panels will be fitted with consistent bus bar size and rating throughout and will be from the same manufacturer, with a full-size neutral bus bar and appropriate integral ground bar and surge protection devices. All bussing will be copper throughout the system.

3.5.4.1 480/277-V Power Distribution Panels

Power distribution panels will be distributed throughout the facility to provide localized power distribution for mechanical and plumbing equipment and all MBTA-furnished fixed and portable equipment. Power panelboards of 480 V will be provided for motors (1/2 horsepower and larger), and other heavy loads greater than 5 kW. 277 V will be used for VAV fan terminal units.

Arc flash labeling for electrical systems greater than or equal to 240 V will be provided in accordance with NFPA 70E, Standard for Electrical Safety Workplace. The power distribution panels will contain circuit breakers and copper bussing. The panelboards will be sized with 25% spare capacity (10% spare breakers and 15% spaces for future breakers).

3.5.4.2 Step-down Transformers

The standard 480-V to 120/208-V three-phase transformers will provide unclean power for general distribution on each floor. All transformers will be of K-13 rating.

The designer will work with the MBTA to determine each facility’s requirements for isolated 480-V to 120/208-V three-phase transformers to provide clean power for workstation computers, servers, security services, and audiovisual equipment. An isolated grounding distribution system is recommended for loads such as computers, printers, and data rooms.

Step-down transformers with minimum efficiencies will comply with the latest U.S. Department of Energy regulations for determining energy efficiency for distribution transformers and will be designed for calculated demand plus 25% spare capacity.

3.5.4.3 208/120-V Power Distribution Panels

Receptacle outlets, special lighting, fire alarm system, security systems, communication, motors 1/3 horsepower and less, and other small appliance loads will be wired to 208/120V, three-phase, four-wire panels. For dedicated receptacles and other equipment, 208 V will be provided as required.

Power distribution panels will contain circuit breakers and copper bussing. The panelboards will be sized with 25% spare capacity (10% spare breakers and 15% spaces for future breakers).

3.5.5 Lighting System

Illumination per MBTA Lighting Standard and Design Directive requirements will be provided at all areas to the levels necessary unless applicable building codes require a higher level of illumination.

Lighting distribution panels will be used to feed lighting circuits only. Lighting distribution panels will contain circuit breakers and copper bussing. The panelboards will be sized with 25% spare capacity (10% spare breakers and 15% spaces for future breakers).

3.5.5.1 Reducing Operational Energy Consumption

To reduce operational costs and improve operational flexibility, the designer will ensure the design meets LEED EA Prerequisite *Minimum Energy Performance* and LEED EA Prerequisite and Credit *Optimize Energy Performance.*

To achieve these goals, the Lighting Power Density including task lighting in addition to other operational metrics such as heating and cooling loads will be substantially lower than the ASHRAE baseline. LED lighting will be used throughout. Comprehensive intelligent control lighting including vacancy sensors for office spaces, motion sensors for common areas and dimming sensors for daylit areas will be included.

The plug and process loads will be reduced with built-in control devices or programmable devices sensing the occupancy to deenergize the plug and process loads when the space is vacant and energize when the users are present.

In addition, variable-frequency drives and soft-starters overcurrent protections for larger electrical, mechanical, and plumbing equipment will be designed to reduce the overall operational energy of the building.

For LEED documentation purposes only, the facility will utilize the mandatory Massachusetts Building Energy Code and prescriptive provisions of the American National Standards Institute (ANSI)/ ASHRAE/Illuminating Engineering Society (IES) of North America Standard 90.1–2010 in the associated calculations; 2013, 2016, or 2019 may also be used for documentation via LEED Interpretation #10481 and associated addenda. For additional points, levels of energy performance will be increased beyond the Prerequisite levels to reduce environmental and economic harms associated with excessive energy use.

3.5.5.2 Interior Lighting

Interior lighting will be provided in accordance with MBTA Lighting Standard and Design Directive requirements and the architectural reflected ceiling plans. Areas not covered by the MBTA Lighting Standard and Design Directive will be approved by the Office of the Chief Engineer before installation.

To adhere to MBTA sustainability goals and ensure worker comfort, the designer will ensure the design meets LEED EQ Credit *Interior Lighting*.

3.5.5.3 Interior Lighting Quality

<u>Ensure Color Rendering Quality</u>

Specify lighting fixtures that render color realistically for a comfortable space and healthy environment for users.

- For all spaces except circulation areas, electric lighting will meet at least one of the color rendering requirements in occupied spaces (decorative fixtures, emergency lights and other special-purpose lighting may be excluded from these requirements) shown in **Table 3.51**.

Table 3.5-1. Color Rendering Thresholds

Metric	Threshold
Color Rendering Index	Color Rendering Index ≥ 90
Color Rendering Index, R9	Color Rendering Index ≥ 80 with R9 ≥ 50
IES TM-30-18	IES $R_f \geq 78$, IES $R_g \geq 100$, $-1\% \leq$ IES $R_{cs,h1} \leq 15\%$

Refer to LEED EQ Credit *Interior Lighting, Option 2: Lighting Quality.*

Light Levels for Visual Acuity

All indoor and outdoor spaces (including transition areas) comply with illuminance recommendations specified in the IES Lighting Handbook 10 Edition or IES Lighting Library. Design specifications will include the reference guideline used, illumination levels achieved, and height of work plane or target of illumination.

The architect and electrical engineer will coordinate their design approach to best address this goal. A lighting designer may be consulted if appropriate.

Manage Glare from Electric Lighting

In all regularly occupied spaces, each luminaire will meet one of the following requirements. Wall wash fixtures and task lamps positioned as specified by manufacturer's data, as well as decorative fixtures, may be excluded from meeting these requirements:

- 100% of light is emitted above the horizontal plane.
- Unified Glare Rating values are met as per the following conditions:
  - Luminaires installed at a height of 5 m [16 feet] or lower meet Unified Glare Rating of 19 or lower.
  - Luminaires installed at a height greater than 5 m [16 feet] meet Unified Glare Rating of 22 or lower.

Shielding angles are as described in **Table 3.5-2**.

Table 3.5-2. Electric Lighting Shielding Angles

Luminance	Shielding angle, α (α = 90-degree cut-off angle)
< 20,000 cd/m² (including reflected sources)	No shielding required
20,000 cd/m² to 50,000 cd/m²	15 degrees
50,000 cd/m² to 500,000 cd/m²	20 degrees
> 500,000 cd/m²	30 degrees

Note:

cd/m² = candela per square meter

Fixture luminance that does not exceed 10,000 cd/m at any angle from 45 to 90 degrees from nadir, and/or fixture luminous intensity that does not exceed 1,000 candela at any angle from 45 to 90 degrees from nadir.

<u>Manage Brightness</u>

At least four of the following requirements will be met in all regularly occupied spaces:

- Main rooms do not exhibit 10 times greater or lesser luminance than an ancillary space. This is to avoid substantial changes in light levels as occupants move from one space to another.
- Surfaces do not exhibit 3 times greater or lesser luminance than an adjacent surface. This is to avoid substantial changes in light levels as occupants look around their immediate area.
- Surfaces do not exhibit 10 times greater or lesser luminance than another remote surface in the same room. This is to avoid substantial changes in light levels as occupants look around the room.
- Changes in light levels to 1.5 times higher or lower than initial light levels are carried out over the span of at least 30 minutes in steps or with a smooth transition. Timing considerations in the rate of change of light levels or spectrum diminish abrupt or disruptive lighting transitions.
- Uniformity of at least 0.4 is achieved on work planes. Exclude supplemental lighting from calculations.
- One section of the ceiling does not exhibit 10 times greater or lesser luminance than another section of the ceiling in the same room. Distribution of light across ceilings in a given room that maintains lighting variety but avoids both dark spots and bright spots.

3.5.5.4 Exterior Lighting

The primary function of exterior lighting is to make the maintenance facility site safe and secure to emphasize potential hazard, informational signage, and major focal and access points. It will also provide adequate visibility and comfort by providing the appropriate level of lighting, appropriate contrast between lighting levels and minimizing reflected glare. Light sources will not be located within the normal visual angle of pedestrians or drivers. The designer will follow the MBTA Lighting Directive requirements in designing exterior lighting.

The interior and especially exterior lighting design will minimize light pollution (uplight, glare, and light trespass) to the greatest extent possible while maintaining adequate lighting levels for safety and code. To adhere to MBTA sustainability goals and respect our neighbors, the designer will ensure the design meets LEED SS Credit *Light Pollution Reduction.* The electrical and civil engineers and architect will coordinate their unified design approach in order to best address this goal.

3.5.5.5 Emergency Egress and Night Lighting System

Under normal circumstances, emergency lighting will be powered by the facility power; in cases of power lose, emergency lighting will be power from the emergency generator. Emergency lighting and exit signs will provide minimum foot-candle along egress routes, corridors, and staircases as defined by the MBTA Lighting Standard and Design Directive.

The designer will follow the MBTA Lighting Directive requirements in designing emergency egress and night lighting.

3.5.5.6 Raceways

All wiring will be installed within rigid galvanized conduit schedule 80 with threaded, matching galvanized fittings within the facility. Electrical metallic tubing, intermediate metal conduits, and aluminum intermediate metal conduits will not be allowed.

Underground raceways for medium- and low-voltage will be fiberglass reinforced epoxy conduit.

Aboveground conduit will be 0.75-inch trade size minimum. Underground conduit will be 1-inch trade size minimum.

3.5.6 Grounding and Bonding

A comprehensive grounding system is required in accordance with the NEC with Massachusetts Amendments, local codes, and ANSI/TIA/EIA 607/NFPA 70/NFPA 780.

A main ground loop will be provided around the building. The ground loop will consist of 3/4-inch by 10-foot-long ground rods, test wells, and a #4/0 copper cable buried 3 feet below grade.

Rebar/reinforcing steel and building steel will be connected to the ground loop in accordance with the NEC with Massachusetts Amendments and in conformance with Massachusetts Building Code using an exothermic weld.

Bare copper cable ground loop risers will be routed from the main ground loop up vertically with the columns. Exterior steel wall girts, electrical equipment rooms ground bus bars, major mechanical equipment, cable tray, racks, steel stairways, steel railing, roof steel, support steel, and the roof lightning protection system will be connected to the main ground loop risers via copper cable. The lightning protection system will be connected to the building ground loop and ground electrodes via down conductors.

The substation and switchgear components will be fitted with copper ground bars, for general connection of grounding systems. Each of the copper ground bars will allow for the connection of all of the local building ground provisions, with spare connections and will incorporate a proprietary link facility to enable disconnection for test purposes, without the loss of the system ground connection. These ground bars will be bonded together and connected back to the single point ground in the main substation per NEC with Massachusetts Amendments, local requirements and the suppling utility. The medium-voltage switching station ground system will be designed in accordance with IEEE80 and will achieve a minimum ground resistance of 2 ohms per MBTA requirements. If the switching station is located within the facility, then specific attention will be applied to meet this same requirement. The local power utility Outdoor Customer substation area will be separately grounded and meet the local utility design requirements but will not be less than the MBTA requirements.

All grounding connection to the municipal water service pipe will be provided per NEC codes with Massachusetts amendments.

Transient Voltage Surge Protection will be supplied for all panel boards. Transient Voltage Surge Protection will be the parallel type, where surge protectors are connected in parallel with the circuit and operate when a transient voltage exceeds a preset limit. Parallel surge protectors have little interaction with the circuit under normal conditions. The following systems also will require surge protection:

- Fire alarm systems
- Telephone and data systems
- Electronic equipment data lines

If required, an external grounding conductor will be used for medium-voltage cables. The grounding conductor will be included in the cable for multi-conductor low-voltage cables.

A separate telecommunications ground grid connection bus bar will be provided for telecommunications equipment rooms. The telecommunications ground grid will be connected to the main ground loop at one point below grade.

A separate instrumentation ground grid connection will be provided for the programmable logic controller (PLC) and Building Management System and 24-V instrumentation and control circuits. The PLC and Building Management System ground grid will be connected to the main ground loop at one point below grade using insulated copper cable.

The ground system will provide an effective low impedance path for power fault and transient currents to the earth. Soil conditions (resistivity of the earth) can impact the overall impedance of the ground system. If the code-required resistance levels cannot be met, an electrolytic ground system may be required. Any modification to the soil will be approved by MBTA and Office of the Chief Engineer. The installing contractor will perform ground system testing per the Institute of Electrical and Electronics Engineers standards. The ground system test report will be recorded and submitted to the MBTA's Office of the Chief Engineer for review and written approval.

3.5.7 Lightning Protection

A full coverage lightning protection system will be provided for the facility. The purpose of this system is to minimize life-safety risks and damage to the structure due to lightning strikes directly to the building or nearby structures. The lightning protection system will comply with NFPA-780 and Underwriters Laboratories (UL) Standards UL 96 and UL 96A, and Standard for Installation of Lightning Protection Systems.

3.5.8 Hazardous Area Classification

An electrical hazardous location analysis will be performed to define hazardous areas. The design will incorporate electrical installation enhancements for hazardous locations according to applicable requirements. The complete electrical installation, including all enclosures, raceways, and fittings, will meet the requirements of the NEC with Massachusetts Amendments, Authorities Having Jurisdiction (AHJs), and all local requirements.

Enclosures for electrical equipment will entail the following:

- Electrical non-classified, non-washdown areas – National Electrical Manufacturers Association (NEMA) 1 or 12
- Electrical classified areas – NEMA 7 and NEMA 8 depending on application
- Electrical non-classified, washdown areas – NEMA 4X Stainless-Steel
- Outdoors – NEMA 4X Stainless-Steel

3.5.9 Fire Alarm Systems

Fire alarm systems will be developed to comply with local and NFPA code requirements. The design and installation will be based on system reliability while at the same time avoiding false alarms.

The new addressable fire alarm system will include initiation devices, notification system, monitor, and control modules. Fire alarm systems will interface with the building sprinkler system, HVAC equipment controls, and fire suppression systems, wiring, fittings, and all accessories required to provide a complete operating system. The addressable fire alarm system will be capable of identifying precise areas of fire/alarm enabling rapid direct response to an incident. The design of the fire alarm system will comprise the division of the building into zones for ease of identification. The size of each zone will be in compliance with statutory standards and requirements.

Refer to **Section 3.8, Fire Protection**, for fire protection system design requirements.

3.5.10 Renewable Energy

In addition to energy efficiency strategies that reduce energy use, renewable energy can be generated onsite to reduce the need for energy produced by fossil fuel sources and delivered through the distribution system.

As a potential approach, a comprehensive solar analysis will be conducted for each site to analyze and determine the feasibility of the installation of a photovoltaic solar array at each facility within the open spaces of the rooftop and above any surface parking areas. Based on the quantity of open space, building orientation, and the shading of surrounding buildings and trees, the optimized solar layout with approximate installation size will be proposed. The facility must then at least be designed to be ‘solar ready’ according to MA Base Energy Code and Energy Efficiency Amendments.

Power produced from the photovoltaic system will be supplied 100% to the facility. The excess renewable solar power will not back feed to the grid; any unused power could be stored onsite. The design team will work directly with the MBTA to determine the preferred approach to onsite energy generation and storage. A set of bid documents will be provided by the third-party vendor to identify potential solar contracts to design, procure, construct, and maintain the array.

Refer to LEED EA Credit *Renewable Energy.*

3.5.11 Other Sustainability Design Requirements

3.5.11.1 Inclusive/Universal Design

To create an inclusive design, a full range of ability, age, language, culture, gender, and other characteristics of human diversities will be considered. For a more inclusive, adaptive design, the Project will include some of the following practices.

- Ambient lighting will be appropriate to space, either controlled by occupancy, daylight, or other auto-sensor methods. Adjustable task lighting at office or public-use surfaces will be included.
- Non-glare monitors and lit screens will be installed.
- Visual or audible emergency alarm signaling will be implemented to help individuals navigate in the case of an emergency.
- Voice or screen operated controller for systems that affect user comfort, such as thermostats, lighting, and window shades will be implemented.

Refer to LEED Pilot Credit *Inclusive Design*

3.5.11.2 Responsible Materials and Product Transparency

Specify products that are salvaged, reused, or contain recycled content. Prioritize products from companies that use sustainable procurement and manufacturing practices, and can provide documentation outlining their carbon footprint, minimum cradle to gate scope, environmental product declarations, or other proofs of their transparency of process. The entire Project Team is responsible for selecting compliant products.

Refer to LEED MR Credits *Building Product Disclosure Information*, and EQ Credit *Low Emitting Materials.*

3.5.11.3 Commissioning

The purpose of commissioning services is to ensure that the equipment and systems are installed properly and are functioning as intended, in accordance with ASHRAE Guideline 0 and ASHRAE Guideline 1.1. Additional services expand the roles and responsibilities of the commissioning authority, to ensure that the design and its execution are in compliance with the Owner’s Project Requirements and/or with the BOD, the Operating Personnel are trained in the use of the equipment, and that the equipment is tested and is operating in accordance with the design in different seasons.

Typical electrical systems to be commissioned include switchgear, batteries, cables, bus charging systems, generators, transfer switches, transformer, distribution systems, lighting, and controls, including daylighting controls. Renewable energy systems are included when present. Additional systems may include life safety, communications and data systems, fire protection and fire alarm, and process equipment.

Refer to LEED EA Prerequisite and Credit *Fundamental Commissioning and Verification* and *Enhanced Commissioning*.

3.5.12 Resilient Design Considerations

Electrical design will consider the resilience performance goals included in **Appendix A, Section A.3, General Resilience Requirements**, under the conditions for the disruptors outlined in **Section A.3.3, Resilience Performance Requirements and Goals** (i.e., extreme storms, coastal flooding, extreme precipitation, extreme heat, and pandemic/disease). The performance goals include design thresholds to build assets/infrastructure such that there are no damages and no disruption in critical functionality under specified conditions for each disruptor. If those conditions are exceeded, there are secondary performance goals to manage and minimize disruptions such that critical functionality is restored in a quick and safe manner to minimize risk to the bus maintenance facilities and MBTA workforce.

Strategies to meet these performance goals in design and operations/maintenance planning will vary based on the Project site and conditions. Several strategies specific to electrical elements are included in the following subsections by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

3.5.12.1 Extreme Storms

Exposure of non-resilient designs to extreme storms (e.g., snow, ice, nor'easters, extreme wind, and hurricanes) could result in the following consequences:

- Accelerated deterioration of electrical equipment (e.g., exterior systems and generators)
- Possible system failure due to exceeded snow, ice, and wind loads
- Equipment failure due to wet or damp equipment

Possible electrical design strategies include the following:

- Provide underground utilities with multiple feeders where available
- Seal, insulate, and secure elements (e.g., conduits, tubing).
- Provide redundancy in power and battery supply.
- Provide extra battery supply for buses in storage and extra charging capacity.
- Provide power supply for both critical functions and for full operations through charging stations, transmission systems, and diverse energy sources including utility scale and distributed generation assets such as microgrids equipped with renewable energy and battery storage devices (recommended minimum of three power supply sources for redundancy)

3.5.12.2 Coastal Flooding

Exposure of non-resilient designs to coastal flooding could result in the following consequences:

- Accelerated deterioration and possible damages to electrical systems and equipment due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment
- Replacement of equipment damaged during an extreme flooding incident
- Accessibility to fuel for standby power if the site is exposed to current and/or future coastal flooding

Possible electrical design strategies include the following:

- Elevate electrical systems above design flood elevation.
- Relocate critical power supply systems out of flood zones as possible.
- Provide redundancy in backup battery supply for buses in storage and extra charging capacity.
- Provide feeders and raceways resilient to flooding.
- Consider alternate fuel sources for standby power.

3.5.12.3 Extreme Precipitation

Exposure of non-resilient designs to extreme precipitation and associated flooding from stormwater and/or riverine conditions could result in the following:

- Accelerated deterioration and possible damages to electrical equipment (generators switchgears, insulation, circuitry, fuses, controllers, capacitors, etc.) due to flooding.
- Potential for corrosion, short circuits, and equipment failure from inundation and infiltration through unsealed system pathways.

  Possible electrical design strategies include the following:
- BEB charging equipment, transformers, operational standby generators, switchgears and circuit panels, and other critical electric systems located above design flood elevation
- Consider using submersible exterior transformers and substations
- Consider submersible sump pumps with water level sensors
- Seal transformer maintenance holes to prevent water runoff infiltration/intrusion into manholes
- Seal electrical conduits at exterior manholes and points of entry into building
- Consider temporary flood barriers around generators for emergency scenarios
- Provide enclosures rated for the extreme environments with heating and ventilation

3.5.12.4 Extreme Temperatures

Exposure of non-resilient designs to extreme temperatures could result in the following consequences:

- Overheated electrical equipment, increasing risk of fire, explosion, personal injury, and more
- Sustained extreme ambient temperatures may also result in electrical equipment operating at temperatures above the safe operating range
- Damages to assets may require replacement of equipment

Possible electrical design strategies include the following:

- Install heat exchangers in enclosed systems to dissipate heat.
- Provide extra battery supply for buses in storage and extra charging capacity.

- Consider thermic barriers and zones to reduce building energy demand and during extended temperature extremes.
- Install electrical distribution equipment in well ventilated areas.
- Provide cast coil transformers with fans for the distribution system.

3.5.12.5 Diseases/Pandemic

Exposure of non-resilient designs to disease/pandemic increases the risk and vulnerability to MBTA workforce and occupants at bus maintenance facilities. Possible electrical design strategies include the following:

- Select easy to clean materials and surfaces.
- Provide touchless (motion sensor) lighting.

3.6 Plumbing

Plumbing systems and equipment will be designed to meet the requirements outlined in the following subsections. The designer will consider health and safety, resilience, and energy efficiency when making final decisions that are not dictated by code. Plumbing design will provide a plumbing system integrated with the requirements for mechanical, electrical, fire protection, industrial equipment, architectural design intent, and the facility service needs. The needs of the MBTA in terms of future adaptability of the spaces and current flexibility of use will be carefully considered.

3.6.1 Codes, Standards, and Regulations

The design will adhere to the latest versions of the following codes, standards, and regulations as applicable:

- 248 CMR 4.00, *Massachusetts Fuel and Gas Code*
- NFPA 54, *National Fuel Gas Code*
- 248 CMR 10.00, *Uniform State Plumbing Code*
- Massachusetts Water Resources Authority (MWRA) 360 CMR
- MWRA 360 CMR 10.000, *Sewer Use*
- 29 CFR 1910, *Occupational Safety and Health Standards*
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals

The plumbing engineer is responsible for coordinating with the Project Team to help ensure compliance with the following LEED requirements as applicable to each project :

- IP Credit *Integrative Process*
- WE Prerequisite *Indoor Water Use Reduction*
- WE Credit *Indoor Water Use Reduction*
- WE Prerequisite *Building-level Water Metering*
- WE Credit *Water Metering*
- WE Optimize *Process Water Use*
- EA Prerequisite *Fundamental Commissioning and Verification*
- EA Credit *Enhanced Commissioning*
- MR Credits *Building Product Disclosure Information*
- EQ *Credit Low Emitting Materials*

3.6.2 Plumbing Fixtures

Hand washing stations will be provided in shop areas. Eyewash and safety showers will be in hazardous areas, in repair bays, and at the service island as required by the Occupational Safety and Health Administration. If emergency shower/eyewash stations are in proximity, it is preferred to use a central system for tempered water. If emergency shower/eyewash stations are distributed within the facility, thermostatic mixing values will be located at each station.

Plumbing fixtures will be supplied in sufficient quantity to meet or exceed the requirements of the Plumbing Code requirements and will provide ¾-inch water service hose bib every 30 feet in bus maintenance bays. Applicable fixtures will be low-flush/low-flow to conserve water.

To slow the spread of bacteria and viruses, handwashing stations will be designed in a way that allows the user to avoid unnecessary contact with fixtures or surfaces.

Facility resilience will be considered in fixture selection. The MBTA prefers auto-sensor operated toilets with a manual override (in case of natural disasters). The MBTA prefers auto-sensor-operated faucets in restrooms, manual faucets in breakrooms/kitchenettes, and foot-pedal operated faucets in maintenance work areas.

3.6.3 Drains

All floor/area drains, except in bathrooms/locker rooms, will be provided with oil water separator protection. Drain covers at each drain will be provided. The plumbing engineer and architect will address the following requirements in the design:

- There will be no drains in the lubricant storage area. Double-walled tanks will be provided.
- 12-inch-wide formed trench drains are to be considered standard. Precast or fabricated types are unacceptable.
- Some areas (i.e., lift pits, steam clean bays (chassis wash), component cleaning, and exterior bus wash bays) will pass through an adequately sized wastewater reuse system before discharging to sewer. These components will be identified and coordinated during detailed design.
- Install drains in all lift pits to grouped sumps with lift stations.

3.6.4 Compressed Air System

Compressed air suitable for tool operation and tire pressurization will be provided to all maintenance work areas and to other locations as defined by MBTA. Compressed air may be distributed throughout the new facility from a centrally located room through a central system. Compressed air drops on trapezes will have a ½-inch quick disconnect. All compressed air drops will consist of the following components:

- Ball cut-off valve
- Filter
- Regulator with gauge
- Lubricator
- 0.25-inch quick disconnect
- Six-inch drip leg with ball valve

3.6.5 Other Sustainability Design Requirements

3.6.5.1 Water Consumption Reduction

Per LEED Prerequisite requirements, all toilets, urinals, lavatory faucets, kitchen faucets and showerhead will reduce aggregate water consumption by a minimum of 20% of code-required levels (baseline); all newly installed toilets, urinals, private lavatory faucets, and showerheads that are eligible for labeling will be WaterSense; and all new appliances will be Energy Star or performance equivalent.

Refer to LEED Prerequisite *Indoor Water Use Reduction*.

For additional points, reduce indoor potable water consumption beyond the Prerequisite levels.

To achieve these goals, the project team will select high water-efficient fixtures and fittings and consider alternative water sources where applicable and permitted by the local jurisdiction. Alternative water sources may include municipally supplied reclaimed water (“purple pipe”), graywater, rainwater, stormwater, treated seawater, condensate, foundation dewatering water, used process water, and reverse osmosis reject water. The project team will also consider future implementation of alternative fixtures and may elect to install separate piping infrastructure to enable this approach after initial Project construction. This approach will be discussed with and have final approval from MBTA prior to implementation. Before choosing alternative sources of water, the project team will always prioritize the uses of least treatment first to minimize energy consumption. Examples could include using rainwater for outdoor irrigation or indoor toilet flushing.

Refer to LEED Credit *Indoor Water Use Reduction*.

3.6.5.2 Water End-use Metering

To meet the LEED Prerequisite requirements, support MBTA efforts to monitor and reduce natural resource use, and identify opportunities for additional water savings, the facility will include a permanent water meter that measures total potable water use for the building and associated grounds. The MBTA will share the resulting whole-project water usage data with the U.S. Green Building Council for a 5-year period.

Refer to LEED WE Prerequisite *Building-level Water Metering*.

For additional LEED points, the project team will identify two or more water subsystems and install permanent submeters to measure 80% to 100% of flow. These water subsystems could be irrigation, indoor plumbing fixtures and fittings, domestic hot water, boiler water, reclaimed water, or other process water, depending on the individual facility. Bus wash systems will also be included in these considerations.

Before installing permanent submeters, the project team must consider which subsystems consume the most water, cost the most to operate, or the most closely meet the goals of the building management. Additionally, the teams will select the most appropriate subsystems based on the Project scopes.

Refer to LEED WE Credit *Water Metering.*

3.6.5.3 Responsible Materials and Product Transparency

Specify products that are salvaged, reused, or contain recycled content. Prioritize products from companies that use sustainable procurement and manufacturing practices, and can provide documentation outlining their carbon footprint, minimum cradle to gate scope, environmental product declarations, or other proofs of their transparency of process. The entire Project Team is responsible for selecting compliant products.

Refer to LEED MR Credits *Building Product Disclosure Information* and EQ Credit *Low Emitting Materials*.

3.6.5.4 Commissioning

The purpose of commissioning services is to ensure that the equipment and systems are installed properly and are functioning as intended, in accordance with ASHRAE Guideline 0 and ASHRAE Guideline 1.1. Additional services expand the roles and responsibilities of the commissioning authority, to ensure that the design and its execution are in compliance with the Owner’s Project Requirements and/or with the BOD, the Operating Personnel are trained in the use of the equipment, and that the equipment is tested and is operating in accordance with the design in different seasons.

The plumbing system will be commissioned to ensure correct installation for occupational health and safety. The plumbing engineer will work with the commissioning authority throughout the design process to maximize efficient and effective design of these components.

Refer to LEED EA Prerequisite *Fundamental Commissioning and Verification* and LEED EA Credit *Enhanced Commissioning*.

3.7 Industrial Equipment

The industrial facility design work includes bus maintenance equipment that will be coordinated into the building design with architectural, structural, mechanical, plumbing, and electrical disciplines.

The industrial equipment includes the following categories:

- Fuel system equipment
- Service lane equipment
- Bus wash system, water reclaim system, rainwater harvest and industrial wastewater treatment systems
- Steam bay equipment
- Maintenance bay equipment
- Shop areas equipment
- Parts and tire storage
- Fluid storage and distribution systems
- Battery retrieval, storage, and maintenance equipment

3.7.1 Codes, Standards, and Regulations

The latest versions of the following codes, standards, and regulations for industrial design will be used:

- Buy America compliance based on the FTA requirement FTA-5323(j)
- 527 CMR 1.00, *Massachusetts Comprehensive Fire Safety Code*
- NFPA 1, *Fire Code*, as modified by 527 CMR 1.05
- NFPA 30, *Flammable and Combustible Liquids Code*
- NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*
- 780 CMR, *Massachusetts State Building Code*
- 40 CFR 112, *Oil Pollution Prevention*
- 310 CMR 80.00, *Underground Storage Tank (UST) Systems*
- UL Standards
- MWRA 360 CMR 10.00, *Sewer Use*
- Automotive Lift Institute Standards
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals

The designer will ensure that the design addresses the following LEED items to meet the MBTA's sustainability goals and operational priorities. The industrial engineer is responsible for contributing to compliance with and providing documentation for the following items as applicable to each project:

- SS Credit *Rainwater Management*
- WE Credit *Optimize Process Water Use*
- WE Prerequisite *Building-level Water Metering (required)*
- WE Credit *Water Metering*
- EA Prerequisite *Minimum Energy Performance (required)*
- EA Credit *Energy Use Optimization*

3.7.2 Fueling System and Service Lanes

3.7.2.1 Fuel Storage

Evaluate if diesel and gasoline fueling capabilities will be needed at the new facility. It is assumed that gasoline fueling should not be needed for a BEB facility, but this must be confirmed. Diesel fuel may be needed for auxiliary bus heaters and backup power generators for a new BEB facility. If diesel fueling is needed, it is preferred to use aboveground double-walled tanks as opposed to underground, if space permits. For aboveground, it is likely that the storage tanks will need to be UL 2085 listed, 2-hour fire rated, based on building and fire codes. Consideration should be given to the use of rectangular tanks versus cylindrical aboveground double-walled steel tanks, to help save on space and to facilitate access to the top of the tank for maintenance purposes. The height of these tanks should be selected to allow for appropriate ceiling clearance when installing submersible pumps, level probes, drop tubes, etc. If underground tanks are needed, consider UL 1316 listed double-walled fiberglass tanks with a 30-year extended warranty. Also review appropriate fire codes for the location of the fueling facilities relative to a building entrance for fire department access.

Storage of surplus/waste diesel fuel purged from the auxiliary bus heaters following the heating season must also be evaluated.

The fuel tanks will require continuous electronic leak monitoring, a high-level alarm, overfill protection and spill prevention in accordance with 40 CFR 112 and State regulations. If the capacity of the tanks is above the maximum allowable quantity per the control area, the storage room(s) will likely need to be classified as a Group H-3 High Hazard in accordance with the Massachusetts Building Code.

3.7.2.2 Service Lanes

A fluid management system unit will be provided in each service lane. This will extract information from each vehicle and update the data in the fleet management software. The fluid management system will also extract the vehicle number, mileage, odometer, engine diagnostics and the quantity of fluids added.

The equipment required for this area includes, but is not limited to, the following:

- Diesel dispensers which are coordinated with fuel pumps, tanks, and leak detection systems
- Fluid Reels (coolant and windshield washer fluid)
- Compressed air reels
- Fleet Watch (or similar) – Fluid Management/Bus Data Collection System
- Fare vault and counting equipment (provided by the MBTA)

Refer to **Section 4.3.1, Fueling Operation,** for more information on these spaces.

3.7.3 Bus Wash Systems

The wash bays should include tire guides, spray arches, four brushes (minimum), undercarriage wash, tire wash, freshwater final rinse, and blowers. The brushes will have the ability to wash the sides and wrap around the front and back of the bus. The brush controls should include an option to turn off the rear/front brush wash function, and just use the brushes to wash the sides. When the front/rear brushes are turned off, a touchless high pressure water spray should be used to wash the front/back of the bus. Note that the MBTA currently uses bus wash systems manufactured by NS Corporation. Consideration should be given to using an NS system as the BOD, with other or equal systems allowed for procurement purposes.

The bus wash bays will include trench drains down the center of the bay that drain to a center sump to begin the sand and grit removal process. The wastewater will then flow from the center sump to a settling tank and an oil water separator. Following this pre-treatment process, the water can then be treated further by the water reclamation system for reuse, or it can be purged to the industrial wastewater treatment system, prior to discharge to the sewer system. Additional details on these systems are provided in the following sections.

Refer to **Section, 4.3.3 Bus Wash,** for more information on these spaces.

3.7.4 Steam Bay Equipment

In addition to the automatic bus wash bays the facility will also be equipped with a separate steam bay. The goal of the steam bay will be to clean the undercarriage of the buses with high pressure hot water and detergents. Please note that although it is referred to as a steam bay, high pressure hot water is used to wash the undercarriage, not steam, due to the potential for injuries associated with using steam. This bay will have a platform lift designed for wash bay environments which will lift the bus to allow access for personnel to wash the underside of the bus using a hand-held high pressure water gun. The bay includes a large trench drain down the center connecting to a pit that will help remove settleable solids. The wastewater will then flow through an oil water separator and tie into the industrial wastewater treatment system.

The equipment in this bay and associated equipment room will include the following:

- High pressure wash system with water heater (located in the steam bay equipment room). Based on guidance from the manufacturer, operating temperature will stay between 165˚F to 185˚F for worker safety.
- Water gun/hose systems at strategic locations in the steam bay.
- Flush mounted platform lift designed for a wet and corrosive environment, recessed into the floor slab with undercarriage lighting.
- All equipment and utilities inside the bay will be designed for wet and corrosive environments.
- Rubber rapid acting doors designed for wash bay use to keep overspray from leaving the bay.
- Ventilation system linked with the wash system to help evacuate corrosive water mist that is created when using the hot-water wash system.

Refer to **Section 4.1.2, Steam Clean Bay (Chassis Wash),** for additional information.

3.7.5 Wastewater Reclamation and Rainwater Harvest Systems

A wash wastewater reclamation system will be utilized with the bus wash equipment to help minimize the use of potable water. The water reclamation system will achieve 50% water reuse or better.

Approximately 63% water reuse can be achieved using reclaim water for the functions recommended by the vehicle wash manufacturer, which include the following:

- Double hung brushes
- High pressure arch
- Wheel wash cycles

As recommended by the wash system manufacturer, potable water must be used for the following functions:

- Detergent application arch
- Undercarriage wash
- Final rinse arch

The use of rainwater collected from roof runoff should also be assessed. Assuming that the rainwater is used with the undercarriage wash, and reclaimed water is used for the other recommended functions described previously, the amount of freshwater used per wash can be reduced by approximately 20%. In this scenario, 80% of the water being used during washing would consist of reclaimed water and rainwater.

With a rainwater harvest system roof runoff would be collected and stored in tanks. The rainwater would then be treated using a filter and ultraviolet light system prior to being used with the bus wash. Further assessment and water quality chemical analysis of the rainwater is recommended prior to implementing this option.

Equipment utilized with the water reclamation system will include the following:

- Settling tank/oil water separator
- Twin cyclone separators/filters
- Sludge cart

A water quality and bus condition monitoring program will be implemented to ensure that the use of reclaimed water during bus washing does not result in corrosion. Salt and deicing chemicals used on the roads during snow and ice fighting season are corrosive, and the use of reclaimed water can concentrate these chemicals in the wash water, which can cause significant corrosion issues if the process is not properly monitored and managed. The wash bay ventilation system should also be interlinked with the wash equipment to help evacuate corrosive water overspray/mist as quickly as possible.

It is assumed that reverse osmosis treatment of bus wash rinse water will not be performed. However, the freshwater supply quality should be analyzed to confirm this, and to assess for the potential use of a water softening treatment system.

It is assumed that buses will be washed every other service day as discussed with the MBTA.

Refer to **Section 4.3.3.1, Bus Wash Bay,** for more information on these spaces.

3.7.5.1 Industrial Wastewater Treatment System

A wastewater reuse (reclamation) system will be used along with an industrial wastewater treatment system. The water reclamation and treatment system must meet MWRA standards, including their discharge requirements. The discharge from the bus wash as well as the steam bay will run through the treatment system.

The designer should obtain samples of the bus wastewater discharge from a similar existing facility and analyze them for the parameters required by the MWRA. This data can then be used to design the treatment system. It should also be noted that MWRA may require that the treatment systems be operated by a licensed wastewater treatment system operator. These requirements should be further assessed and reviewed with the MBTA.

Refer to LEED SS Credit *Rainwater Management*, and WE Credit *Optimize Process Water Use.*

3.7.6 Maintenance Bay Equipment

The following assumptions have been made in the design of the maintenance equipment. We are assuming that typical bus preventive maintenance and repairs will be performed. These will need to be confirmed for each facility. We also assume that the following functions will not be performed at the proposed facility:

- Painting
- Body work
- Tire work – MBTA utilizes outside vendor servicing of all tires
- Bus overhaul work

It is also assumed that the fare vault and counting equipment will be provided by the MBTA. Assumptions for each facility should be evaluated at the start of each project.

3.7.6.1 Lifts

Bus lifts will be provided in the maintenance bays, as well as the steam bay. The maintenance bays will have a mixture of platform lifts, inground piston lifts, and mobile column lifts; the number and types of lifts for each facility will be coordinated with MBTA stakeholders. The steam bay will have a platform lift that is designed for a wet corrosive environment. This lift will include fully galvanized runways and all stainless-steel parts and accessories, along with a light kit.

Lifts should be strategically located throughout the maintenance area to be in proximity to the appropriate workshop space, and to facilitate bus circulation patterns. Refer to **Appendix B**, **Maintenance Lift Supplement,** for more information on the lift types, vendors, code requirements, and industry standards. Refer to **Section 4.1.1, Bus Maintenance Area,** for more information on these spaces.

3.7.6.2 Bus Roof Access

The facility will include dedicated roof access bays, which are specialty bays designed for safe and efficient bus roof access. These bays should have a mobile scaffolding platform at bus roof height on all four sides of the bus with stair access to the platform. These bays will also have an overhead bridge crane to aid in maintaining bus equipment and removing/installing roof top batteries.

The designer should specify mobile scaffolding platforms that are OSHA compliant that do not require additional fall protection. Vehicle lifts should not be installed in these bays due to safety and clearance issues.

Refer to **Section 4.1.1.3, Roof Access Bay,** for more information on this space.

3.7.7 Shop Areas Equipment

General maintenance and shop equipment includes items in the maintenance bays, machine, welding, and other shops, and other maintenance support areas. The maintenance bays will be equipped with workbenches, vises, and parts washers. The welding shop will be properly equipped with enhanced ventilation and proper welding outlets. The equipment in the machine and other shops and other support areas will include, but is not limited to, the following:

- Buffer/grinder on stand with dust collector
- Drill press
- Cut-off saw
- Hydraulic press
- Abrasive blast cabinet
- Shelving units
- Workbenches with vices
- Storage cabinets
- Parts washers
- Parts degreasers (steam cabinet)
- Compressed air drops
- Tool carts
- Scissor lift
- Fluids carts/waste fluid caddies
- AC recovery/recharge units
- Floor scrubber
- Bus tug
- Mig Welder
- Fume extractors
- Welding Benches
- Torch Carts
- Belt Sanders
- Plasma cutter

Refer to **Section 4.1.3, Maintenance Support Shops and Spaces,** for more information on these spaces.

3.7.8 Parts and Storage

The equipment in the other parts storage areas includes the following items:

- Pallet racks
- Cantilever storage rack (if needed)
- Heavy-duty shelving units
- Flammable storage cabinets
- Storage cabinets
- Modular drawer cabinets
- Small bin storage
- Sorting tables

The location and layout of these items should be further assessed with input from MBTA for each project, as shelving and pallet racks require anchoring and will become fixed equipment. This fixed equipment will require coordination with wall outlets and lighting.

Refer to **Section 4.1.4, Parts Storage,** for more information on this space.

3.7.9 Tire Storage

Tire work is assumed to be done offsite. The MBTA utilizes an outside vendor for servicing tire work. However, the design will include equipment for the storage of new and repaired tires.

Tire carousels will be considered as they save floor space and deliver tires at an ergonomic height to the worker. The shortest standard-size carousel is greater than 15 feet high, and the largest is 23 feet high. These units can extend up through an opening in the ceiling and added electronic controls on the first floor would still allow for primary loading and unloading of tires to occur on the first floor.

Tire racks will also be provided which are 16-feet long and 8-feet high to carry miscellaneous tires. These will have two tiers to double stack the tires. A tire rack hoist should be provided to aid in lifting the tires to the second-tier rack.

The volume of tire storage required should be further assessed with MBTA during the design phase, and once volume requirements are confirmed, fire proofing and sprinkler system designs should be revisited as necessary.

Refer to **Section 4.1.3.2, Tire Storage,** for more information.

3.7.10 Fluid Storage and Distribution Systems

An all-electric fleet will have fewer maintenance fluids distributed to the service lanes and maintenance bays. Only coolant and windshield washer fluid (WWF) reels will be needed in service lanes. Automatic transmission fluid (ATF) and chassis grease reels, along with coolant reels will be provided in the maintenance bays. No engine oil will be provided in the maintenance bays and ATF storage may be reduced after researching the specific needs of the buses. Other fluids such as gear oil and brake fluids will be used but will only be stored in 55-gallon drums with hand pumps.

3.7.10.1 Compressed Air System

Compressed air suitable for tool operation and tire pressurization will be provided to all maintenance work areas and to other locations as defined by MBTA. Compressed air drops on trapezes will have a ½-inch quick disconnect. All compressed air drops will consist of the following components:

- Ball cut-off valve
- Filter
- Regulator with gauge
- Lubricator
- 0.25-inch quick disconnect
- Six-inch drip leg with ball valve

3.7.10.2 Liquid Bulk Distribution

The following liquid consumables may be distributed throughout the new facility from a centrally located lube room through a central lubricant system:

- Gear oil (GO)
- Diesel exhaust fluid (DEF)
- ATF
- Engine coolant (EC), type 1 (EC1) and type 2 (EC2)
- Waste oil
- Waste coolant
- WWF

Other consumable materials, such as power steering fluid, and chassis grease on mobile carts, may be required depending upon the fleet mix. Above-grade bulk storage tanks will be the source and are the preferred storage method. The tanks will be double-wall construction negating the need for constructed dikes and/or collection pits. The designer will work with MBTA to define the size of the tanks.

The central lubricant system will provide a variety of lubricants to the appropriate locations using the following components:

- Air piston lubricant pumps (drum, wall, and tank mounted)
- Compressed air to operate lubricant system
- Lubricant and fluid hose reels in maintenance bays mounted overhead in a reel bank
- Bulk lubricant and fluid storage tanks and associated piping
- Lubricant dispensers
- Lubricant reels
- Fluid dispensing and control system

The fluid storage room will be researched further for each facility to determine fluids necessary, as well as the capacity of each fluid. Refer to **Section 4.1.3.7, Fluid Distribution and Waste Storage – Tanks and Compressor/Air Dryer,** for more information on these spaces.

3.7.11 Battery Storage and Maintenance Equipment

The battery storage room will be designed to handle large banks of batteries. It consists of wash stations, storage racks, and handling equipment. This room should be forklift accessible and properly ventilated to prevent migration of fumes. Equipment should be provided for any type of battery extraction: rear, side, overhead, and underneath.

This equipment should include, but not be limited to, powered mobile lift tables (overhead and underneath extraction), battery transfer carriages (rear and side extraction), and automotive battery racks for the small lead acid batteries.

A bridge crane with a battery lifting beam attachment is suggested to extract the overhead batteries from the bus roof and to facilitate movement of the batteries to/from lift tables and transfer carriages. The battery storage room should be equipped with pallet racks and battery roller stands for storing batteries. Battery wash stations will be located in the proposed battery storage room. These will allow both lithium-ion and lead acid batteries to be washed. Battery testing needs should also be identified and accommodated.

Provisions to store damaged high voltage batteries outside of the main facility and remote from other assets should also be provided.

Battery storage space and equipment should be further assessed per project as the technology is constantly advancing. Refer to **Section 4.1.3.3, Battery Storage Room,** for more information on this space.

3.7.12 Resilient Design Considerations

Industrial design will consider the resilience performance goals included in **Appendix A, Section A.3, General Resilience Requirements**, under the conditions for the disruptors outlined in **Section A.3.3, Resilience Performance Requirements and Goals** (i.e., extreme storms, coastal flooding, extreme precipitation, extreme heat, and pandemic/disease). The performance goals include design thresholds to build assets/infrastructure such that there are no damages and no disruption in critical functionality under specified conditions for each disruptor. If those conditions are exceeded, there are secondary performance goals to manage and minimize disruptions such that critical functionality is restored in a quick and safe manner to minimize risk to the bus maintenance facilities and MBTA workforce. Refer to MBTA's Flood Resiliency Design Directive.

Strategies to meet these performance goals in design and operations/maintenance planning will vary based on the Project site and conditions. Several strategies specific to industrial elements are included in the following subsections by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

3.7.12.1 Extreme Storms

Exposure of non-resilient designs to extreme storms (e.g., snow, ice, nor'easters, extreme wind, and hurricanes) could result in accelerated deterioration, corrosion and/or damage to industrial systems or equipment due to exposure or loss of power. Increased frequency of storms may also result in increased systems/equipment maintenance.

Possible industrial design strategies include the following:

- Secure elements that could become debris during an extreme storm event.
- Design redundant systems to prevent compromised functionality of industrial equipment.
- Develop operations and maintenance plan for mitigating the impacts of power loss and preparing, responding to, and recovering from extreme storm events.
- Adjust BAS equipment to save energy and continue operations during power outages.

3.7.12.2 Coastal Flooding

Exposure of non-resilient designs to coastal flooding could result in accelerated deterioration, corrosion, and possible damages due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment.

If the site is exposed to current and/or future coastal flooding, industrial design will meet the resilience performance goals under the coastal flooding conditions outlined in Appendix A. Possible industrial design strategies include the following:

- Locate critical systems and equipment out of flood zones whenever possible.
- Where possible, relocate potentially vulnerable portable assets to protected locations in advance of a flooding event.
- Select corrosion-resistant materials/equipment.
- Secure elements that could become debris during flooding.

3.7.12.3 Extreme Precipitation

Exposure of non-resilient designs to extreme precipitation and associated flooding from stormwater and/or riverine conditions could result in flooding of basement facilities or accelerated deterioration, corrosion and possible damages to industrial systems and equipment. Increased frequency of extreme precipitation may also result increased systems/equipment maintenance. Possible industrial design strategies include the following:

- Locate critical systems and equipment out of flood zones whenever possible.
- Where possible, relocate potentially vulnerable portable assets to protected locations in advance of a flooding event.
- Secure elements that could become debris during flooding.
- Consider and establish cleaning requirements for industrial equipment post-stormwater flooding.

3.7.12.4 Extreme Temperatures

Exposure of non-resilient designs to extreme temperatures could result in accelerated deterioration of assets such as equipment prone to overheating and/or freezing and human health impacts. Loss of power supply and/or service discontinuity is also possible due to extreme temperature and associated events.

Possible industrial design strategies include the following:

- Develop operations and maintenance plan for mitigating heat and cold impacts, including impacts to workforce and health and safety protocols.
- Adjust BAS equipment to save energy and continue operations during power outages.
- Accommodate demand response and plan to delay electrical loads, such as battery charging during peak power demands such as extreme daytime heat or nighttime cold.

- Seal and insulate temperature sensitive industrial equipment.
- Consider reflective exterior industrial equipment and/or canopies.
- Coordinate with mechanical strategies on ventilation and location of industrial equipment.

3.8 Fire Protection

The following types of fire protection and suppression systems will be provided and will meet the requirements outlined in the following subsections:

- Dry chemical fire suppression systems in the fueling area
- Automatic fire sprinkler systems (wet and dry as required) throughout facility
- Clean agent fire suppression system similar to Novec 1230 for communication rooms

3.8.1 Codes, Standards, and Regulations

The design will adhere to the latest versions of the following codes, standards, and regulations as applicable:

- Massachusetts Building Code
- International Building Code
- Massachusetts Fire Code
- International Fire Code
- Applicable NFPA codes
- Local codes and ordinances
- Municipal fire and inspectional service departments
- Owner's insurance underwriter
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals

3.8.2 Fire Protection Service

The water supply for the water-based fire protection systems will be provided by a separate connection to the public water system. The dry pipe system will be fed from the same water supply as the wet system but will be separated inside the building with dry pipe valves and an air compressor to keep the lines pressurized with air until activated.

3.8.2.1 Hydrant Flow Test

A hydrant flow test is required to analyze the water supply and (if necessary) size the fire pump and suppression piping. Flow test information will be conveyed to the fire protection contractor for use in performing hydraulic calculations. The fire protection contractor will be required to perform a hydrant flow test at the beginning of construction to reconfirm the water supply information. Flow test for design submission to the AHJs will be performed no more than one year prior to the date of submission.

3.8.2.2 Sprinklers

A hydraulically designed combined wet standpipe/sprinkler system will provide 100% sprinkler protection throughout the building; any deviation from 100% coverage must be in compliance with NFPA 13 and reviewed with the AHJ.

3.8.2.3 Fire Department Connections

- The fire department connection will be required to be within 100 feet of a fire hydrant or as directed by the fire department.

3.8.2.4 Fire Entrance Rooms

- If required as a result of the hydrant flow test, fire entrances rooms will include fire and jockey pumps and controllers, double check valve assembly, and wet-pipe valves.

3.8.3 Building Space Recommendations

The designer is responsible for reviewing applicable codes for updates and coordinating with the AHJ (e.g., fire department, building inspector) and MBTA to verify the space requirements noted in **Table 3.8-1,** on an individual building basis. The designer will give special consideration to the areas where buses will be located given the risk for thermal events with lithium-ion batteries and assess opportunities to enhance fire protection in these areas.

Table 3.8-1. Minimum Recommended Standards by Building Space

Building Space	Minimum Recommended Standards
Administrative Areas	Light Hazard
Bus Storage/Charging Areas	Extra Hazard Group 2
Bus Maintenance Areas	Extra Hazard Group 2
Mechanical Rooms	Ordinary Hazard Group 1
Fuel Pump Rooms	Extra Hazard Group 2
Electrical Rooms	2-hour enclosure with no sprinkler
Communication Rooms	Either a 2-hour enclosure with no sprinkler system or a protected with a clean agent system, similar to Novec 1230 fire suppression system connected to the building fire alarm panel to provide notification Will include control panels, cylinders, activation devices, heat and smoke detectors, distribution nozzles and all other appurtenances to provide a complete fire suppression system

3.9 Communications and Security Systems

The communications systems will include all apparatus to transmit voice, data, and video within the facility and through the MBTA WAN and SWAN and will be designed to meet the requirements outlined in the following subsections.

3.9.1 Codes, Standards, and Regulations

The design will adhere to the latest versions of the following codes, standards, and regulations as applicable:

- Institute of Electrical and Electronics Engineers standards for Ethernet protocols 802.1, 802.3u, 802.11, 802.3af, 802.3an, 802.3bt
- Insulated Cable Engineers Association, Inc. standards S-83-596-2016, S-87-640-2011, S-90-661-2012, S104-696-2013, S-56-434
- Telecommunications Industries Association standards for copper and fiber optic cabling (TIA455, TIA472, TIA492, TIA526.7-A, 526.14-C, 568-C.2.2, 569-D, 598-D, 758-B), grounding (TIA607-C), and labeling (TIA606-B-1)
- Electronic Industries Alliance EIA-310-D, *Cabinets, Associated Equipment and Racks, Panels*
- Building Industry Consulting Service International (BICSI)
  - ANSI/BICSI *Telecommunications Distribution Methods Manual*
  - ANSI/BICSI 006-2020, *Distributed Antenna System Design and Implementation Best Practices*
  - ANSI/BICSI 007-2020, *Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises*
  - ANSI/BICSI 008-2018, *Wireless Local Area Network Systems Design and Implementation Best Practices*
  - ANSI/BICSI N1-2019, *Installation Practices for Telecommunications and ICT Cabling and Related Cabling Infrastructure*
  - ANSI/BICSI N2-17, *Practices for the Installation of Telecommunications and ICT Cabling Intended to Support Remote Power Applications*
- International Electrotechnical Commission 60268-16, *Objective Rating of Speech Intelligibility by Speech Transmission Index*
- American Public Transportation Association 34, *Standard for SCADA System Inspection, Testing, and Maintenance*
- NEMA 250, *Enclosures for Electrical Equipment*
- International Electrotechnical Commission (IEC) 60950-1, including all relevant national deviations as listed in the IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE) Bulletin—Product Category OFF: Information Technology and Office Equipment
- Telcordia Technologies
  - GR-771-CORE, *Generic Requirements for Fiber Optic Splice Closures*
  - GR-196-CORE, *Generic Requirements for Optical Time Domain Reflectometer-type Equipment*
  - SR-4731, *Special Requirements for Optical Time Domain Reflectometer Data Format*
- International Electrotechnical Commission
  - Standard 60068, *Environmental Testing*
  - Standard 60529, *Degrees of Protection Provided by Enclosures*

  - Standard 61131-3, *Programming Industrial Automation Systems*
- International Electrotechnical Commission IEC/TR EN 61000, *Electromagnetic Compatibility Standards*
- Federal Communications Commission FCC Part 15, general provisions for unlicensed radio frequency interference
- Massachusetts State Building Code (780 CMR)
- Massachusetts Electrical Code (527 CMR 12.00) (NFPA-70 NEC, amended)
- National Electrical Contractors Association's Standard of Installation
- ASTM International (ASTM)
  - ASTM D1248, *Standard Specification for Polyethylene Plastic Extrusion Material for Wire and Cable*
  - ASTM E814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*
- UL Standards
- International Organization for Standards ISO 9001, *Quality Management Systems - Requirements*
- Massachusetts Architectural Access Board 521 CMR
- ADA Standards for Accessible Design
- MBTA's Engineering Directives
- MBTA's Design Standards and Guidelines, Standard Specifications and other Design and Construction Policy and Procedure Manuals

The designer is responsible for coordinating with the Project Team to help ensure compliance with the following LEED requirements as applicable to each project:

- MR Credits *Building Product Disclosure and Optimization*
- EQ Credit *Low Emitting Materials*

The following will be included as Project design requirements:

- Compliance with MBTA's *Hazardous Substances Directive* for equipment and cabling where possible.
- The UPS systems for communication, security systems, and for other building systems will be optimized and combined to minimize the total number of batteries used.

3.9.2 Communications Rooms and Closets

A main communications room (main distribution frame) will be provided at the facility to house the various systems' equipment listed in this section and have at least 25% spare space for future equipment cabinets. Other communications rooms/closets (intermediate distribution frame) will be provided as required to serve communications and security devices throughout the facility.

Separate, lockable cabinets will be provided for each system (i.e., public address, local area network [LAN], security, etc.). Each cabinet will be sized to meet proposed equipment requirements. Each cabinet will have perforated doors, vertical power distribution units, document drawer, slide out shelf, cable management, and top mount fans. Cabinets will have a minimum of 3 feet of access to the front and rear doors. A cable tray will be provided in the room(s)/closet(s) to route data cables. Power cables will be routed separately in dedicated conduits from the room/closet power panel. The power panels will derive their power from the Standby/Legal Required side of the generator system; each separate rack of equipment will have its own self-contained UPS system to protect them individually, but generally, the generator will supply power in an emergency.

Communications rooms and closets will include wall space for items that include power panel, electronic access control panel, door lock power supply cabinet, telephone company point-of-demarcation, wall telephone, and thermostat.

Heat loads for proposed equipment will be provided and HVAC systems capacity will be determined to maintain equipment within manufacturer recommended operating temperatures.

Lighting will be provided within each communications room and closet with sufficient lighting levels at access points to equipment racks and cabinets.

Power receptacles will be provided around the perimeter of the rooms and closets spaced per NEC with Massachusetts Amendments requirements and at telephone backboards, wall-mounted equipment, and cabinets, and within equipment racks.

A Telecommunications ground busbar will be provided in each communications room and closet. All equipment, cabinets, conduit, and cable tray will be bonded.

Communications rooms will be equipped with a dry chemical fire suppression system.

3.9.3 Telecommunications and Data Communications

3.9.3.1 Wide Area Network

The WAN provides the communications medium for voice and data transmission from the facility to other MBTA facilities, including the data center, Operations Control Center, and Power Dispatch.

The MBTA currently has fiber optic cable connections to a majority of its facilities. To support the WAN, a new OS2 single mode fiber optic cable will be installed from the new bus facility to the closest fiber node as defined by the MBTA. If a fiber optic cable connection is not feasible, then leased wired/wireless data connections will be provided that are suitable for the bandwidth requirements of the facility.

3.9.3.2 Telephone/Data Wiring

At a minimum, Category 6 data cable will be installed to each data jack and IP device. Shielded Category 6 cable will be installed to each IP video surveillance camera. The data cables will be terminated on matching Category 6 patch panels in the communications room(s)/closet(s).

Factory manufactured Category 6 patch cables will be provided for all connections. Shielded Category 6 patch cables will be provided for all IP video surveillance cameras. Provide patch cables in appropriate lengths to maintain a neat installation and coordinated connections.

Dual port data outlets will be provided in each office, conference room, and other locations as required by the MBTA. Picking rooms will have additional data outlets to support future HASTUS software-based picking requirements.

Stainless-steel single port wall outlets will be provided in support rooms that will include communications, electrical, and mechanical; and will support installation of wall-mounted telephones.

3.9.3.3 Local Area Network

A LAN that supports the MBTA corporate network will be provided for the new facility, inclusive of a core network switch in the main communications room and aggregation switches in communications room(s)/closet(s) as required to meet Ethernet distance standards. Switches will be connected in a ring topology with either copper or fiber optic cable as the installation dictates. The LAN minimum bandwidth will be 10GB.

3.9.3.4 Wireless Access Points

Wireless access points will be provided on the corporate network to provide wireless connectivity for operations and maintenance systems. Locations and quantities will be proposed to provide coverage throughout and along the perimeter of the facility including in all maintenance and storage areas for MBTA vehicles (e.g., buses, trains, or inspector cars).

3.9.3.5 Telephone System

A telephone gateway will be provided for the facility that will be an extension of the existing MBTA telephone system. This gateway will, at a minimum, include all of the features of the MBTA system, including VoIP, analog, and digital functions. Voicemail boxes will be provided for facility personnel as required by the MBTA.

Desk telephones will be provided for each office, and wall telephones will be provided for each support room.

3.9.3.6 Miscellaneous Data Connections

Data cabling and outlets will be provided to devices that include but are not limited to the following:

- Printers/Copy/Fax Machines
- MBTA's asset management system
- Defibrillators
- Fuel Management System
- HVAC/BMS system
- Video display monitors
- Fire Alarm System
- Bus Charging System
- FleetWatch System
- Timekeeping Kiosks
- Hand scanners
- MCRS Kiosks
- Informational Monitors
- Automated Fare collection (Vaulting and video surveillance for PCI)

3.9.4 Public Address

The facility will have a public address system to allow communications with employees throughout the facility and at select exterior locations. Public address equipment will be designed to comply with ADA accessibility guidelines. The system will be able to initiate announcements from the MBTA telephone system and local microphones.

Voice intelligibility will meet or exceed the minimum standards set forth in NFPA 72. Sound trespass to areas adjacent to the facility will be minimized to meet local ordinances or adjustable to levels approved by the AHJ. At least 95% of the facility will have a uniform audio level within ± 3 decibels with nominal Sound Pressure Levels at 10 decibels over normal bus and ambient noise at 5 feet above floor level. The desired public address system Speech Transmission Index will be minimum of 0.6 measured at 95% of the facility. Minimum levels will be obtained when buses are not operating and when the ambient noise level is minimal. Ambient sensing microphones will be included throughout the maintenance and storage areas to provide for automatic public address levels to compensate for ambient noise conditions.

The 70.7-V public address power amplifier and loudspeaker distribution equipment will be redundant such that the failure of any one public address channel/amplifier will not result in the total loss of public address coverage in any facility area. Additionally, to provide redundancy, every other loudspeaker in a zone will be wired to a different audio channel. Include end of line monitoring for each loudspeaker array. The public address system will also be divided into zones throughout the facility to facilitate customized audio settings and messaging for each area.

Cabling to the loudspeakers will be 2 conductor shielded audio cable with drain wire. Calculations will be provided showing voltage drop to determine conductor size.

3.9.5 Security System

3.9.5.1 Security Wide Area Network

The SWAN provides the communications medium for voice and data transmission from the facility to other MBTA facilities, including the data center, Security Operations Control Center, Operations Control Center, Hub Centers, and Transit Police.

The MBTA currently has fiber optic cable connections to a majority of its facilities. To support the SWAN, a new OS2 single mode fiber optic cable will be installed from the new bus facility to the closest fiber node as defined by the MBTA. If a fiber optic cable connection is not feasible, then leased wired/wireless data connections will be provided that are suitable for the bandwidth requirements of the facility security system.

A SWAN core switch, the same or newer generation of those currently used on the SWAN will be provided for the facility in the main communications room. Aggregation security network switches will be provided in communications rooms/closets to maintain Ethernet distance standards for connections to devices.

For security network connectivity at motorized fence gates and personnel gates, environmentally hardened security network switches will be provided in NEMA 4X security termination cabinets. These cabinets would connect to the closest communications room/closet via OS2 single mode fiber optic cable.

3.9.5.2 Security Local Area Network

A separate LAN will be provided for the facility security devices listed in the following sections.
The Security LAN will include a core network switch compatible with the existing security network switches used at the MBTA. Aggregation switches, configured in a ring topology, will be provided as required to connect security devices throughout the facility. Network switches provided in security terminal cabinets will be temperature hardened.

Wireless access points, connected to the Security LAN, will be provided in the bus storage and maintenance areas to off load video files from the bus video system. The quantity of wireless access points will be sufficient to provide adequate bandwidth to simultaneously off load video from buses when in the facility.

Power over Ethernet surge suppressors will be provided for all exterior devices.

3.9.5.3 Video Surveillance

Video Surveillance Systems will be provided per MBTA Specification 16840. IP based, Power over Ethernet cameras compatible with the existing MBTA video management system will be provided along the perimeter of the building, and as required along the perimeter of the site. Cameras will provide views of all perimeter doors, motorized gates, and personnel gates. Cameras will be placed within the building to view critical infrastructure and secured doors.

Cameras with secure digital (SD) cards, will be vandal-resistant fixed, single or multi-imager devices, with remote varifocal lens to provide the desired fields-of-view and pixels per inch required by the MBTA. Category 6 cable will be installed from each camera to the security network switch. Surge suppressors will be installed on cabling to exterior devices.

Provide a video managements system and server for the facility that is fully compatible and integrated to the MBTA PSIM System.

Video storage calculations will be provided to furnish appropriately sized network video storage appliances at the MBTA data center based on 30 days of storage, and MBTA requirements for frames per second and resolution. If a fiber optic connection to the SWAN is not feasible, a network video recorder will be provided at the facility.

3.9.5.4 Electronic Access Control System

An electronic access control system will be provided per MBTA Specification Section 13700 to secure facility exterior doors, interior doors of support rooms such as communications, electrical, and mechanical rooms, motorized gates, and personnel gates. The electronic access control system will be compatible with the existing MBTA electronic access control system and will interface to the MBTA PSIM. The electronic access control system control boards and door lock power supplies will be located in communications rooms, closets, and security terminal cabinets. Doors will be equipped with card readers, request to exit devices, electrical mortise or rim cylinder locks, and door contacts. Secondary doors to support rooms and roll up doors may be equipped with door contracts only as approved by the MBTA.

Provide licenses and service level agreements to include new electronic access control system devices in the MBTA enterprise-wide access control system.

3.9.5.5 Intercom System

Provide an ADA-compliant IP intercom, compatible with the MBTA’s existing Security Department VoIP server, at all motorized gates, personnel gates, and at the loading dock for communications with the forepersons’ office and parts office.

Provide a desktop IP intercom, located in an area defined by the MBTA, to locally answer calls initiated by remote IP intercom units. Update the IP server and provide licenses as required to account for new devices.

3.9.5.6 Physical Security Information Management System

The PSIM located at the MBTA Operations Control Center will be updated with maps of the facility, with icons placed to show locations of security, surveillance, and intercom devices. Alarms, camera names, room names, and camera call up will be programmed per MBTA requirements.

A PSIM client workstation will be provided for the facility, located in an area defined by MBTA. The workstation will consist of a computer (that meets PSIM high-level performance requirements), keyboard, mouse, two 24-inch desktop monitors, and one 400-inch wall-mounted monitor.

Provide licenses and service level agreements as required to add new security devices to the PSIM system.

3.9.6 Supervisory Control and Data Acquisition

3.9.6.1 Supervisory Control and Data Acquisition for Power Equipment

For proposed medium-voltage switching station, facility double-ended unit substations and BEB unit substations, an automation system with PLC or SCADA Remote Terminal Units will be provided for monitoring of these locations. The SCADA system interface requirements, main station and control center location, and system configuration will be defined by MBTA. The designer will include proposed control center graphical user interfaces for the new facility including, functionality, and alarms.

The MBTA may opt, in the future, to integrate this into MBTA Power Department SCADA system.

3.9.6.2 Supervisory Control and Data Acquisition for Other Electrical Equipment

The facility will be provided with a PLC to monitor indications for elevators, generators, and pumps. The SCADA system interface requirements, main station and control center location, and system configuration will be defined by MBTA. The designer will include proposed control center graphical user interfaces for the new facility including functionality, and alarms. The MBTA may opt, in the future, to integrate this into the HMCS/Vent Fan SCADA system.

3.9.7 Two-way Radio System and Cellular Service

3.9.7.1 Bidirectional Amplifier

Provide a bidirectional amplifier for the facility to provide two-way radio communications for the MBTA 800 megahertz (MHz) Systemwide Radio, municipal first responder radio frequencies as required by the AHJs, and cellular service.

Include an antenna tower with directional antenna pointed at the nearest MBTA Systemwide Radio transmitter tower, directional antenna(e) to support municipal first responder frequencies per the AHJs, and cellular antenna(e) to provide service for the major cellular providers. Size the antenna tower to support required antennae, with additional capacity to support 50% additional antennae. Tower height will also be sufficient to maintain separation between antennae to prevent interference between systems.

If the tower is roof-mounted, provide a raised walkway from the roof access location to the antenna tower.

3.9.7.2 Distributed Antenna System

Provide a distributed antenna system that will provide two-way radio communications throughout the facility for the MBTA 800-MHz Systemwide Radio, municipal first responder radio frequencies as required by the AHJs, and cellular service. Include radiating antenna(e), splitters, terminations, lightning arrestors, cabling, and directional antenna(e) appropriate for the required frequencies.

3.9.7.3 Systemwide Radio Units

800-MHz desktop two-way radios will be provided for the supervisor(s), desk inspector(s) and maintenance garage forepersons to provide two-way radio communications with buses, non-revenue vehicles, and bus operations personnel. The radios will be compatible with the MBTA's existing 800-MHz radio system and programmed with all of the bus operations radio frequencies and talk groups.

Non-revenue vehicles supplied with the new facility will include 800-MHz mobile two-way radios compatible with the MBTA's existing 800-MHz radio system and programmed with all of the bus operations radio frequencies and talk groups.

3.9.8 Audiovisual Systems

Audiovisual systems will be provided for conference rooms, classrooms, training rooms, break rooms, and offices as directed by the MBTA.

Large format (approximately 65 to 70 inches) flat panel touch screens will be provided in each class and training room. Large format flat panel monitors will be provided in conference rooms and offices. Large format flat panel monitors will be provided in the operator's and mechanic's breakrooms, the fitness room, and the pull-out starter room to display information from the MBTA intranet.

Audiovisual jack panels and wireless presentation systems will be provided in each room equipped with a large format monitor.

Host computer system supporting each monitor will be located within the same room, in a 28-rack unit tall enclosure.

3.9.9 Other Sustainability Design Requirements

3.9.9.1 Responsible Materials and Product Transparency

Specify products that are salvaged, reused, or contain recycled content. Prioritize products from companies that use sustainable procurement and manufacturing practices, and can provide documentation outlining their carbon footprint, minimum cradle to gate scope, environmental product declarations, or other proofs of their transparency of process. The entire Project Team is responsible for selecting compliant products, though a larger role rests with the architecture team for achievement.

Refer to LEED MR Credits B*uilding Product Disclosure and Optimization,* LEED EQ Credit Low *Emitting Materials*.

4 AREA MODULES

The area modules for the maintenance, transportation, and servicing areas of the facility in this section outline the functional uses and typical equipment and activities that occur for standard rooms and spaces in MBTA bus maintenance facilities related to each function. Diagrams are provided for illustrative purposes only. Specific room or area layouts and orientations will be determined through the design process with input from MBTA.

Each area module is preceded by its respective space adjacency bubble diagram, which visualize spatial connections or adjacencies, as well as people and vehicle movement between spaces that facilitate transportation, service, and maintenance operations.

The designer will use the space adjacency diagrams and the Facility Program Matrix (see **Table 4.1-1**) during the design process to ensure the final design conforms with the baseline spatial requirements for operational efficiency. Space bubble size roughly correlates with area size. Bubble location and orientation on the page does not dictate facility layout, but the design will adhere to and reflect the spatial connections and relationships depicted.

The general maintenance facility adjacency diagram (**Figure 4-1**) depicts baseline requirements and relationships of standard spaces in MBTA bus maintenance facilities (excluding heavy maintenance).

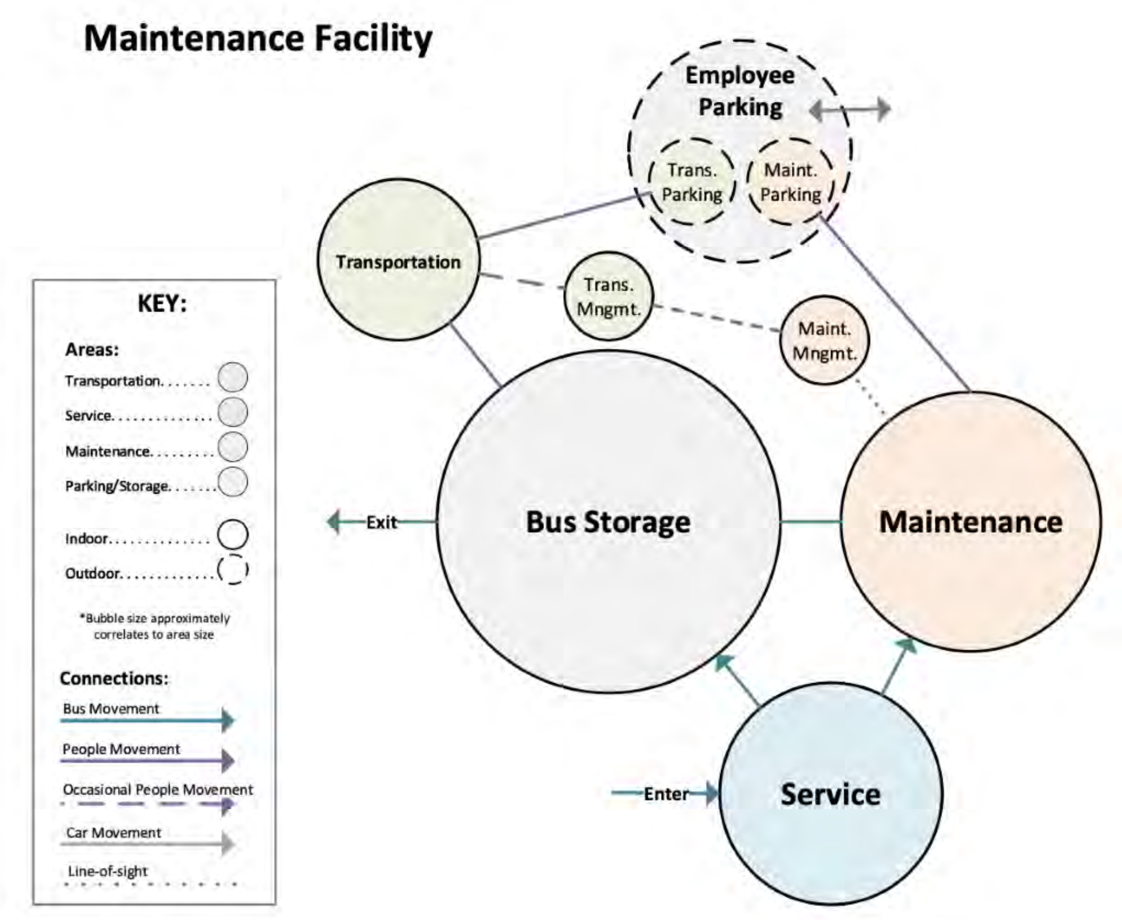


Figure 4-1. Maintenance Facility Adjacency Diagram

4.1 Maintenance

Figure 4.1-1 illustrates the standard spaces found in the maintenance area and the preferred adjacencies and connections.

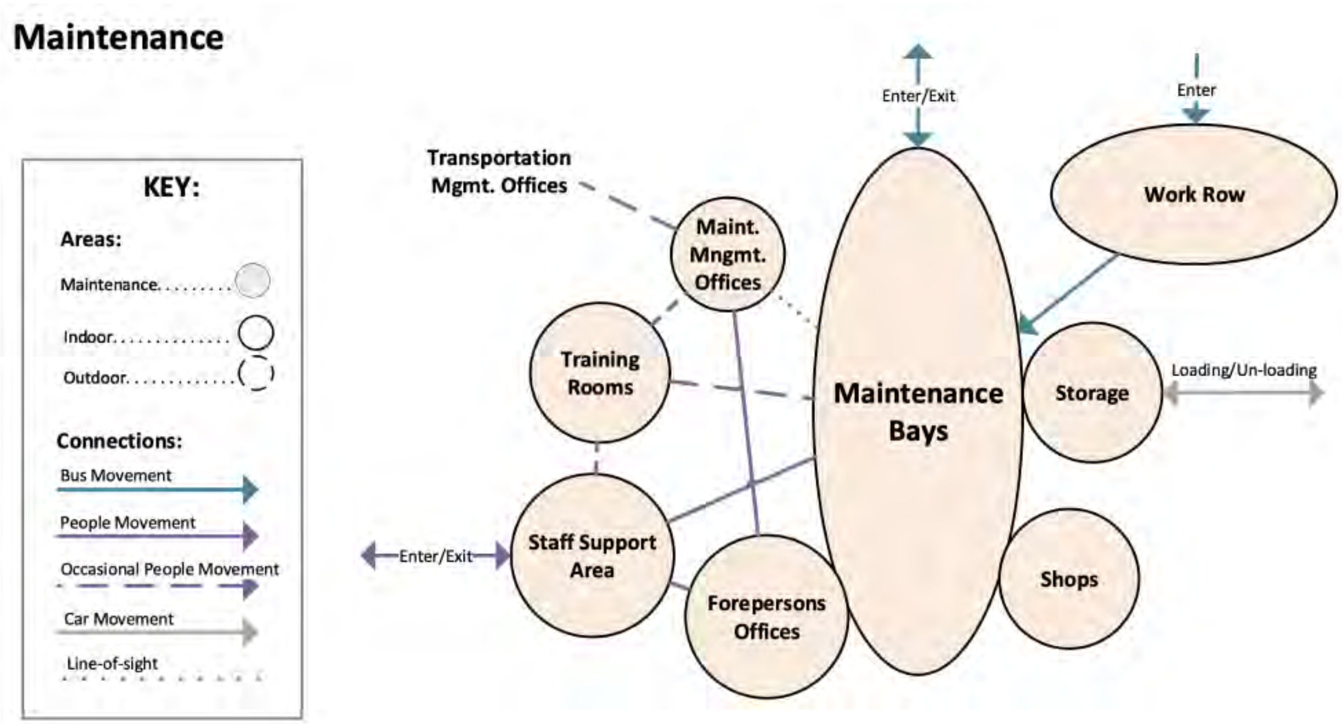


Figure 4.1-1. Standard Maintenance Spaces

Table 4.1-1 is a guideline for sizing rooms and spaces in bus maintenance facilities. It should be used to develop initial space programming for the building and site. The initial program must cover both the site and building and apply proper percentage factors for vehicle circulation, walls, site amenities, utilities, easements, landscaping, halls, entries, data rooms, and mechanical and electrical spaces. Areas must be tested and updated as needed throughout the design process. Specific and detailed discussion with end users and MBTA management regarding operations, fleet profile, level of maintenance, and considerations for future needs are needed to confirm these preliminary assumptions for each facility.

Table 4.1-1. Facility Program Matrix

Section	Room/Space Name	Minimum Area	Quantities	Notes
4.1	**Maintenance**			
4.1.1. Bus Maintenance Area	Bus Work Row	40-foot bus: 12 by 45 feet 60-foot bus: 12 by 65 feet	0.7 to 1 parking spots per maintenance bay	Industry standard: 0.3 to 0.5 per maintenance bay Dedicated work row space is preferred but not required; designer may consider designating lanes within bus storage to double as work row.
	Maintenance Bay	40-foot bus: 22 by 57 feet 60-foot bus: 24 by 77 feet 21-foot overhead clearance for bays with lifts	1 bay per 12 to 15 buses (including roof access bays, excluding inspection and steam clean bays)	Preferred for 40-foot bus: 24 by 60 feet Preferred for 60-foot bus: 24 by 80 feet
	Roof Access Bay	40-foot bus: 24 by 60 feet 60-foot bus: 24 by 80 feet 24-foot overhead clearance		Quantity dependent on bus sizes, roof equipment type and associated maintenance requirements
	Inspection Bay	40-foot bus: 25 by 60 feet 60-foot bus: 25 by 80 feet	1 bay per 100 to 120 buses 1 bay for each bus size	
	Inspection Equipment Room	120 square feet	1 per inspection bay	
	Maintenance Lubrication and Compressor Room	600 to 800 square feet		Dependent on fleet size, fluid delivery schedule, and fluid storage and compressor location
	Toilet Room	300 square feet	Male and female Number based on code	Could include secure single stall and/or toilet room
4.1.2. Steam Clean Bay (Chassis Wash)	Steam Clean Bay (Chassis Wash)	40-foot bus: 20 by 60 feet 60-foot bus: 20 by 80 feet	1 bay per 150 to 200 buses	Preferred 25 feet wide If only 1 bay, design for largest bus size
	Chassis Wash Steam Equipment Room	80 square feet		

Section	Room/Space Name	Minimum Area	Quantities	Notes
4.1.3. Maintenance Support Shops and Spaces	Common Work Area and Specialized Shops	Machine Shop: 500 square feet Welding Shop: 400 to 600 square feet		Varies depending on equipment, use and bay layout Machine Shop could include hydraulic press, drill press, sand blaster, parts cleaner Welding Shop could include mig welder, fume extraction system, helmet/gloves, gas, extension cords, welding benches, oxy/acetylene torch and variety of heads, bench grinders/wire wheels and belt sander
	Tire Storage	600 to 800 square feet		Dependent on outside service Room must accommodate 15-foot to 25-foot tall tire carousels and 16-foot by 8-foot tire racks
	Battery Storage Room	500 square feet (based on 200 BEB fleet)		Space should accommodate 18 to 24 new standard size batteries and 6 new high voltage propulsion batteries.
	Used High Voltage Battery Storage	500 square feet (based on 200 BEB fleet)		Used or damaged high voltage batteries must be stored outside of the building and isolated from other assets, as feasible. Designer will follow manufacturer recommendations for additional battery storage requirements.
	Portable Equipment Storage	Dependent on equipment list.	Area may be distributed based on equipment/workflow.	Could include fume extractors, portable lifts, jacks, floor scrubber, drain pans, and part carts.

Section	Room/Space Name	Minimum Area	Quantities	Notes
4.1.3. Maintenance Support Shops and Spaces (Continued)	Tools & Equipment Storage	Dependent on equipment list.	Area may be distributed based on equipment/workflow.	Could include pallet jacks (with ability to charge), forklift (with ability to charge), wheel dollies, battery charging cart, Shephard's bar, shelves for tire guns, air tools, kingpin press, axle/wheel-end tools, and larger hand tools.
	Secured Tools & Equipment Storage	Dependent on equipment list.	Area may be distributed based on equipment/workflow.	Could include electronics and specialty diagnostic tools, fleet-specific tools, battery fixtures and special tools, vending machines, space for yet unknown tools for fleet and (6-foot by 3-foot by 6-foot) shift boxes.
	Toolbox Storage	30 square feet	Per mechanic	Accommodate 4- to 6-foot by 2- to 3-foot toolboxes and 2-foot by 3-foot carts.
	Fluid Distribution and Waste Storage	800 to 1,000 square feet		Size dependent on fleet size/type and needs of facility. Could include storage for diesel fuel, automatic transmission fluid, power steering fluid, engine coolant, gear oil, chassis grease, waste oil, waste coolant windshield washer fluid.
4.1.4. Parts Storage	Loading Dock/Shipping and Receiving Area	1,600 square feet (Dependent of facility need)		Can be combined with parts storage; see site loading dock requirements below. Space should be sized to receive new inventory and staging for return parts and recyclables; must accommodate electric forklift and charging station, dock levelers, receiving table, hoist, and hand pallet.
	Parts Management Office	120 square feet		
	Parts Storage	4,500 square feet or based on need	Per 100 buses	Area may be distributed; accessible to elevator if on a different floor from maintenance bays

Section	Room/Space Name	Minimum Area	Quantities	Notes
4.1.4. Parts Storage (continued)	Parts Room Consumable Distribution Area	80 to 90 square feet	Minimum 2 spaces (parts room and end of maintenance bay row)	Distributed within the maintenance area
4.1.5. Bus Maintenance Management Suite	Superintendent's Office	150 square feet		
	Supervisor's Office	100 square feet		
	Workstation(s)	50 square feet		
	Break Room	180 square feet		
	Toilets	90 square feet	1 male and 1 female	Secured, single stall
	Conference Room	350 square feet		
	Copy/Print/Supplies/Storage Room	150 square feet		Includes dead file storage area
4.1.6. Mechanics and Forepersons Support Area	Mechanics' Locker Rooms	700 square feet	1 male and 1 female	Includes toilet room, shower room and 1 full-size and 1 half-size locker per mechanic
	Uniform Pick Up/Drop Off	4 square feet	Per mechanic	
	Mechanics' Break Room	50 square feet	Per mechanic (peak shift)	Include space for storage
	Forepersons' Office Suite	600 to 800 square feet		Suite to accommodate copy/storage room, 1 foreperson office, and workstations for shift forepersons
	Forepersons' Locker Rooms	700 square feet	1 male and 1 female	Includes toilet room, shower room and 1 full-size and 1 half-size locker per foreperson
	Mechanics Kiosk Niche	15 square feet	1 per bay	
	Mechanics Training Room	600 to 1200 square feet		Size based on the anticipated training activities at each facility. The space could include a classroom, equipment/lab training space and workstations
	Mechanics Training Storage	150 square feet		

Section	Room/Space Name	Minimum Area	Quantities	Notes
4.2	**Transportation**			
4.2.1. Transportation Operations Area	Interior Bus Storage	40-foot bus:12 by 45 feet 60-foot bus:12 by 65 feet	Per bus	75-foot minimum drive aisle width where buses turn 90 degrees 15-foot pass through aisle between every 3 to 4 rows of storage
	Desk Inspector's Office	200 square feet		
	Pull Out Inspector's Office	150 square feet		Accommodates 4 pull out inspectors
	Toilet Rooms	90 square feet	1 male and 1 female	Secured, single stall
	Operators' Picking Room	200 square feet		Needs may change if procedure becomes computerized
	Time-Keeping Kiosk	12 square feet	Per kiosk	Integrated into operator's entrance or alcove
4.2.2. Transportation Management Suite	Superintendent's Office	150 square feet		Accommodates 1 superintendent and 2 guests
	Division Chief Office	150 square feet		Accommodates 1 division chief and 2 guests
	Transportation Supervisors Workstation(s)	50 square feet	Per supervisor	
	Safety/Facility Manager Workstation	150 square feet		Accommodates 7-foot by 7-foot workstation and storage
	Huddle/Disciplinary/Privacy Room	180 square feet		
	Conference Room	500 square feet		Accommodates 15 people
	Copy/Print/Supplies/File Storage	150 square feet		Includes dead file storage area
	Management Break Area	250 square feet		
	Toilet Room	80 square feet	1 male and 1 female	Secured single stall

Section	Room/Space Name	Minimum Area	Quantities	Notes
4.2.3. Transportation Operations Support Areas	Operators Day Room	15 square feet	Per peak bus pullout	
	Operators and Inspectors Locker Rooms	3,000 square feet; dependent of staff per facility	1 male and 1 female	Accommodates toilet room, standard and accessible shower rooms 1 full-size locker per operator, 1 half-size locker for each field and onsite inspector
	Wellness Room	100 square feet	Large facilities may need more than 1	Include sink and refrigerator, chair or couch and side table
	Operators Training Room and Storage	1,200- to 1,800-square-foot training room 300- to 400-square-foot storage	Based on operator shift numbers	Dependent on whether the facility will be a local or central training site Includes workstation in training room for instructor
4.3	**Servicing**			
4.3.1. Fueling Operation	Fueling Bay	80 by 22 feet	1 per 100 buses	Assume additional square footage if above ground fluid storage is needed Minimum width 22 feet
	Service Lubrication and Compressor Room	600 to 800 square feet		Dependent on fleet size, fluid delivery schedule, and fluid storage and compressor location
4.3.2. Fueling Support	Fuelers' Work Area	300 square feet		
	Fare Collection Room	120 square feet		
	Fare Vault Room	120 square feet		
	Fuelers Storage	200 square feet		

Section	Room/Space Name	Minimum Area	Quantities	Notes
4.3.3. Bus Wash	Bus Wash Bay	22 by 90 feet	1 per fuel lane (2 total for up to 250 buses)	Minimum width 22 feet
	Bus Wash Equipment Room and Industrial Waste System Space	Minimum 100 feet in length		
	Bus Cleaning Storage	100 square feet	1 cleaning storage room for each level of bus storage	
	Site Spaces			
	Employee Parking	9 by 18 feet	Per space	Number of spaces will be determined for each facility and noted in the project brief.
	Visitor Parking	9 by 18 feet	Per space	Number of spaces will be determined for each facility and noted in the project brief.
	ADA Parking	13 by 20 feet for cars 14 by 20 feet for vans (Includes access aisle)	Per space	Number of spaces will be determined for each facility and noted in the project brief.
	Bus queuing	40-foot bus:12 by 45 feet 60-foot bus:12 by 65 feet		Dependent on peak return and bus route schedule Queuing can either be provided inside/ double with bus storage or as a designated space outside
	Non-revenue vehicle parking	10 by 20 feet	Per space	i.e., tow truck, tug, vans, pickups, service truck Number of spaces will be determined for each facility and noted in the project brief.
	Loading dock site area	4,000 square feet		Delivery/truck circulation must not conflict with bus movement Site must accommodate space for trash/ recycle dumpsters and circulation of a trash truck. If space is constrained, largest design vehicle (WB-65) may be accommodated via

Section	Room/Space Name	Minimum Area	Quantities	Notes
				an adjacent roadway that allows trucks to pull straight through and permits temporary parking to load/unload. Design exception from MBTA is required if the design cannot accommodate the largest design vehicle.

Note:
BEB = battery electric bus

4.1.1 Bus Maintenance Area

4.1.1.1 Bus Work Row

Functional Characteristics

Function

- Queuing area for buses awaiting maintenance or repairs (i.e., down line or ready line)

Critical Dimensions

- Spaces will be sized to accommodate a 5-foot clear space around the parked vehicle to adjacent work row space or any physical obstructions.
- Vertical clearance to the structure will be 15 feet minimum.

Design Features

- Drive-through configuration required for 60-foot buses (preferred for 40-foot)
- Parking spaces delineated by floor traffic striping

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry for light reflectance, soil and grease resistant
- Ceiling: Epoxy painted exposed structure for light reflectance

Structural

- Structural system at the ceiling level will accommodate installation of mechanical, electrical, and plumbing components above the bottom of steel to maintain the 15-foot clearance envelope.
- Columns that project into the work row will have a supplemental guardrail or bollards installed around the column.
- Provide support structures and guards to protect mechanical, electrical, and plumbing elements at floor level from incidental damage from vehicle impact.

Mechanical

- Space will be ventilated in accordance with the IMC requirements for a repair garage.
- Space will be provided with heating, to maintain the minimum temperature of 55˚F.
- Space will be provided with some form of cooling, to maintain a maximum temperature of 80˚F.

Electrical

- High bay 60,000 lumen LED luminaires
- 75 foot-candle average is required throughout the area
- General convenience receptacles
- 208-V and 480-V receptacles
- Power provided to room equipment

Plumbing

- 0.75-inch water hose bib with standard faucet 2-foot above finished floor (AFF)
- Compressed air line with shut-off valve, drip valve, regulator, lubricator, and quick disconnects on air/electric drop “trapeze” at 4-foot AFF. Provide disconnects for 0.5-inch and 1inch impact tools at locations to be determined during detailed design
- As required by equipment

Fire Protection

- Wet sprinklers with heads spaced a maximum of 130 square feet apart
- Alarm manual pull stations
- Alarm speaker and strobe devices

Systems

- Wi-Fi, public address, data jacks, bi-directional amplifier/distributed antenna system

4.1.1.2 Maintenance Bay

Functional Characteristics

Function

- Individual bays for preventive maintenance and exchange of parts

Critical Dimensions

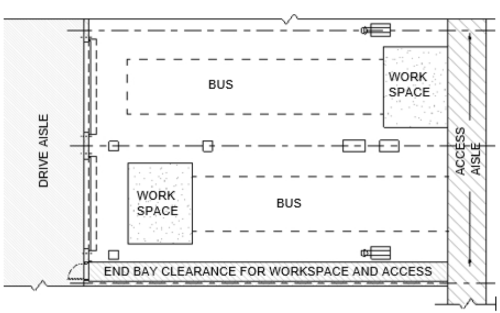
- Bay for 40-foot bus: minimum 22 feet by 57 feet; prefer 24 feet by 60 feet
- Bay for 60-foot bus: minimum 24 feet by 77 feet; prefer 24 feet by 80 feet
- Bays may be wider if columns are between bays and/or if bay is adjacent to a fixed wall
- Spaces will be sized to accommodate a 5-foot clear space around bus to adjacent bays or physical obstructions
- Bays with lifts minimum 21-foot overhead clearance

Equipment/Furnishings (Per Bay)

- Vertical rise platform lift, axle-engaging lift, and portable lift (refer to **Appendix B**)
- Fluid reels (oil, coolant, transmission fluid, DEF, windshield wiper fluid)
- Compressed air reel and compressed air drops (at columns)
- Vehicle exhaust system (located at the rear of the bus for diesel-hybrid buses)
- Access to filter crusher, portable oil drain, and coolant drain caddies, used oil and coolant pumps
- Small parts washer
- Workbench with vise

Design Features

- 1 bay per 12 to 15 buses (including roof access bays)
- Bays delineated by floor traffic striping
- All maintenance bays, including specialty bays, will be a drive-through configuration for 60-foot buses (preferred configuration for 40-foot buses)
- Bays will be connected with an 8- to 10-foot-wide circulation access aisle for parts, components, and staff movement
- Toolboxes, jacks, common shop equipment, shelving, tires, and specialty equipment will be stored at the end of the circulation aisle or behind the bay
- Bay floors will be flat (no slope)
- Layout will allow for easy access by an electric walk behind or riding floor cleaner for bay cleaning after a bus is removed



Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener (to provide reflective light to the underside of the vehicle), and clear breathable sealer
- Wall: Epoxy painted masonry for light reflectance; soil and grease resistant
- Ceiling: Epoxy painted exposed structure for light reflectance

Architectural Doors

- Personnel doors will be hollow metal sized as required for use
- Exterior overhead doors will be coiling metal doors for utility locations and fast acting insulated fabric doors for vehicle entries and exits
- Bollards on exterior at jambs of overhead or coiling doors (two each)

Structural

- Control joints in-floor slab at adequate spacing, joints within service row, will be aligned with orientation of lift/service bay
- Structural pits as needed to support recessed or in-floor telescoping lift equipment
- Provide support structures and guards to protect mechanical, electric, and plumbing elements at floor level from incidental damage resulting from vehicle impact
- Trowel finish on floor slab (refer to the architectural finishes considerations for floor slab treatment)

Mechanical

- Source capture exhaust system (industrial-grade exhaust fan with hose-reel with a means of connecting directly to the bus exhaust)
- Source of ventilation to comply with the IMC requirements for a repair garage and to provide a source of makeup air to the exhaust system
- Heating to maintain a minimum temperature of 55˚F
- Cooling to maintain a maximum temperature of 80˚F
- Air curtains and procedure controls if exterior facing doors

Electrical

- High bay 60,000 lumen LED luminaires
- 75 foot-candle average is required throughout the area
- General convenience receptacles
- 208-V and 480-V receptacles
- Power provided to room equipment

Plumbing

- Trench drain with sediment bucket and removable cover to oil water separator
- Lube reel banks with ATF, EC1, EC2 at end of bay
- Reel banks with GO mid-bay (shared, one each per two bays)
- 0.75-inch water hose bib with standard faucet at rear of bay 2-foot AFF (one per three bays)

- Compressed air line with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnects on air/electric drop "trapeze" between each bay (at mid-bay) and at 4-foot AFF (between bay doors)
- Disconnects for 0.5-inch and 1-inch impact tools at locations to be determined during detailed design
- Compressed air line to vehicle lift control box for locking legs
- Hydraulic supply and return lines between vehicle lift control box and lift power unit in single trench with steel plate cover (pipe run anchored for hydraulic line shock)
- 1.5-inch tempered water to free standing emergency shower/eyewash where hazardous liquids or chemicals are stored
- Utilities as required by equipment

Fire Protection

- Wet sprinklers with heads spaced a maximum of 130 square feet apart

Systems

- Wi-Fi, public address, data jacks, bidirectional amplifier/distributed antenna system

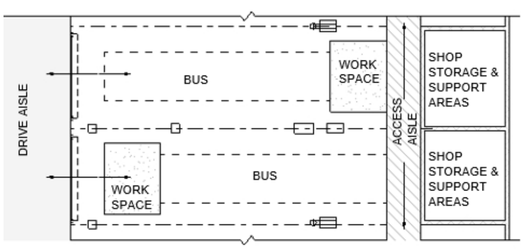
Option 1: Single Bay – Single Door

Common Applications

- Constrained sites with smaller/specialized fleets
- Chassis wash (water containment) and roof access bays (bays with access to roof without fall protection)
- Where direct access from bays to shops is needed

Limitations and Constraints

- Reduced operational and spatial efficiency
- Less efficient use of space because of lineal alignment
- Creates long lineal workflow pattern requiring more travel between spaces
- Can limit communication and line of site for mechanics and supervisors



Option 2: Drive-through Bay (Required for 60-foot Bus, Preferred for 40-foot)

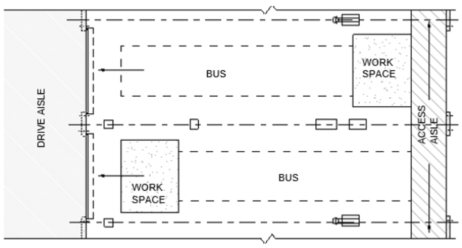
Common Applications

- Inspection, fuel, quick-fix (rapid emergency repair for running vehicle), and drive-through wash bays
- Wherever rapid processing of buses is operationally beneficial
- Where forward drive-through movement is needed

Limitations and Constraints

- Building footprint increases in a lineal fashion as bay counts increase

- Shops are distant from the maintenance bay rows and decrease operational efficiency, or between bays reducing visibility and safety
- Main drive aisles require more space
- Single access aisle (passageway for shops, parts, supervisors, and support areas) is on engine-side and will be driven across by buses so extra safety precautions are required
- Requires entrance visibility mirrors



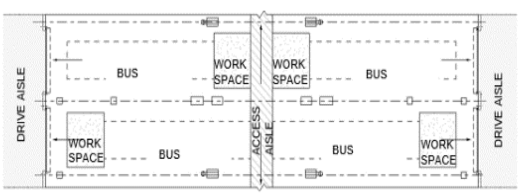
Option 3: Double Stacked Bay

Common Applications:

- Larger fleets to consolidate maintenance bay area and solve site constraints
- Consolidates utility, fluid, mechanical, and other systems
- Higher safety and operational efficiency due to central corridor access aisle
- Layout provides drive-through potential where needed

Limitations and Constraints:

- Drive aisles on either side of the maintenance bays require additional space
- Can be configured as drive-in/back-out or back-in/drive-out



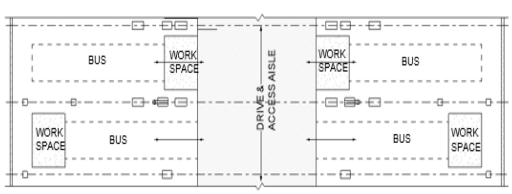
Option 4: Interior Drive Aisles

Common Applications:

- To minimize exterior vehicle travel and reduce the number of overhead doors

Limitations and Constraints:

- Significantly higher initial capital and long-term maintenance and operational costs due to significant increase in building size
- Location of drive aisle relative to the configuration of bays will be considered
- Requires careful attention to interior building circulation



4.1.1.3 Roof Access Bay

Functional Characteristics

Function

- Specialty bay designed for bus roof access by fixed or mobile platform; at bus roof height on all four sides

Critical Dimensions

- Bay for 40-foot bus: minimum 24 feet by 60 feet
- Bay for 60-foot bus: minimum 24 feet by 80 feet
- Bays may be wider if columns are between bays and/or if bay is adjacent to a fixed wall
- Minimum 24-foot overhead clearance

Equipment/Furnishings

- Bridge crane for removing and installing bus rooftop equipment
- Occupational Safety and Health Administration (OSHA) compliant roof access platform (that can maintain a gap of less than 6 inches between the bus and platform) with stair(s) and perimeter guardrail
- Fall protection system (with trolley for multiple tie-off safety harnesses)
- Tire guides to position bus in bay and avoid collisions between the bus and platform
- Compressed air reel and compressed air drops (at columns)
- Vehicle lifts will not be installed due to safety and clearance issues

Design Features

- 1 roof access bay per 150 buses (if only one platform is provided in a facility, 1 to 2 additional bays without such a platform will be provided with tie-off safety harness trolley and monorail for temporary roof access)

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, and slip-resistant concrete; integral non-metallic light reflective hardener; clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Structural

- Overhead hoisting capabilities will be provided utilizing bridge crane with electric hoist.
- Monorail will extend into the adjacent circulation aisle to permit offloading of materials directly from delivery vehicles.
- Minimum capacity of the hoist will be 4 tons with the monorail rated for double this capacity.

Mechanical

- Space will be ventilated in accordance with IMC requirements for a repair garage.
- Space will be provided with heating to maintain the minimum temperature of 55˚F.
- Cooling to maintain a maximum temperature of 80˚F.

Electrical

- High bay 60,000 lumen LED luminaires
- 75 foot-candle average is required throughout the area
- General convenience receptacles
- 208-V and 480-V receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers
- Alarm manual pull stations
- Alarm speaker and strobe devices

Systems

- Public address

4.1.1.4 Inspection Bay

Functional Characteristics

Function

- Bay with pit to allow inspection of bus undercarriage and fluid exchanges

Critical Dimensions

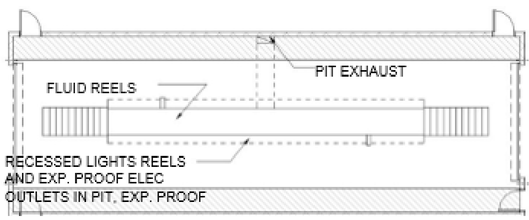
- Bay for 40-foot bus: 25 feet by 60 feet
- Bay for 60-foot bus: 25 feet by 80 feet
- Minimum 16-foot overhead clearance
- Pit depth: minimum 5 feet 3 inches

Equipment/Furnishings

- Motor oil/transmission fluid/chassis grease reel
- Compressed air reels and compressed air drops along walls
- Bay net or pit cover for fall protection

Design Features

- 1 inspection bay per 100 to 120 buses



Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Overhead doors on each end of space to permit pass-through operation
- Personnel doors with view panels

Structural

- Inspection pit will include recesses on both sides to allow lighting and other equipment to be stored out of the aisle.
- Floor will be sloped to one side with sump pits in opposing corners.

Mechanical

- Ventilation to comply with the IMC requirements for a repair garage and to provide a source of makeup air to the exhaust system(s)
- Heating to maintain a minimum temperature of 55˚F
- Cooling to maintain a maximum temperature of 80˚F

Electrical

- High bay 60,000 lumen LED luminaires
- 75 foot-candle average is required throughout the area
- Vapor tight LED lighting
- Convenience ground-fault circuit interrupter (GFCI) receptacles
- Power provided to room equipment

Plumbing

- Industrial waste sump pump in pit with galvanized steel cover (one on each side)
- Lube reel banks with chassis grease
- 0.75-inch water hose bib with standard faucet at rear of bay 2-foot 0-inch AFF
- Compressed air line with shut-off valve, separator, regulator, lubricator, and quick disconnects on air/electric drop “trapeze” at 4-foot 0-inch AFF. Provide disconnects for 0.5-inch and 1inch impact tools at locations to be determined during detailed design
- 1.5-inch tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored
- As required by equipment

Fire Protection

- Wet sprinklers
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone and data jacks
- Bidirectional amplifier/distributed antenna system

4.1.1.5 Inspection Equipment Room

Functional Characteristics

Function

- Room to store equipment used to inspect fleet

Critical Dimensions

- Area: 120 square feet
- One equipment room per inspection bay

Equipment/Furnishings

- Shelving and drawer units, as required

Design Features

- One equipment room per inspection bay

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Personnel doors with view panels to meet applicable code exit requirements

Mechanical

- Heating to maintain a minimum temperature of 55˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers
- Alarm speaker and strobe devices

Systems

- Electronic access control
- Public address

4.1.1.6 Maintenance Lubrication and Compressor Room

Functional Characteristics

Function

- Storage and distribution of fluids for maintenance bays

Critical Dimensions

- Area: 600-800 square feet; dependent on fleet size, fluid delivery schedule, and fluid storage/compressor location

Equipment/Furnishings

- Motor oil and transmission fluid pump
- DEF and coolant pumps
- WWF pump
- Shelving units
- Aboveground transmission fluid tank (250 gallons)
- Aboveground motor oil and WWF tanks (500 gallons each)
- Aboveground tank (750 gallons) for coolant/antifreeze
- Aboveground DEF tank (1,000 gallons)
- Air compressor and refrigerator/dryer
- Emergency safety shower/eyewash

Design Features

- Exterior access for delivery of bulk fluids by truck via overhead coiling door
- Fill-ports for fluid tanks are preferred to be on the exterior of the building
- Acoustically and physically separated from other areas to prevent migration of noise and vibration if possible
- Grated area below tanks to serve as spill sump

Technical Considerations

Architectural Finishes

- Floor: Epoxy concrete sealer; soil, grease, water and slip-resistant
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Personnel doors to meet applicable code exit requirements
- 3-foot 0-inch-wide hollow metal door with interior exit device
- No thresholds

Structural

- Control joints in-floor slab at adequate spacing
- Raised concrete housekeeping pad under compressors and air dryers
- As needed to support equipment

Mechanical

- Exhaust per IMC Section 502
- Ventilation for makeup to exhaust system
- Heating to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- 0.75-inch water hose bib with standard faucet 2-foot AFF
- Compressed air system with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnect on wall at 4-foot AFF for each lubricant pump
- Tank mount all lubricant pumps except hoist-mounted chassis grease and wall-mounted EC diaphragm pump with siphon kit
- Water tank with float valve for water to EC diaphragm pump
- Floor drains on building oil water separator system
- As required by equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head, medium temperature heads
- Alarm manual pull stations, speaker, and strobe devices

Systems

- Public address, telephone/data jacks

4.1.1.7 Bus Maintenance Area Toilet Rooms

Functional Characteristics

Function

- General use toilet rooms and/or secure single stall facilities accessible to the bus maintenance area.

Critical Dimensions

- Area: 90 to 300 square feet; number/size of based on occupancy and code

Equipment/Furnishings

- Urinals, wash sinks
- Toilets with stainless-steel partitions and accessories

Design Features

- Includes adjacent custodial closet with utility sink to service this space

Technical Considerations

Architectural Finishes

- Floor: Ceramic or porcelain over waterproof membrane (wet areas)
- Walls: Ceramic or porcelain tile/Epoxy painted gypsum board
- Ceiling: Epoxy painted gypsum board

Architectural Doors

- Electronic door hardware/Controlled Access entry into room

Mechanical

- Exhausted/ventilated per IMC (no recirculation)
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,800 lumen Recessed LED luminaires
- 50 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Domestic hot/cold water, sanitary and vent to water closets, urinals, and toilets
- Floor drains with trap primers
- Hose bibs underneath toilets

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm strobe devices

Systems

- Public address

4.1.2 Steam Clean Bay (Chassis Wash)

4.1.2.1 Steam Clean Bay (Chassis Wash)

Functional Characteristics

Function

- Enclosed room with weather resistant overhead or coiling doors for washing of bus undercarriages, engine compartments, and large components

Critical Dimensions

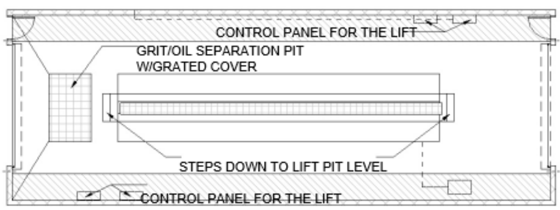
- Bay for 40-foot bus: 20 feet by 60 feet; 25-foot width preferred
- Bay for 60-foot bus: 20 feet by 80 feet; 25-foot width preferred

Equipment/Furnishings

- Drive-on vertical rise platform lift (recessed or flush with floor level) designed for wet conditions and with lights to Illuminate the undercarriage
- High pressure washer and remote starters
- Compressed air reel

Design Features

- 1 bay per 150 to 200 buses



Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete coating; drive lanes delineated by traffic striping; galvanized steel grating with stainless-steel frame and hardware
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Stainless-steel personnel doors for wet environment with view panels
- Overhead doors on each end to permit pass-through operation will include stainless-steel hardware and be installed on the exterior face of the wall to minimize exposure of door operating equipment to water spray

Structural

- Galvanized structural steel with marine grade coating system

Mechanical

- Exhausted/ventilated per IMC for a repair garage, aluminum ductwork
- Heated to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- 30 foot-candle average is required throughout the area
- Convenience GFCI receptacles suitable for wet-service and direct water spray
- Power provided to room equipment

Plumbing

- Trench drain with sediment bucket and removable cover to oil water separator
- Domestic cold water with backflow preventer to MR-2 high pressure washer
- Waste oil draining pan
- Overhead lube reels
- 1.5-inch tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored
- As required by equipment

Fire Protection

- Wet sprinklers with heads spaced a maximum of 130 square feet apart
- High temperature sprinklers
- Alarm manual pull stations
- Alarm speaker and strobe devices

4.1.2.2 Chassis Wash Steam Equipment Room

Functional Characteristics

Function

- Accommodates portable chassis wash equipment and general chassis wash storage

Critical Dimensions

- Minimum Area: 80 square feet

Equipment/Furnishings

- High Pressure Washer

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- 3-foot-wide hollow metal door with interior exit device

Structural

- Housekeeping pads for floor-mounted equipment

Mechanical

- Exhausted/ventilated per IMC for a repair garage, aluminum ductwork
- Heated to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- 30 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Floor drain on oil water separator system
- As required by equipment

Fire Protection

- Wet sprinklers with heads spaced a maximum of 130 square feet apart
- High temperature sprinkler heads
- Alarm manual pull stations
- Alarm speaker and strobe devices

4.1.3 Maintenance Support Shops and Spaces

4.1.3.1 Common Work Area and Specialized Shops (General Machine Shop and Welding Shop)

Functional Characteristics

Function

- General machine shop is close to maintenance bays (specifically axle-engaging post lift repair bays) with test benches and diagnostic tools to check electronic parts and other components
- Welding shop is where metal parts are repaired

Critical Dimensions

- General machine shop area: ~ 600 square feet (dependent on equipment, use and bay layout; can be split into multiple areas if needed)
- Welding shop area: ~ 400 to 600 square feet (dependent on equipment, use and bay layout)

Equipment/Furnishings

- Buffer/grinder on stand with dust collector
- Drill press, off saw, hydraulic press
- Abrasive blast cabinet, shelving units, workbenches with vises, storage cabinets
- Parts washer and degreaser (steam cabinet)
- Compressed air drops
- Tools carts, fluid carts/waste fluid caddies, scissor lift
- AC recovery/recharge units
- Floor scrubber
- Bug tug
- Mig welder, fume extractors, welding benches, torch carts, belt sanders, plasma cutter

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Structural

- Structural reinforcements as required to support specific equipment needs

Mechanical

- Source of ventilation to comply with the IMC requirements for a repair garage
- Ventilation for welding shop in conformance with Industrial Ventilation Handbook
- Heating to maintain a minimum temperature of 55˚F
- Cooling to maintain a maximum temperature of 80˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- 40 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Provide domestic cold water with backflow preventer to MB-9 parts washer
- Compressed air line with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnects on air/electric drop “trapeze” at 4-foot AFF. Provide disconnects for 0.5inch and 1-inch impact tools at locations to be determined during detailed design
- 1.5-inch tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored
- As required by equipment

Fire Protection

- Wet sprinklers with heads spaced a maximum of 130 square feet apart
- Alarm manual pull stations
- Alarm speaker and strobe devices

Systems

- Public address

4.1.3.2 Tire Storage

Functional Characteristics

Function

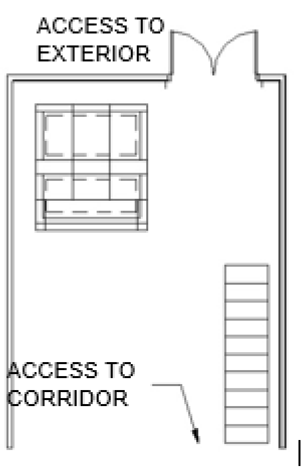
- MBTA utilizes outside vendor for tire work, but onsite tire storage is required for new or repaired tires and tires needing repair for use by mechanics
- Located near maintenance bays with post lifts where work is done and open to access aisle/maintenance bay

Critical Dimensions

- Area: 600 to 800 square feet based on capacity to store at single site (dependent on storage needs per facility and building code)
- Room must accommodate 15- to 25-foot-tall tire carousels (can extend through opening in ceiling)

Equipment/Furnishings

- Tire carousel
- Tire storage racks
- Tire rack hoist



Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer; trowel finish and special light reflective hardener on concrete floor slab
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Doors for outside access that accommodate passage of a forklift

Structural

- Structural reinforcements as required to support specific equipment needs

Mechanical

- Source of ventilation to comply with the IMC requirements for a repair garage
- Heating to maintain a minimum temperature of 55˚F

Electrical

- 3,500 lumen LED pendant or surface luminaires
- 40 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Compressed air line with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnects at 4foot AFF; provide disconnects for 0.5-inch and 1-inch impact tools at locations to be determined during detailed design
- As required by equipment

Fire Protection

- Wet sprinklers
- Alarm smoke detector devices
- Alarm speaker and strobe devices

Systems

- Public address
- Electronic Access Control on exterior doors

4.1.3.3 Battery Storage Room

Functional Characteristics

Function

- Provides storage for new standard and high voltage propulsion batteries to be installed
- Provides staging for used standard batteries to be picked up for servicing
- Used or damaged high voltage propulsion batteries must be stored outside of building and isolated for other assets as feasible

Critical Dimensions

- Area: ~ 500 square feet for 200 BEB fleet (dependent on fleet size)

Equipment/Furnishings

- Battery wash station
- Pallet rack/battery rack
- Battery roller stands
- Power mobile lift tables and/or battery transfer carriages (dependent on type of battery extraction)

Design Features

- Forklift accessible
- Physically separated from other areas and ventilated to prevent migration of fumes
- Adjacent to parts room and repair bays

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Hollow metal double doors to main access aisle to maintenance bays

Structural

- Structural reinforcements as required to support specific equipment needs

Mechanical

- Adequate ventilation (15 air changes per hour minimum)
- Stainless-steel duct work and fans

Electrical

- 3,500 lumen LED pendant or surface luminaires
- 40 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- 1.5-inch tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored.

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm smoke detector devices
- Alarm speaker and strobe devices

4.1.3.4 Portable Equipment Storage

Functional Characteristics

Function

- Unlocked storage area with easy access to the maintenance bays designed for storing portable equipment such as fume extractors, portable lifts, jacks, floor scrubber, drain pans, and part carts

Critical Dimensions

- Area: Dependent on equipment list
- Space may be distributed based on equipment and/or workflow.

Design Features

- Space may be distributed as needed based on equipment and maintenance bay layout

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Double-leaf 3-foot-wide hollow metal doors

Structural

- Structural reinforcements as required to support specific equipment needs

Mechanical

- Heating to maintain a minimum temperature of 55˚F

Electrical

- 3,500 lumen LED pendant or surface luminaires
- 40 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm smoke and heat detector devices
- Alarm speaker and strobe devices

System

- Public address

4.1.3.5 Secured Tool Storage

Functional Characteristics

Function

- Locked storage for diagnostic, fleet-specific and/or other specialty tools and equipment, as well as forepersons' shift boxes
- Access controlled by forepersons

Critical Dimensions

- Area: Dependent on equipment list and number of shift forepersons.
- Space may be distributed based on equipment and/or workflow.

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Mechanical

- Heating to maintain the minimum temperature of 55˚F

Electrical

- 3,500 lumen LED pendant or surface luminaires
- 40 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm smoke detector devices
- Alarm speaker and strobe devices

System

- Public address
- Electronic access control

4.1.3.6 Toolbox Storage

Functional Characteristics

Function

- Locked area where mechanics leave their toolboxes when off duty

Critical Dimensions

- Area: 30 square feet per mechanic

Equipment/Furnishings

- 2 feet by 3 feet tool carts
- 4 to 6 feet by 2 to 3 feet toolboxes

Design Features

- Enclosed wire mesh partition and wide sliding gate opening for access to toolboxes (or open storage if individual toolboxes are locked)

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Mechanical

- Heating to maintain a minimum temperature of 55˚F

Electrical

- 3,500 lumen LED pendant or surface luminaires
- 40 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm smoke detector devices
- Alarm speaker and strobe devices

Systems

- Electronic access control
- Public address

4.1.3.7 Fluid Distribution and Waste Storage – Tanks and Compressor/Air Dryer

Functional Characteristics

Function

- Bulk fluid storage for fueling, inspection, and maintenance bays

Critical Dimensions

- Area: 800 to 1,000 square feet (based on 200 BEB fleet); size dependent on fleet size/type and needs of facility.

Equipment/Furnishings

- Above-grade, double-wall bulk storage tanks
- Air pumps, valves, regulator, piping to reels and leak detection alarms
- Compressor receiver and dryer
- Emergency safety shower/eyewash
- Fluids may include diesel fuel, ATF, power steering fluid, EC, GO, chassis grease, waste oil, waste coolant WWF

Design Features

- Exterior access for delivery
- Ideally located on ground floor due to vibration from compressor
- Acoustically and physically separated from other areas to prevent migration of noise and vibration
- Piping to exterior for filling bulk storage containers by outside vendors

Technical Considerations

Architectural Finishes

- Floor: Epoxy concrete sealer; soil, grease, water and slip-resistant
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Personnel doors to meet applicable code exit requirements
- Double 3-foot-wide hollow metal door with interior exit device
- Forklift accessible

Structural

- Structural reinforcements as required to support specific equipment needs
- Raised concrete housekeeping pad under compressors and air dryers

Mechanical

- Ventilation in accordance with the IMC requirements for a repair garage
- Heating to maintain the minimum temperature of 55˚F
- Cooling to maintain a maximum temperature of 80˚F

Electrical

- 3,500 lumen LED hazardous location rated luminaires
- 50 foot-candle average is required throughout the area

- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- 0.75-inch water hose bib with standard faucet 2-foot AFF
- Compressed air system with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnect on wall at 4-foot AFF for each lubricant pump
- Tank mount all lubricant pumps except for hoist-mounted chassis grease and wall-mounted EC diaphragm pump with siphon kit
- Water tank with float valve for water to EC diaphragm pump
- 1.5-inch tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored
- As required by equipment

Fire Protection

- Wet sprinklers spaced maximum 100 square feet per head
- Smoke detector devices
- Alarm speaker and strobe devices
- Alarm manual pull stations

Systems

- Public address
- Electronic access control for exterior doors

4.1.4 Parts Storage

4.1.4.1 Loading Dock/Shipping and Receiving Area

Functional Characteristics

Function

- Enclosed or open area adjacent to parts storage; where incoming parts can be received, checked and logged into inventory and where used parts and recyclables are staged for pickup

Critical Dimensions

- Area: 1,600 square feet (can be combined with parts storage)

Equipment/Furnishings

- Electric forklift and charging station
- Dock levelers
- Receiving table
- Hoist
- Hand pallet

Design Features

- Forklift accessible

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Personnel doors to meet applicable code exit requirements

Mechanical

- Air curtains at overhead doors
- Heating to maintain minimum temperature of 55˚F

Electrical

- 60,000 lumen LED high bay luminaires
- 40 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers spaced maximum 130 square feet per head
- Smoke detector devices
- Alarm speaker and strobe devices
- Alarm manual pull station

System

- Electronic Access Control
- Intercom and buzzer
- CCTV cameras
- Public address
- Data jacks

4.1.4.2 Parts Management Office

Functional Characteristics

Function

- Offices where the stores department manages and distributes parts (e.g., log the receipt and application of parts, order additional parts, manage disposal and recycling of used parts)

Critical Dimensions

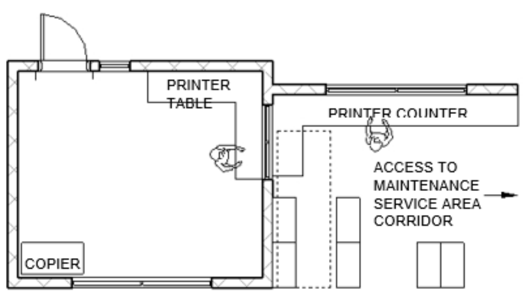
- Area: 120 square feet

Equipment/Furnishings

- Computer workstations
- Telephones
- Printer/copier station
- Parts counter (e.g., table and chairs)
- Storage cabinets and parts cart

Design Features

- Stainless-steel service counter with sliding window
- Visual connection to maintenance and parts storage areas
- Accessed from parts room only



Technical Considerations

Architectural Finishes

- Floor: Epoxy concrete sealer; soil, grease, water and slip-resistant
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted gypsum board

Architectural Doors

- Electronic door hardware with controlled access entry into room

Mechanical

- Ventilation in compliance with IMC
- Heating to maintain minimum temperature of 70˚F
- Cooling to maintain maximum temperature of 75˚F

Electrical

- 4500 lumen LED pendant luminaires

- 60 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers spaced maximum 130 square feet per head
- Alarm speaker and strobe devices

Systems

- Electronic access control
- CCTV cameras
- Public address
- Wi-Fi
- Telephone/data jacks
- Intercom base station

4.1.4.3 Parts Storage Room(s)

Functional Characteristics

Function

- Secured storage and distribution of vehicle parts and materials on and in pallet racks, shelving, and drawer units

Critical Dimensions

- Area: 4,500 square feet per 100 buses
- Area may be distributed; preferred on ground floor; accessible to elevator if on multiple floors

Equipment/Furnishings

- Part carts and hand pallet truck
- Optional vertical lift module or other automated storage systems for parts inventory

Design Features

- Forklift accessible

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Personnel doors with view panels to meet applicable code exit requirements
- Exterior overhead door: High-lifting sectional, steel, insulated, 10 feet by 12 feet, with view panels, automatic operator, interior and exterior push button controls, and lockout on exterior
- Electronic door hardware with controlled access entry into room

Mechanical

- Heating to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers spaced maximum 130 square feet per head
- Smoke detector devices
- Alarm speaker and strobe devices
- Alarm manual pull station

Systems

- Data jacks
- Buzzer at parts window
- Electronic access control
- Wi-Fi
- Public address

4.1.4.4 Parts Room Consumable Distribution Area

Functional Characteristics

Function

- One or more small areas open to maintenance bays to provide mechanics access to consumable small parts and supplies that are not inventoried

Critical Dimensions

- Area: 80 to 90 square feet (distributed throughout maintenance area with a minimum of two spaces; one at the parts room and one at the end of the maintenance bay area)

Equipment/Furnishings

- Shelving units, cabinets, storage bins
- Parts cart

Design Features

- Located in the maintenance area

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Mechanical

- Heating to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers spaced maximum 130 square feet per head
- Alarm speaker and strobe devices
- Alarm manual pull station

Systems

- Wi-Fi
- Public address

4.1.5 Bus Maintenance Management Suite

4.1.5.1 Superintendent's Office

Functional Characteristics

Function

- Private office for superintendent with accommodations for guests as needed

Critical Dimensions

- Area: 150 square feet accommodates one superintendent and up to four guests (dependent on facility specific needs)

Equipment/Furnishings

- Printer, radio console, and other equipment to be identified by MBTA (e.g., desk with return, chairs, lateral files, audiovisual including wall-mounted television monitors)

Technical Considerations

Architectural Finishes

- Floor: Vinyl composition tile (VCT)/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Secured entry by single 3-foot door

Mechanical

- Ventilation in accordance with IMC requirements for an occupied space
- Heating to maintain a minimum temperature of 70˚F
- Cooling to maintain the maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Domestic cold water
- Point of use electric water heater
- Sanitary and vent to print room sink

Fire Protection

- Wet sprinklers spaced maximum 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.1.5.2 Supervisor's Office

Functional Characteristics

Function

- Private office for supervisor with accommodations for guests as needed

Critical Dimensions

- Area: 100 square feet accommodates one supervisor and up to two guests (dependent on facility specific needs)

Equipment/Furnishings

- Printer, radio console, and other equipment to be identified by MBTA (e.g., desk with return, chairs, lateral files, audiovisual including wall-mounted television monitors)

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Secured entry by single 3-foot door

Mechanical

- Ventilation in accordance with IMC requirements for an occupied space
- Heating to maintain a minimum temperature of 70˚F
- Cooling to maintain the maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers spaced maximum 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.1.5.3 Maintenance Management Suite Workstation(s)

Functional Characteristics

Function

- Freestanding workstations

Critical Dimensions

- Area: 50 square feet per workstation; number based on facility needs

Equipment/Furnishings

- Workstation desk with return and chair
- Lateral files

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm speaker and strobe devices
- Alarm manual pull station

Systems

- Public address
- Telephone/data jacks
- Telephone
- Wi-Fi

4.1.5.4 Break Room

Functional Characteristics

Function

- Used at a break room for maintenance management staff

Critical Dimensions

- Area: 180 square feet

Equipment/Furnishings

- Counter space and upper cabinets
- Sink with disposal
- Microwave, coffee maker, refrigerators
- Tables and chairs
- Audiovisual including wall-mounted, large format television monitors and audiovisual panel

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Secured entry by single 3-foot door

Mechanical

- Ventilation in accordance with IMC requirements for an occupied space
- Heating to maintain a minimum temperature of 70˚F
- Cooling to maintain the maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Provide domestic hot/cold water, sanitary and vent to break room sinks

Fire Protection

- Wet sprinklers spaced maximum 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.1.5.5 Maintenance Management Suite Toilet Rooms

Functional Characteristics

Function

- Secured, single stall toilet rooms for maintenance management staff.

Critical Dimensions

- Area: 90 square feet; one male and one female

Equipment/Furnishings

- Urinals, wash sinks, toilets, accessories

Design Features

- Includes adjacent custodial closet with utility sink to service this space

Technical Considerations

Architectural Finishes

- Floor: Ceramic or porcelain over waterproof membrane (wet areas)
- Walls: Ceramic or porcelain tile/Epoxy painted gypsum board
- Ceiling: Epoxy painted gypsum board

Mechanical

- Exhausted/ventilated per IMC (no recirculation)
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,800 lumen Recessed LED luminaires
- 50 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Domestic hot/cold water, sanitary and vent to water closets, urinals, and toilets
- Floor drains with trap primers
- Hose bibs underneath toilets

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm strobe devices

Systems

- Public address

4.1.5.6 Conference Room

Functional Characteristics

Function

- Conference room for maintenance management, including forepersons, and guests

Critical Dimensions

- Area: 350 square feet accommodates 15 forepersons, other management, or guests

Equipment/Furnishings

- Conference table, telephone, credenza, and chairs
- Audiovisual including wall-mounted, large format television monitor(s) and audiovisual panel

Design Features

  - Visual connection to management suite

Technical Considerations

Architectural Finishes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s); borrowed lite/glazing with privacy shade into management suite
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Painted hollow metal door and frame with soundproofing seals

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment
- Audiovisual and power connections for presentation equipment

Fire Protection

- Alarm speaker and strobe devices
- Alarm manual pull station

Systems

- Public address
- Telephone/data jacks
- Wi-Fi
- Wireless video sharing system

4.1.5.7 Copy/Print/Supplies/Storage Room

Functional Characteristics

Function

- Dedicated area room for copier, fax machine, printer, storage of office supplies, and dead file storage

Critical Dimensions

- Area: 150 square feet

Equipment/Furnishings

- Printer and copier
- Fax machine
- Work surface and shelving
- Filing cabinets

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment
- Ethernet data jack points

Fire Protection

- Alarm speaker and strobe devices
- Alarm manual pull station

System

- Public address
- Telephone/data jacks
- Wi-Fi

4.1.6 Mechanics and Forepersons Support Area

4.1.6.1 Mechanics Locker Room

Functional Characteristics

Function

- Toilets, lockers, and showers for mechanics and lockers for forepersons

Critical Dimensions

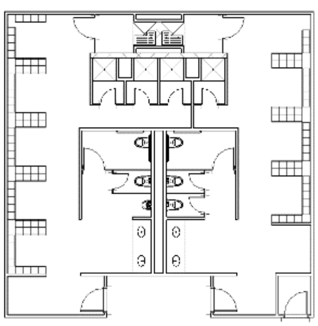
- Area: ~ 700 square feet, dependent of staffing per facility

Equipment/Furnishings

- Urinals, wash sinks, showers, lockers
- Toilets with stainless-steel partitions and accessories

Design Features

- Toilet count per occupant load
- One full- and one half-height locker per mechanic
- One full-size locker per foreperson
- Includes adjacent custodial closet with utility sink to service this space
- Positioned near maintenance area and adjacent to maintenance management



Technical Considerations

Architectural Finishes

- Floor: Ceramic or porcelain over waterproof membrane (wet areas)
- Walls: Ceramic or porcelain tile/Epoxy painted gypsum board
- Ceiling: Epoxy painted gypsum board

Architectural Doors

- Electronic door hardware/Controlled Access entry into room

Mechanical

- Exhausted/ventilated per IMC (no recirculation)
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,800 lumen Recessed LED luminaires
- 50 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Domestic hot/cold water, sanitary and vent to water closets, urinals, lavatories, and showers
- Floor drains with trap primers
- Hose bibs underneath lavatories

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm strobe devices

Systems

- Public address

4.1.6.2 Uniform Pickup/Drop-off

Functional Characteristics

Function

- Room for mechanics to pick up clean hangered uniform and deposit soiled uniforms

Critical Dimensions

- Area: 4 square feet per mechanic

Design Features

- Usually in or adjacent to locker rooms
- Includes a closet with large rolling bin for soiled uniforms

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address

4.1.6.3 Mechanics Break Room

Functional Characteristics

Function

- Used as a break area for mechanics and forepersons

Critical Dimensions

- Area: 50 square feet per mechanic during peak shift

Equipment/Furnishings

- Counter space and upper cabinets
- Sink with disposal
- Microwave, coffee maker, refrigerators
- Vending machines
- Tables, chairs, and soft seating areas
- Audiovisual including wall-mounted, large format television monitors and audiovisual panel

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Provide domestic hot/cold water, sanitary and vent to break room sinks

Fire Protection

- Provide wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks
- Wi-Fi
- Wireless video sharing system

4.1.6.4 Forepersons Office Suite

Functional Characteristics

Function

- Office suite with separate office for garage foreperson, workstations for shift forepersons, and copy/storage area

Critical Dimensions

- Area: 600 to 800 square feet, accommodates one garage foreperson and three shift forepersons

Equipment/Furnishings

- Desks and chairs, additional guest chairs as needed
- Workstations for shift forepersons
- Sink
- Lateral or under surface vertical files
- Storage cabinets and counter to accommodate printer/copier/radio consoles and other equipment to be identified by MBTA
- Audiovisual including wall-mounted television monitor

Design Features

- Centrally located, adjacent and visible to maintenance bay and mechanics kiosk

Technical Considerations

Architectural Finishes

- Floor: Epoxy concrete sealer; soil, grease, water and slip-resistant
- Walls: Epoxy painted masonry; soil and grease resistant; borrowed lite/glazing for visual into maintenance bay area
- Ceiling: Epoxy painted gypsum board

Architectural Doors

- Electronic door hardware/Controlled Access entry into room

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average throughout the area
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Domestic cold water, point of use electric water heater, sanitary and vent to copy room sink

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks
- Telephone
- Wi-Fi
- Intercom base station
- Two-way radio desktop unit

4.1.6.5 Mechanics Kiosk Niche

Functional Characteristics

Function

- Kiosks/computer stations for data entry by mechanics (one per bay)

Critical Dimensions

- Area: 15 square feet

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete, integral non-metallic light reflective hardener, and clear breathable sealer
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Audiovisual and power provided to each kiosk
- Ethernet data jack points

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices
- Alarm manual pull station

Systems

- Data jacks for each kiosk

4.1.6.6 Mechanics Training Room

Functional Characteristics

Function

- Training room with chairs and desks for flexible arrangement for different forms of training with large and small vehicle components
- Workstations for trainers, vehicle engineering staff and/or vendors

Critical Dimensions

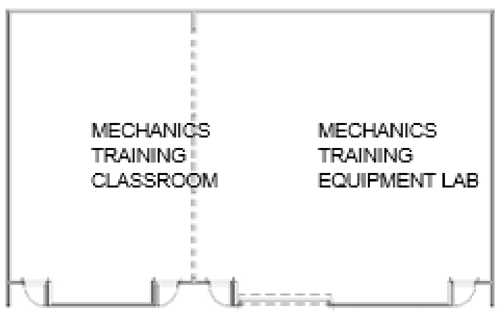
- Area: 600 to 1,200 square feet; size based on training activities at each facility

Equipment/Furnishings

- Tables, desks, chairs as needed
- Large format touch screen monitors with audiovisual panels

Design Features

- Easy access to staff support areas



Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Electronic door hardware/Controlled Access entry into room

Mechanical

- Ventilated per IMC with carbon dioxide sensors for demand-controlled ventilation
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment
- Audiovisual and power connections for presentation equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks
- Telephones
- Wi-Fi
- Wireless video sharing systems

4.1.6.7 Mechanics Training Room Storage

Functional Characteristics

Function

- Training material storage for small local training in conference room

Critical Dimensions

- Area: 150 square feet

Technical Considerations

Architectural Finishes

- Floor: VCT
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Electronic door hardware/Controlled Access entry into room

Electrical

- 500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment
- Audiovisual and power connections for presentation equipment

Fire Protection

- Speaker and strobe devices

Systems

- Public address
- Telephone/data jack

4.2 Transportation

Figure 4.2-1 illustrates the standard spaces found in the transportation area and the preferred adjacencies and connections.

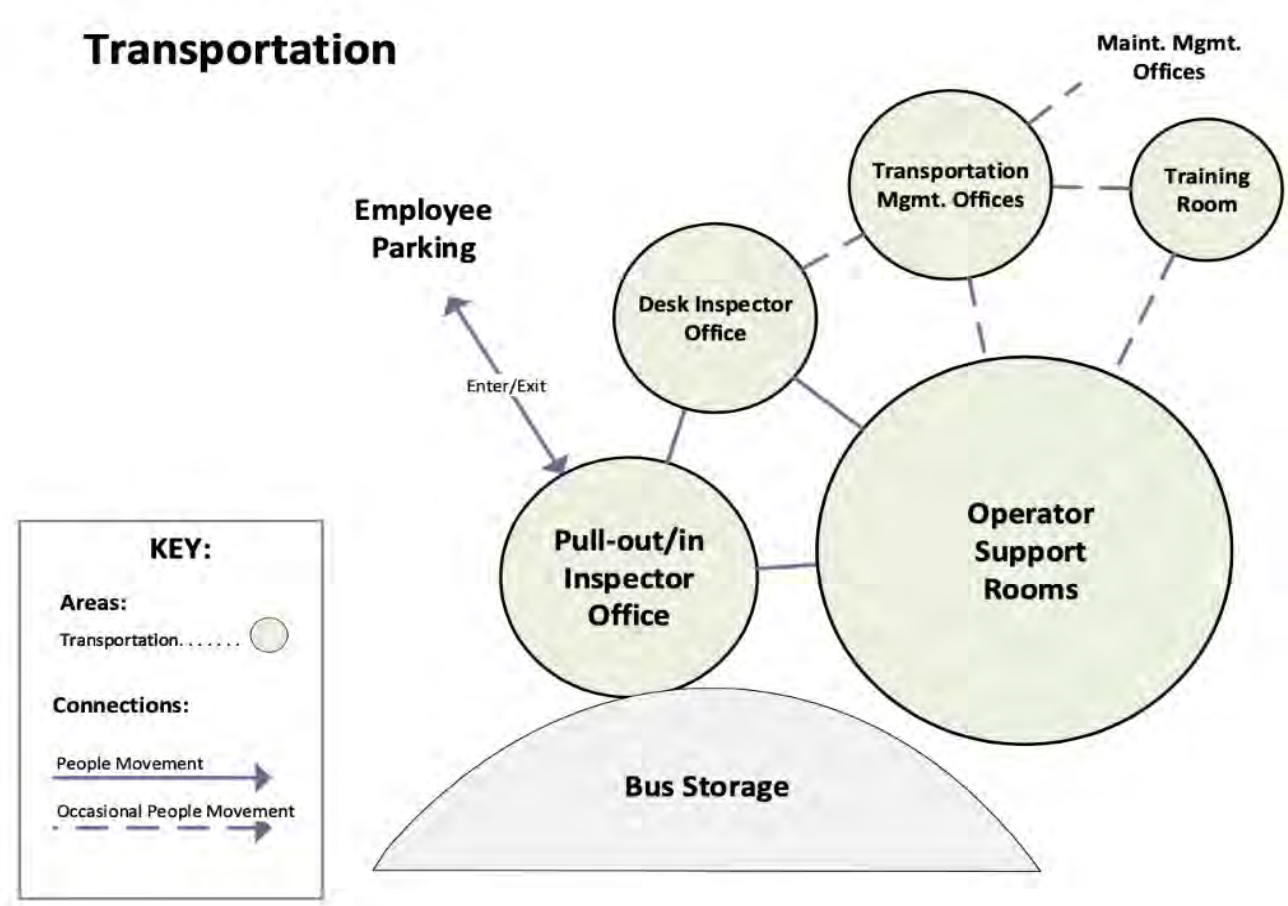


Figure 4.2-1. Standard Transportation Spaces

4.2.1 Transportation Operations Area

4.2.1.1 Interior Bus Storage

Functional Characteristics

Function

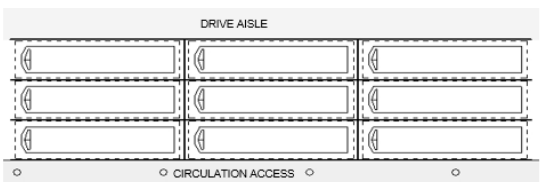
- Secured interior storage area for parking buses when not in service and for charging BEB

Critical Dimensions

- Area per 40-foot bus: 12 by 45 feet
- Area per 60-foot bus: 12 by 65 feet
- Drive aisle minimum width: 75-feet to accommodate 90 degree turning movements into storage row
- Pass-through aisle minimum width: 15-feet between every three to four rows

Design Features

- One-way counterclockwise circulation
- Drive lanes and pedestrian walkways delineated by floor traffic striping



Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Personnel doors with view panels to meet applicable code exit requirements
- Exterior entry and exit overhead fast action, high-lifting insulated fabric doors
- Bollards on exterior side of jambs of overhead door (two each)

Structural

- Control joints in-floor slab at adequate spacing
- Concrete paving will be used for drive lanes floor slabs will be designed to accommodate bus and tow vehicle.

Mechanical

- Ventilation in compliance with IMC requirements for a parking garage
- Heating to maintain minimum temperature of 55˚F with energy recovery component (desiccant wheel)
- Air curtains and procedure controls

Electrical

- High bay 60,000 lumen LED luminaires
- General convenience receptacles

Plumbing

- Floor drains on oil water separator system
- 0.75-inch water hose bib with standard faucet at rear of bay 2-foot 0-inch AFF at four locations around exterior walls, on outside of fuel area, and light transit vehicle washer area
- Compressed air connections

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Heat/smoke detector
- Alarm speaker and strobe devices
- Alarm manual pull station

Systems

- Public address
- Telephone/data jacks, Wi-Fi, and telephone
- Bidirectional amplifier/distributed antenna system
- Access control and CCTV

4.2.1.2 Desk Inspector's Office

Functional Characteristics

Function

- Area with a service counter where one or more inspectors work with operators on staffing items

Critical Dimensions

- Area: 200 square feet

Equipment/Furnishings

- Desks and chairs for two or more administrative staff behind the counter
- Chairs on the visitor side of the counter for waiting operators
- Lateral and under surface vertical files
- Audiovisual including wall-mounted television monitor

Design Features

- Located conveniently to operators as they report for work and where they pull in buses
- Visual connection to operators' room

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Doors

- Electronic door hardware/controlled access entry into room

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks and telephone
- Two-way radio desktop unit
- Bidirectional amplifier/distributed antenna system

4.2.1.3 Pull-out Inspector's Office

Functional Characteristics

Function

- Area where operators report for duty, are assigned buses, and report vehicle defects

Critical Dimensions

- Area: 150 square feet accommodates four pull-out inspectors

Equipment/Furnishings

- Computer and counter workstations, break table, chairs, and lateral files
- Printer, fax, copier, shredder
- Radio consoles and portable radio desktop charger
- Audiovisual including wall-mounted, large format television monitor

Design Features

- Enclosed and weather protected
- Close access to restroom (may share with operator support area if adjacent)
- Visual connection to bus storage and bus yard
- Service window and work counters, workstations, or chairs

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base, recessed walk-off matt at circulation areas
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Epoxy painted gypsum board

Architectural Doors

- Electronic door hardware/controlled access entry into room

Mechanical

- Ventilation per IMC
- Heating to maintain minimum temperature of 70˚F
- Cooling to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Provide cold water connection with backflow preventer to coffee machine

Fire Protection

- Provide wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices
- Alarm manual pull stations

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi
- Access control

4.2.1.4 Inspectors Toilet Rooms

Functional Characteristics

Function

- Secured, single stall toilet rooms in inspectors' work area.

Critical Dimensions

- Area: 90 square feet; one male and one female

Equipment/Furnishings

- Urinals, wash sinks, toilets, accessories

Design Features

- Includes adjacent custodial closet with utility sink to service this space

Technical Considerations

Architectural Finishes

- Floor: Ceramic or porcelain over waterproof membrane (wet areas)
- Walls: Ceramic or porcelain tile/Epoxy painted gypsum board
- Ceiling: Epoxy painted gypsum board

Mechanical

- Exhausted/ventilated per IMC (no recirculation)
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,800 lumen Recessed LED luminaires
- 50 foot-candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Domestic hot/cold water, sanitary and vent to water closets, urinals, and toilets
- Floor drains with trap primers
- Hose bibs underneath toilets

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm strobe devices

Systems

- Public address

4.2.1.5 Operators Picking Room

Functional Characteristics

Function

- Room where inspectors facilitate assignment selection by operators

Critical Dimensions

- Area: 200 square feet accommodates two inspectors

Equipment/Furnishings

- Worktable and chairs
- Audiovisual including wall-mounted, large format television monitor(s) and audiovisual panel
- Visual Display Boards
- White boards/tack boards

Design Features

- Room requirements may change when picking becomes electronic
- Visual connection to Operators’ Day Room

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Electronic door hardware/Controlled Access entry into room

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.2.1.6 Timekeeping Kiosk

Functional Characteristics

Function

- Computer kiosk adjacent to desk inspector's office or in alcove at transportation staff entrance

Critical Dimensions

- Area: 12 square feet per kiosk

Equipment/Furnishings

- Electronic timekeeping station

Design Features

- Easy access to pull-out inspector’s office and operators’ day room

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Electrical

- 3,500 lumen LED pendant luminaires
- 50 foot-candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Alarm speaker and strobe devices
- Alarm manual pull station

Systems

- Data jacks

4.2.2 Transportation Management Suite

4.2.2.1 Division Chief's Office

Functional Characteristics

Function

- Private office for Division Chief

Critical Dimensions

- Area: 150 square feet accommodates one Division Chief and two guests

Equipment/Furnishings

- Desk with return, chair, and guest chairs
- Lateral files
- Printer/radio console
- Audiovisual including wall-mounted television monitor(s)

Design Features

- Visual connection to management suite with privacy shade

Technical Considerations

Architectural Finishes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Secured door with key

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.2.2.2 Superintendent's Office

Functional Characteristics

Function

- Private office for Superintendent

Critical Dimensions

- Area: 150 square feet accommodates one Superintendent and two guests

Equipment/Furnishings

- Desk with return, chair, and guest chairs
- Lateral files
- Printer/radio console
- Audiovisual including wall-mounted television monitor(s)

Design Features

- Visual connection to management suite with privacy shade

Technical Considerations

Architectural Finishes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Secured door with key

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.2.2.3 Safety/Facility Manager Workstation

Functional Characteristics

Function

- Workstation for the safety and/or facility manager

Critical Dimensions

- Area: 150 square feet accommodates one, shared workstation and storage

Equipment/Furnishings

- Desk with return, chair, and guest chairs
- Lateral files
- Printer/radio console

Technical Considerations

Architectural Finishes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephones, and Wi-Fi

4.2.2.4 Transportation Supervisors Workstation(s)

Functional Characteristics

Function

- Freestanding workstations for transportation supervisors

Critical Dimensions

- Area: 50 square feet accommodates one workstation; number dependent on staffing at each facility

Equipment/Furnishings

- Workstation desk with return and chair
- Lateral files

Technical Considerations

Architectural Finishes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.2.2.5 Huddle/Disciplinary/Privacy Room

Functional Characteristics

Function

- Office set up with extra guest chairs

Critical Dimensions

- Area: 180 square feet

Equipment/Furnishings

- Desk with chair, and guest chairs
- Large format monitors and audiovisual panels

Technical Considerations

Architectural Finishes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen light-emitting diode (LED) pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi
- Wireless video sharing system

4.2.2.6 Conference Room

Functional Characteristics

Function

- Conference room for transportation management

Critical Dimensions

- Area: 500 square feet; accommodates 15 staff

Equipment/Furnishings

- Conference table, credenza, and chairs
- Audiovisual including panels and wall-mounted, large format television monitor(s)

Design Features

- Visual connection to management suite

Technical Considerations

Architectural Finishes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Floor boxes, number per NEC
- Power provided to room equipment
- Audiovisual and power connections for presentation equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi
- Wireless video sharing system

4.2.2.7 Copy/Print/File Storage Room

Functional Characteristics

Function

- Dedicated room or alcove for copier, fax machine, printer, and storage of a small amount of office supplies and dead files

Critical Dimensions

- Area: 150 square feet

Equipment/Furnishings

- Copier
- Fax machine
- Computer printer
- Work surface and shelving
- Filing cabinets

Technical Considerations

Architectural Finshes

- Floor: Carpet/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.2.2.8 Management Break Area

Functional Characteristics

Function

- Small break area with coffee bar for management suite

Critical Dimensions

- Area: 250 square feet

Equipment/Furnishings

- Counter space and upper cabinets
- Sink with disposal
- Microwave, coffee maker, refrigerators
- Tables and chairs
- Audiovisual including wall-mounted, large format television monitors and audiovisual panels

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilation in accordance with IMC requirements for an occupied space.
- Heating to maintain a minimum temperature of 70˚F.
- Cooling to maintain the maximum temperature of 75˚F.

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Provide domestic hot/cold water, sanitary and vent to breakroom sink
- Provide domestic cold water with backflow preventer to coffee machine

Fire Protection

- Provide wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices
- Alarm heat detector

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.2.3 Transportation Operations Support Areas

4.2.3.1 Operators Day Room

Functional Characteristics

Function

- General break area dedicated to operator use

Critical Dimensions

- Area: 15 square foot per peak bus pull-out; dependent on fleet size/service

Equipment/Furnishings

- Casework with sink/faucet
- Appliances (refrigerators, microwave, coffee maker)
- Vending machines
- Tables and chairs with soft seating areas
- Computer alcove
- Audiovisual including panels and wall-mounted, large format television monitors

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Provide domestic hot/cold water, sanitary and vent to operation sinks

Fire Protection

- Provide wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jack, telephone, and Wi-Fi

4.2.3.2 Operators and Inspectors Locker Room

Functional Characteristics

Function

- Toilers, lockers, and showers, for operators and inspectors

Critical Dimensions

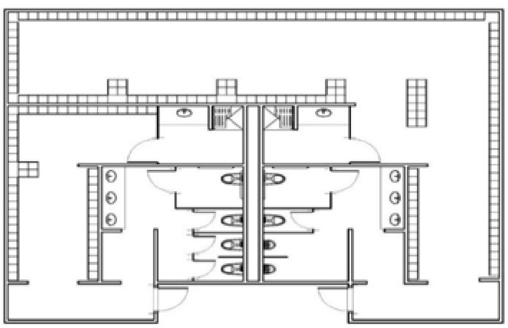
- 3,000 square feet; dependent of staff
- Full locker area: 15 square feet per operator
- Half locker area: 10 square feet for each field and onsite inspector
- Minimum one standard and one accessible shower room; male and female

Equipment/Furnishings

- Toilets, urinals, wash sinks, showers, lockers (toilet fixture count per anticipated occupant load)

Design Features

- One full height locker per operator
- Adjacent custodial closet with utility sink to service this space



Technical Considerations

Architectural Finishes

- Floor: Ceramic or porcelain over waterproof membrane (wet areas)
- Walls: Ceramic or porcelain tile/Epoxy painted gypsum board
- Ceiling: Epoxy painted gypsum board
- Stainless-steel toilet partitions and accessories

Architectural Doors

- Electronic door hardware/Controlled Access entry into room

Mechanical

- Exhausted/ventilated per IMC (no recirculation)
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,800 lumen recessed LED luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Domestic hot/cold water, sanitary and vent to water closets, urinals, lavatories, and showers
- Floor drains with trap primers
- Hose bibs underneath lavatories

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm strobe devices

Systems

- Public address

4.2.3.3 Wellness Room

Functional Characteristics

Function

- Secured, private, quiet room for personal use (e.g., nursing mothers)

Critical Dimensions

- Area: 200 square feet (large facilities may need more than one)

Equipment/Furnishings

- Counter with sink
- Couch or chairs and side table
- Mini refrigerator

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Secured entry; single 3-foot 0-inch door

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Plumbing

- Domestic hot/cold water, sanitary and vent to wellness sink

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, Wi-Fi

4.2.3.4 Operators Training Room and Storage

Functional Characteristics

Function

- Training room with flexible furnishings for different forms of training

Critical Dimensions

- Training room area: 1,200 to 1,800 square feet; dependent whether facility will be local or central training site
- 50 square feet for instructor workstation
- Storage area: 300 to 400 square feet

Equipment/Furnishings

- Tables, desks, and chairs
- Workstation desk with return and chair
- Lateral files
- Audiovisual including panels and wall-mounted, large format monitors
- Shelving in storage area

Design Features

- Easy access to instructors' office and other operator support rooms
- Adjacent material and equipment storage space

Technical Considerations

Architectural Finishes

- Floor: VCT/Resilient wall base
- Walls: Acrylic latex-painted with accent wall color(s)
- Ceiling: Suspended acoustical ceiling grid and tile system

Architectural Doors

- Electronic door hardware/controlled access entry into room

Mechanical

- Ventilated per IMC, with carbon dioxide sensor for demand-controlled ventilation airflow
- Heated to maintain minimum temperature of 70˚F
- Cooled to maintain maximum temperature of 75˚F

Electrical

- 3,500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment
- Audiovisual and power connections for presentation equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm speaker and strobe devices
- Heat/smoke detector

System

- Public address
- Telephone/data jacks, telephone, and Wi-Fi
- Wireless video sharing system

4.3 Servicing

Figure 4.3-1 illustrates the standard spaces found in the service area and the preferred adjacencies and connections.

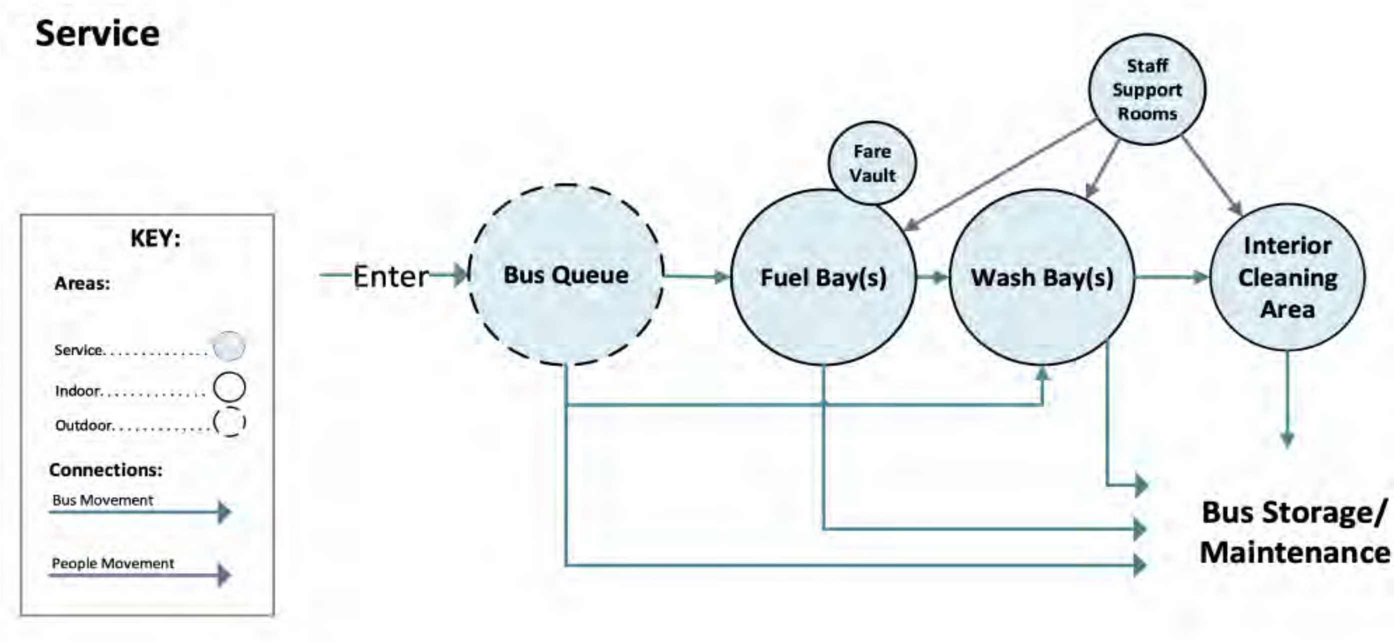


Figure 4.3-1. Standard Service Spaces

4.3.1 Fueling Operation

4.3.1.1 Fueling Bay

Functional Characteristics

Function

- Station for diesel fueling, topping off fluids, fare pull (as needed), and extraction of bus performance data

Critical Dimensions

- Area: 80 feet by 22 feet
- 1 per 100 buses
- Assume additional square footage if aboveground fluid storage is needed

Equipment/Furnishings

- Diesel dispenser and diesel tank and leak detection system (diesel fuel tanks belowground)
- Submersible diesel fuel pump, fluid reels, and compressed air
- Emergency shower/eye wash

Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Electronic door hardware/Controlled Access entry at exterior access doors
- Bollards located at entrance to each lane and in front of fueling equipment

Structural

- Sealed control joints in-floor slab at adequate spacing
- Canopy that prevents accumulation of explosive natural gas mixtures
- As needed to support equipment

Mechanical

- Exhaust in compliance with IMC Section 502 (inlets at 18-inch AFF) with aluminum ductwork
- Ventilation to make up exhausted airflow quantity
- Heating to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment
- Power and signal conduit from island terminals to fueler office for fuel management system
- Devices near canopy ceiling and interlocked to sound alarms for methane gas detection system

Plumbing and Industrial Equipment

- Trench drain with removable traffic rated grating to sediment/oil interceptor (one per two-bay lane)
- Lube reel banks with ATF, EC, EO1, EO2 and WWF at end of bay
- 0.75-inch water hose bib with standard faucet at end of bay 2-foot AFF
- Compressed air line with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnects (0.5inch and 1-inch) on columns between each bay at 4-foot AFF
- Product and vapor recovery piping as required to/from fuel tanks/dispensers
- Water connection to emergency wash
- Compressed air line with cut-off valve, separator, regulator with gauge, and quick disconnects between each lane and at 4-foot AFF. Provide disconnects for 0.5-inch and 1-inch impact tools at locations to be determined during detailed design

Fire Protection

- Dry chemical fire suppression
- Alarm manual pull stations, speaker, and strobe devices

Systems

- Public address, CCTV, bidirectional amplifier/distributed antenna system
- Telephone/data jacks, telephone, Wi-Fi
- Bus data collection system
- Fuel management system
- Methane gas detection system

4.3.1.2 Service Lubrication and Compressor Room

Functional Characteristics

Function

- Storage and distribution of fluids for fueling, and inspection

Critical Dimensions

- Area: 600-800 square feet; dependent on fleet size, fluid delivery schedule, and fluid storage/compressor location

Equipment/Furnishings

- Motor oil and transmission fluid pump
- DEF and coolant pumps
- WWF pump
- Shelving units
- Aboveground transmission fluid tank (250 gallons)
- Aboveground motor oil and WWF tanks (500 gallons each)
- Aboveground tank (750 gallons) for coolant/antifreeze
- Aboveground DEF tank (1,000 gallons)
- Air compressor and refrigerator/dryer
- Emergency safety shower/eyewash

Design Features

- Exterior access for delivery of bulk fluids by truck via overhead coiling door
- Fill-ports for fluid tanks are preferred to be on the exterior of the building
- Acoustically and physically separated from other areas to prevent migration of noise and vibration if possible
- Grated area below tanks to serve as spill sump

Technical Considerations

Architectural Finishes

- Floor: Epoxy concrete sealer; soil, grease, water and slip-resistant
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Personnel doors to meet applicable code exit requirements
- 3-foot 0-inch-wide hollow metal door with interior exit device
- No thresholds

Structural

- Control joints in-floor slab at adequate spacing
- Raised concrete housekeeping pad under compressors and air dryers
- As needed to support equipment

Mechanical

- Exhaust per IMC Section 502
- Ventilation for makeup to exhaust system
- Heating to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing and Industrial Equipment

- 0.75-inch water hose bib with standard faucet 2-foot AFF
- Compressed air system with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnect on wall at 4-foot AFF for each lubricant pump
- Tank mount all lubricant pumps except hoist-mounted chassis grease and wall-mounted EC diaphragm pump with siphon kit
- Water tank with float valve for water to EC diaphragm pump
- Floor drains on building oil water separator system
- As required by equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head, medium temperature heads
- Alarm manual pull stations, speaker, and strobe devices

Systems

- Public address, telephone/data jacks

4.3.2 Fueling Support

4.3.2.1 Fuelers Work Area

Functional Characteristics

Function

- Work and break area for service area attendants (i.e., fuelers, fare staff, and interior cleaners) as needed

Critical Dimensions

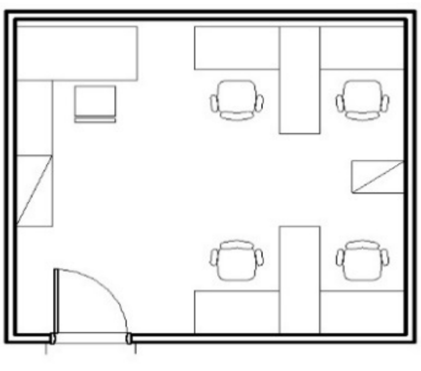
- Area: 300 square feet accommodates four staff

Equipment/Furnishings

- Desks/work surfaces and chairs
- Lateral and under surface vertical files
- Printer/copier/radio consoles
- Audiovisual including wall-mounted television monitor

Design Features

- Visual connection to fueling service areas



Technical Considerations

Architectural Finishes

- Floor: Sealed concrete or vinyl flooring slip-resistant
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Suspended acoustical ceiling

Architectural Doors

- Hollow metal doors and windows
- Insulated tempered glass

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles

- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm manual pull stations
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi

4.3.2.2 Fare Collection Room

Functional Characteristics

Function

- Room for revenue department staff for counting and securing cash revenue prior to pickup (obsolete when fare collection system becomes fully electronic)

Critical Dimensions

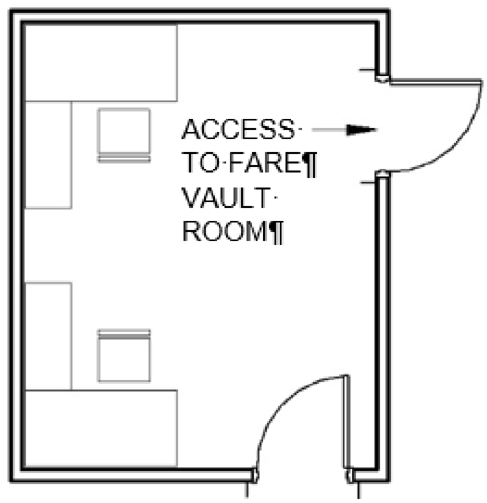
- Area: 120 square feet accommodates two staff

Equipment/Furnishings

- Desks/work surfaces and chairs

Design Features

- Could be located in transportation office area with secondary vault for secure storage



Technical Considerations

Architectural Finishes

- Floor: Sealed concrete with vinyl or carpet flooring
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Suspended ceiling

Architectural Doors

- Electronic door hardware/controlled access

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 225 square feet per head
- Alarm manual pull stations
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks, telephone, and Wi-Fi
- Electronic access control and CCTV

4.3.2.3 Fare Vault Room

Functional Characteristics

Function

- Vault for depositing cash from bus fare boxes (obsolete when fare collection system becomes fully electronic)

Critical Dimensions

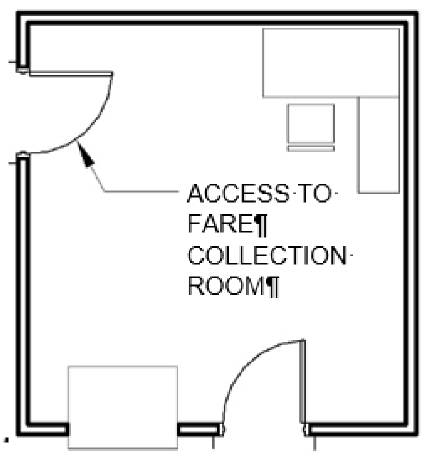
- Area: 120 square feet

Equipment/Furnishings

- Vault
- Worktable and chair
- Workspace, shelf unit and workbench for repairing fare boxes

Design Features

- Back of fare vault opens with combination lock for accountants in transportation to count and bag cash for secure delivery to bank



Technical Considerations

Architectural Finishes

- Floor: Sealed concrete
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Suspended ceiling board ceiling

Architectural Doors

- Hollow metal (no window) secured
- Electronic door hardware/Controlled Access

Mechanical

- Heated and air conditioned
- 74˚F in summer; 68˚F in winter

Electrical

- LED lighting
- Desk office convenience outlets

Fire Protection

- Wet sprinklers

System

- Public address
- Telephone/data jacks, telephone, and Wi-Fi
- Electronic access control and CCTV

4.3.2.4 Fuelers Storage

Functional Characteristics

Function

- Accommodates fuelers' work gear

Critical Dimensions

- Area: 200 square feet accommodates four fuelers

Equipment/Furnishings

- Metal storage shelving and cabinets for supplies and emergency equipment spill containment kit)
- Waste receptacles

Design Features

- One full-size locker per fueler

Technical Considerations

Architectural Finishes

- Floor: Concrete sealer; soil, grease, water and slip-resistant
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted gypsum board

Architectural Doors

- 3-foot-wide hollow metal door

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm speaker and strobe devices

Systems

- Public address

4.3.3 Bus Wash

4.3.3.1 Bus Wash Bay

Functional Characteristics

Function

- Automatic drive-through bus wash

Critical Dimensions

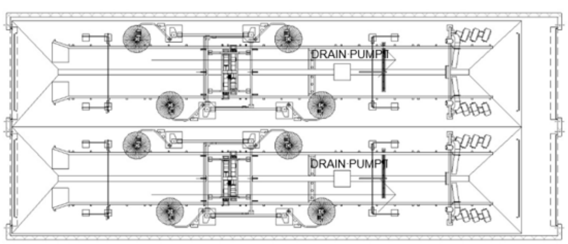
- Area: 22 feet by 90 feet each
- 1 per fuel lane (2 total for up to 250 buses)

Equipment/Furnishings

- Includes pre-wet arch roof mop, undercarriage cleaning, wheel wash, post rinse arch, final rinse arch (purified water through reverse osmosis), and air stripping blowers
- Four brushes with engaged or unengaged front and rear wrap around by control panel

Design Features

- Industrial waste discharge to sewer line and recycle system
- Tire guides and speed control light/audio signal



Technical Considerations

Architectural Finishes

- Floor: Soil, grease, water, slip-resistant concrete
- Wall: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Exterior overhead door: High-lifting sectional, poly, insulated, 14 feet by 14 feet, with view panels, automatic operator, interior and exterior push button controls, and lockout on exterior
- Bollards on exterior at jambs of overhead door (2 each)

Structural

- Control joints in-floor slab at adequate spacing
- Structure as needed to support equipment
- Pit for water reclamation per manufacturer's drawings
- Sloped floor to trench drains

Mechanical

- Heating and ventilating air-handling unit with a fan section, a heating section, and a filtration section with MERV 13 filtration
- Ventilated per IMC
- Heated to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Trench drain down center of bay (with removable cover) to water reclamation system
- 0.75-inch water hose bib with standard faucet at 2-foot AFF
- Water and compressed air connections to wash equipment
- As required by equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head, medium temperature heads
- Alarm manual pull stations
- Alarm speaker and strobe devices

4.3.3.2 Bus Wash Equipment Room and Industrial Waste System Space

Functional Characteristics

Function

- Room for bus wash controls and equipment

Critical Dimensions

- Minimum 100 feet in length; dependent on equipment

Design Features

- Includes approved water reclamation system and storage for reuse water (such as rainwater)
- Industrial wastewater system (separate design and supplier) required to meet MWRA permitting

Technical Considerations

Architectural Finishes

- Floor: Epoxy concrete sealer; soil, grease, water and slip-resistant
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- 3-foot-wide hollow metal door with interior exit device

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 55˚F

Electrical

- 3,500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Industrial waste plumbing system with trench drains tie into a 10,000-gallon below-grade storage tank with hold-down pad
- Provide industrial waste filtration system consisting of pumps, filters, tanks, and controls to meet the MWRA discharge permit (where required)
- Provide floor drains on building oil water separator system
- 0.75-inch water hose bib with standard faucet at 2-footh AFF
- As required by equipment

Fire Protection

- Wet sprinklers maximum spacing 130 square feet per head
- Alarm manual pull stations
- Alarm speaker and strobe devices

Systems

- Public address
- Telephone/data jacks

4.3.3.3 Bus Cleaning Storage

Functional Characteristics

Function

- Storage room for bus interior cleaning staff with lockers and storage for equipment and cleaning supplies

Critical Dimensions

- Area: 100 square feet

Equipment/Furnishings

- Mop sink and toilets
- Metal storage shelving

Technical Considerations

Architectural Finishes

- Floor: Sealed, soil, grease, water, slip-resistant concrete
- Walls: Epoxy painted masonry; soil and grease resistant
- Ceiling: Epoxy painted exposed structure

Architectural Doors

- Single/double as required hollow metal doors

Mechanical

- Ventilation in accordance with IMC requirements for locker room and in accordance with the requirements for a custodial closet
- Heating to maintain the minimum temperature of 55˚F

Electrical

- 3,800 lumen Recessed LED luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Plumbing

- Domestic hot/cold water, sanitary and vent connections
- Floor drains with trap primers

Fire Protection

- Alarm strobe devices

Systems

- Public address
- Telephone/data jacks
- Wi-Fi

APPENDIX A
SUSTAINABILITY AND RESILIENCE SUPPLEMENT

CONTENTS

Tables

Figure

A.1 SUSTAINABILITY AND RESILIENCE

This *Sustainability and Resilience Supplement* is a continuation of the *Design Guideline for Bus Maintenance Facilities* Section 2, Overview of Design at MBTA, particularly Section 2.1.3, Facility Sustainability and Resilience. These sections contain additional details necessary to clarify the full sustainability and resilience (S+R) approach of the new bus facilities and apply to all Project Team disciplines.

A.1.1 Sustainability and Resilience Leadership and Project Management

A.1.1.1 Leadership Roles and Requirements

In the Massachusetts Bay Transportation Authority (MBTA) Request for Proposal for architectural/engineering services and construction bids, both S+R leads must be included as specifically defined key roles. The designated S+R Administrator (S+R Admin) for the Project must be identified during early design phases and continue in that position through the end of construction and through the end of any third-party certification efforts, if applicable. For sustainability requirements, personal qualifications for the Project's S+R Admin and the construction S+R Coordinator must include active accreditations and prior project experience in Leadership in Energy and Environmental Design (LEED) v4/4.1 for any project to pursue certification. Accreditation certificates and other qualifying documentation must be provided for verification. Past qualifications in an interdisciplinary coordination role, including prior project experience designing resilient buildings and in an interdisciplinary coordination role is required. The MBTA will review and approve individuals based on the qualifications provided. Both the S+R Admin and S+R Coordinator may elect to engage their own additional personnel to supplement or focus on specific aspects of the Project, such as an energy efficiency expert or net zero consultant.

A.1.1.2 Sustainability and Resilience Management Plan

The Sustainability and Resilience Management Plan (SRMP) may be a standalone document, or it may be incorporated into larger project management plans. The SRMP must manage the scope, scale, and complexity of the Project's S+R requirements and goals and describe how each will be met. The assessment is based on the organizational policies, authorities, mechanisms, education, and business processes put in place along with a determination of sufficiency. In the design phase, the SRMP must be summarized in the basis of design (BOD) for the Project and provided in its entirety as an appendix to that document. In the construction phase, the SRMP will be a required component of the Project specifications.

To create the SRMP, the S+R Administrator must develop a list of all environmental, economic, and social aspects of the Project that relate to sustainability and resilience; if third-party certification is required, the S+R Administrator must review the certification requirements for certification-specific plans and include them as part of the larger SRMP. Once established, the Project Team will prioritize the list of aspects based on their importance of meeting Project requirements. There may be some variations depending on the project's size, type, and complexity. In the event that a project has more than one facility, the project will have a single SRMP representing the project in its entirety. Requirements must be documented as a holistic effort; however, some components may necessitate individual versions of specific components. Separate plans will be required if any projects require more than one general contractor on a single site; in this circumstance, each portion of the site must individually document compliance as well as coordinate efforts, as appropriate. The S+R Administrator will be responsible for determining the organization of the SRMP with the S+R Coordinator responsible for managing and unifying the construction-related efforts.

The SRMP must have clear processes and controls in place to achieve the requirements (that is, the SRMP is not solely aspirational in nature). All components are required to be evaluated and documented; demonstration of the considerations used, and outcome must be provided for validation by the MBTA. Implementation of the SRMP must be revisited regularly throughout the design phase, updated as needed, and submitted as part of each major milestone submittal to the MBTA Project Manager. The SRMP should recognize that changes in socioeconomic and environmental conditions—including those outside the Project boundary—have the potential to significantly impact projects. SRMPs and their subsequent performance goals must take these changing conditions into account.

A.1.1.2.1 SRMP Content

The SRMP must include (but is not limited to) the following minimum components:

- An internally hyperlinked Table of Contents.
- An Executive Summary outlining the main Project information and applicable SRMP components. Organizational charts and documentation showing the personnel responsible for Project S+R issues, their position in the Project organization, and their authority to make Project decisions and affect change.
- An index of all trackable Project features related to S+R and all aspects that require tracking, reporting, or other documentation. Consider using a table similar to **Table A-1**, summarizing basic Project information and all applicable components and responsible party or parties.
- Prioritized descriptions of Project S+R goals, objectives, and performance targets that consider Project importance and the consequences of change. Goals should be aligned to specific objectives and targets that meet Project needs and issues.
- Description of how the S+R requirements will be communicated to the design team and verified with the MBTA Project Manager (PM). Methods include workshops, internal design coordination meetings, design quality control reviews, milestone deliverable reviews by MBTA technical staff, review of draft SRMP documents. Document alternatives considered, data reviewed, decisions made, action items generated, and follow-up confirming implementation of decisions into Project deliverables.
- Plans for how the S+R requirements will be communicated and transitioned from the design phase to the construction phase through methods such as construction plans and specifications, daily job briefings, subcontractor orientations, or onsite field training sessions; plans for what aspects of the SRMP will carry into operations, such as the S+R Educational Material and Case Study. The design S+R Administrator must document a list of issues for the construction S+R Coordinator to take over.
- Identification of potential areas where changes in key environmental factors or Project design variables may impact future Project performance related to S+R. For example, list instances of use of design criteria exceeding minimum code requirements, or encompassing criteria not required by code. Include evidence that the SRMP accounts for these potential changes and is adaptable. Document original intended measure, discussion of variation, and detail any changes to the planned design. Include meeting minutes, email correspondences, and similar as appropriate.
- Assessment of the Project's environmental, economic, and social impacts including equity of benefits and impacts. This may include the potential for existing, non-sustainable conditions to further deteriorate environmental, economic, or social conditions if left unaddressed.
- Narratives of each major sustainably designed element associated with the building and site, and how that element has impacted overall design. For example, if high-performance glazing is included

in design, it should be noted that the design of the mechanical system sizing is influenced by the performance of that glazing.

- Documentation that regular monitoring and reporting of progress against the SRMP's goals and objectives is occurring throughout the design phase via the BOD, and drafts or completion of SRMP components at Project milestones in accordance with **Table A-1**.

The SRMP must be included in design package submissions to the MBTA in its entirety and contain all relevant information as appropriate for the particular deliverable milestone. Placeholder sections should be provided for content not yet developed and identified as such. The SRMP will be an appendix to the BOD, or may be a standalone document accompanying the drawing sets when the BOD is no longer required in the deliverable package.

At the start of the construction phase, the SRMP must be transferred to the contractor's S+R Coordinator where it will then be updated with content detailing how the construction team intends to assimilate the SRMP components and execute all requirements. The contractor's S+R Coordinator must provide the updated version to the design team's S+R Administrator for review and approval prior to final submission to the MBTA PM, who will then confirm the SRMP satisfactorily complete. The contractor's Coordinator must update the SRMP on an ongoing basis and provide regular updates (quarterly, at minimum, or more frequently if deemed necessary) to the S+R Admin and MBTA PM throughout the construction phase, as well as complete a final version at Project completion including end results of all initiatives to the MBTA PM for record. These requirements must be documented via Project specifications in Division 1 along with other governing S+R requirements.

Refer to *LEED BD+C (v4/4.1): IP Cr 1 Integrative Process*.

The following information will be included in the SRMP Content Tracker:

- Project Name
- Project Type (e.g., new building construction)
- Project Site Size (square feet [sf])
- Project Building Size (sf)
- Project Address
- Design Team PM
- Construction Team PM
- MBTA Representative
- S+R Administrator (Design + Construction)
- S+R Coordinator (Construction)

Table A-1. Sustainability and Resilience Management Plan Content Tracker

SRMP Components	Project Phase	Primary Responsible Party	Notes
Stakeholder Engagement Plan	Planning - Operation	Public Involvement Specialist (MBTA)	
LEED Project Scorecard and Narratives	Planning – CC	S+R Leads	Required at each milestone.
State (MEPA) and Federal (NEPA) Environmental Review Documentation	15% - Cnst	Environmental Manager	
LBE Tracking Form	100%, CC	S+R Leads	For MBTA tracking; include any associated, supporting documentation
Integrative Process Documentation	15, 30, 60, 90, and 100%	Design Project Manager	LEED Requirement
CRP: Operational and Embodied Carbon	15, 30, 60, 90, and 100%	Mechanical and Electrical Engineers, Architect	Identify main aspects of embodied carbon here; details to be included in the MPP. Related to LEED
LCCA	15, 30, 60, 90	Mechanical Engineer, Architect	Documenting HVAC and building envelope component selection/ analysis process. To be updated as needed for each milestone.
ECR	30%	Mechanical Engineer	Related to LEED
MassDEP Global Warming Solutions Act	100%	Mechanical and Electrical Engineers	For MBTA tracking
WPP	30, 60, 90 and 100%	Plumbing, Civil, and Process Engineers	Related to LEED
Baseline Greenhouse Gas Emissions Assessment	15%-100%	S+R Leads	Related to LEED
Universal Design Documentation	30%	Architect	Related to LEED
MBTA Safety Certification Process	30%	S+R Leads	Refer to Chapter 2
Acoustical Implementation Plan	100%	Architect	Related to LEED
Light Pollution Reduction calculations, documentation	90%	Electrical Engineer/ Lighting Designer	Related to LEED
Circulation Documentation	60%	Architect	Related to LEED
S+R Educational Material	100%, Cnst, CC	S+R Leads	Case Study will be living document; MBTA to provide final updates with operational information. Related to LEED
MPP	100%, Cnst	Design Team	Related to LEED
SWPPP including an Erosion and Sedimentation Control Plan	100%, Cnst	Civil Engineer/ Contractor	Related to LEED
Construction Energy and Water Use Documentation	Cnst	Contractor	Related to LEED
CDWMP	Cnst	Contractor	Related to LEED
IAQMP	Cnst	Contractor	Related to LEED

SRMP Components	Project Phase	Primary Responsible Party	Notes
Commissioning Plan	60 and 90%, Cnst, Cx, CC	Commissioning Authority	Related to LEED
Landscape Tracking Plan	Cnst	Contractor	For MBTA tracking, Related to LEED
Risk and Resilience Management Plan	15%-100%	S+R Leads	Related to LEED
MBTA Resilience Forms (refer to **Section A.4**)	Planning – 100%	S+R Leads	For MBTA tracking

Project Phases: Planning 15% Conceptual Design
30% Preliminary Design 60% Design 90% Design 100% PS&E (Final Design)
Cnst = Construction Start Cx = Commissioning CC = Construction Closeout O&M = Operation and Maintenance

Notes:
CDWMP = Construction and Demolition Waste Management Plan
CRP = Carbon Reduction Plan
ECR = Energy Conservation Report
GHG = greenhouse gas
HVAC = heating, ventilation, and air conditioning
IAQMP = Indoor Air Quality Management Plan
LBE = Leading by Example
LCCA = Life-cycle Cost Assessment
MassDEP = Massachusetts Department of Environmental Protection
MEPA = Massachusetts Environmental Policy Act
MPP = Material and Product Plan
NEPA = National Environmental Policy Act
PS&E = plans, specifications, and estimates
SWPPP = Stormwater Pollution Prevention Plan
WPP = Water Performance Plan

A.1.1.3 Pursuit of Third-party Certification: LEED

A.1.1.3.1 Leadership in Energy and Environmental Design

LEED serves as a consensus-based sustainability guideline and assessment mechanism for green building design, construction, operations, and maintenance. LEED adds value to the bus maintenance facilities by providing a framework through which to integrate S+R priorities into occupied projects; LEED also encourages in-depth engagement with the surrounding community, stakeholders, team members, and long-term operators. The framework provides ways to directly address and enhance existing MBTA and industry best practices, as well as create opportunities for expansion of these practices. At a high level, LEED certification is based on compliance with Prerequisites and an accumulation of points from Credits; the final certification level achieved is tiered based on the number of points achieved.

Components of the LEED framework include the following:

- The LEED Scorecard – intended to enable project teams to track status of their Design and Construction Prerequisite and Credit compliance throughout the project's progression.
- LEED Online – the web-based project interface where projects are registered, documented, and reviewed through Green Business Certification, Inc.

- LEED Design and Construction Reviews – The independent, third-party review is performed through LEED Online with the Green Business Certification, Inc; all review comments, fees, and communications are funneled through the project's registered website.
- LEED Certification – Final recognition of the project's achievements; certification plaques and/or certificates may be purchased once certification is complete.
- LEED Green Associate (LEED GA) and LEED Accredited Professional (LEED AP) – Professional accreditations indicating verified understanding of the LEED intent, process, and rating system content.

The project-specific aspects addressed in LEED align with several of MBTA's own plans and policies mentioned previously. Through adoption of frameworks and pursuit of certification, the bus maintenance facilities can help mitigate climate change risks, reduce greenhouse gas emissions, improve MBTA's carbon footprint, conserve natural resources, reduce waste, and improve the indoor environment for its employees, among other benefits.

If a project has more than one occupied facility, each facility must be designed and constructed to the same level of requirements; the U.S. Green Building Council (USGBC) requires each facility to pursue certification individually, with very few exceptions (refer to the LEED Reference Guide for details). The Project may pursue the Campus or Group Approach to maximize the benefits of shared assets and ease of documentation as detailed in the associated resource guidance, available via USGBC's website. The S+R Admin must determine the preferred path forward with the MBTA PM at the start of the Project and prior to development of any strategy, plans, or other associated efforts.

References:

- U.S. Green Building Council (USGBC) (USGBC 2020a)
- LEED for Building Design and Construction (v4 and v4.1 or most recent version) (USGBC 2020b)

A.1.1.4 Integrative Process

Beginning in pre-design and continuing throughout the design phases, the Project Team must identify and use opportunities to achieve synergies across disciplines and building systems. Use the analyses performed to inform the owner's project requirements (OPR), BOD, design documents, and construction documents. For greater insight on integrative process procedures, review the *Integrative Process (IP) ANSI Consensus National Standard Guide 2.0 for Design and Construction of Sustainable Buildings and Communities* and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 189.1, *Standard for the Design of High-Performance, Green Buildings*, Informative Appendix F (Integrated Design).

Integrative actions with external partners, such as with the local governments, private developers, or citizen groups will be led by MBTA staff, and may allow extending the boundaries of collaboration and shared savings. Design staff may be involved in identifying the opportunities for external partnerships and incorporating resulting design changes. The design team may also consider other training or operational partnerships with other public and private entities who are also transitioning from fossil fuel to electric vehicles.

The Project Team will compile all integrative process documentation required in **Table A-1** and submit in final electronic format to the S+R Administrator for inclusion in the SRMP and MBTA PM as part of the design closeout phase. Design team members must contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to *LEED BD+C v4/4.1: IP Credit Integrative Process*.

A.1.1.5 Sustainability and Resilience Educational Material

At a minimum, the S+R Admin must work with the design team to develop a case study living document that includes how the Project incorporated S+R into the Project. At the start of construction, the S+R Admin will transfer the educational material and case study in electronic format to the contractor's S+R Coordinator to complete with additional information relevant to the construction phase.

At Project completion, the construction S+R Coordinator must provide in electronic format finalized material to the design S+R Administrator for review, and MBTA PM for approval and record. The MBTA PM may then update the content with operational data and use the material as appropriate to the project type alongside other MBTA educational and promotional initiatives.

Educational opportunities for buildings should elaborate on construction methods, building material attributes, fixture and system features, operational efficiency, and user environment and experience. Educational features must be considered as appropriate to each project type as well as in the context of the MBTA as a whole. Consider the following approaches; alternatives may be discussed with the Project Team and MBTA PM:

- The development of a manual or guideline to inform the design of other buildings based on the successes of this Project.
- An educational outreach program or guided tour could be developed to focus on sustainable and resilient living, using the Project as an example.

Refer to LEED BD+C v4/4.1: IN Credit Green Building Education (USGBC 2020c).

A.1.1.6 Construction Activities Requirements

A.1.1.6.1 Water Use During Construction

The construction team must similarly address the potential to reduce water consumption during construction. Overuse of water not only depletes waterbodies and lowers groundwater levels, but the treatment of water consumes large amounts of energy. In many cases, it is not necessary to use potable water for the intended task. Greywater, recycled water, and stormwater are alternatives to potable water use, especially in construction.

Additional strategies may be proposed by the construction team to the Project's construction S+R Coordinator and MBTA PM for consideration. The construction S+R Coordinator must submit documentation of potable water use reduction practices actually implemented as a part of each pay application.

A.1.1.6.2 Energy Use During Construction

Because construction energy use is closely linked to emissions, contractors are required to review energy efficiency, energy reduction, renewable energy use, and reduced emissions associated with the construction phase of all projects. The design S+R Administrator will include a copy of the construction performance requirements within the SRMP.

Additional strategies may be proposed by the construction team to the Project's construction S+R Coordinator and MBTA PM for consideration. The construction S+R Coordinator must submit documentation of energy use reduction practices actually implemented as a part of each pay application.

A.1.1.6.3 Construction and Demolition Waste Management and Disposal

All projects must develop and implement a CDWMP. The design team must include requirements within contract documents that require the contractor to submit documentation based on LEED Credit references. The design S+R Administrator will include a copy of the construction performance requirements within the SRMP.

The CDWMP must account for all materials, including land-clearing debris, materials to be used for alternative daily cover, and other materials not contributing to diversion but not included in the diverted waste total. Material sent to landfills for use as cover is still being disposed of in landfills and therefore does not meet the intent of this effort. The safe removal and disposal of hazardous materials must also be covered in the CDWMP. Hazardous materials must be tracked separately and not be included in the Project's total waste. Refer to the LEED Credit references for required documentation and suggested implementation strategies.

All projects must pursue an overall diversion rate of at least 75%, striving for 85% or higher, attained through any combination of strategies appropriate to the project type and scope. Diversion rate = (Total waste diverted from landfill / Total waste produced by Project) × 100. If different from overall diversion totals, the total percentage of *recyclable-only* materials must be at least 90%; this total would not include demolition-specific materials that may not be deemed recyclable by local entities or other authorities.

As part of each pay request, the construction team S+R Administrator must provide progress to date CDWMP documentation with all major waste streams generated, including disposal and diversion rates, and all backup documentation, i.e., hauling receipts and monthly summaries from the hauler. Contractor closeout reports must include the final CDWMP with supporting documentation to the S+R Administrator for inclusion in the SRMP and the MBTA PM for record.

Refer to LEED v4/v4.1 MR Pre 2 *Construction and Demo Waste Management Planning* (most beneficial documentation path between v4 and v4.1 to be determined at the time of construction kickoff).

A.1.1.6.4 Construction Indoor Air Quality Management Plan

Occupied building construction projects must require the contractor to submit a Construction Indoor Air Quality Management Plan based on the requirements and documentation of LEED v4.1 IEQ Cr 3 *Construction Indoor Air Quality Management Plan.* The design S+R Administrator will include a copy of the construction performance requirements within the SRMP.

The following best practices support successful implementation of the IAQMP:

- Identify the key players and someone responsible for implementing the IAQMP, such as the HVAC installer and the general contractor. Make sure they understand the requirements of the plan and help champion its goals.
- Include the IAQMP requirements in contract agreements with subcontractors.
- As subcontractors are selected and deployed onsite, familiarize them with the plan and how it will affect their daily activities. Hold a subcontractors' orientation meeting to review the plan requirements as a group.
- Include construction IAQMP progress check-ins as a regular item in weekly subcontractor meetings and safety meetings.
- Provide a copy of the plan onsite, preferably posted in an accessible area. Translate the plan into the languages spoken by subcontractors and their crews.

- General contractors, construction managers, and owners should verify that the IAQMP is being followed on job walks, ideally daily, so that issues can be addressed with subcontractors as necessary. Creating a checklist of major items for easy reference is often effective.
- Decide whether air handlers need to be used during construction. If so, substituting standalone temporary air handlers or heaters may make it easier to meet the HVAC protection requirement. If permanent air handlers are used during construction, record the filtration media used to meet the documentation requirements.
- Annotate photographs to indicate each IAQMP measure depicted and its general location.
- Provide photographs of the methods employed to protect stored and installed absorptive materials from moisture damage during construction and preoccupancy.

Prior to building envelope completion, the construction team S+R Coordinator must include the IAQMP to the S+R Administrator for inclusion in the SRMP and the MBTA PM for record. Contractor closeout reports must include documentation of implementation of the IAQMP.

Refer to LEED v4 or v4.1 EQ Credit, *Construction Indoor Air Quality Management Plan*.

A.1.1.6.5 Indoor Air Quality Assurance

In addition to the requirements of the LEED EQ Credit *Construction Indoor Air Quality Management Plan*, each project must also prepare for occupancy by ensuring a high level of indoor air quality. The contractor must evaluate the Project schedule at the start of construction and determine if it is in the best interest of the Project occupants to perform a full flush-out of the interior, regularly occupied spaces (for example, offices, open office areas, conference rooms, workrooms, and classrooms), or if air testing is appropriate to confirm indoor contaminants are at levels that will not adversely affect occupants. It is preferred that projects pursue the air testing path under v4.1 criteria, as that documentation path is worth two points when successfully met, whereas the flush-out path is worth one point. When pursuing air testing, it is recommended that projects flush the spaces as much as possible prior to the testing to ensure the minimal quantities of volatile organic compounds (VOCs) from installed items' off-gassing is removed from the building.

The contractor must coordinate with the MBTA PM to determine if there is a preferred path, especially considering the facility type. Regardless of chosen path, the IAQMP must document the Project Team's decision as a matter of record. The selected path must be implemented after construction ends and the building has been completely cleaned. All interior finishes, such as millwork, doors, paint, carpet, acoustic tiles, and movable furnishings (such as workstations and partitions), must be installed, and major VOC punch list items must be finished.

Flush-out

Document calculations that were performed to determine required duration and system set points, and reports confirming conditions were met for the full time required. If conditions fall out of compliance range during the designated timeframe, adjust the overall schedule to accommodate the difference and explain the circumstances via narrative with supporting system reports. All documentation must be added to the final IAQMP and provided to the S+R Administrator to be updated in the SRMP.

Air Testing

Obtain final testing results and reports from the air testing authority. All documentation must be added to the final IAQMP and provided to the S+R Administrator to be updated in the SRMP.

Refer to LEED v4 or v4.1 EQ Credit, *Indoor Air Quality Assessment*.

A.1.1.6.6 Temporary Stormwater Pollution Control Requirements

Projects with total limits of disturbance of 1 acre or more must comply with the requirements of the United States Environmental Protection Agency (EPA) 2022 Construction General Permit (CGP) for discharges from construction activities (EPA 2022). The CGP outlines the provisions necessary to comply with the EPA National Pollutant Discharge Elimination System program, which is administered by EPA in Massachusetts.

The design team must create and implement a SWPPP that includes an Erosion and Sediment Control Plan (ESCP) for all construction activities associated with the Project. Best management practices must be used throughout the SWPPP and ESCP. Once the plans (SWPPP and ESCP) are complete, the design team must file a Notice of Intent with EPA to secure coverage under the CGP. The initial SWPPP/ESCP must be provided to the S+R Administrator for review and inclusion in the larger SRMP.

The EPA CGP and related documents and the SWPPP template and guidance are available on the EPA website.

The construction phase will be considered complete when the site is stabilized, compliance documentation is complete, and a Certificate of Compliance is issued by the appropriate local authority.

During construction, the contractor must record any modifications to the SWPPP / ESCP and provide supporting evidence of the monitoring activities that occur throughout construction. The contractor must submit a final SWPPP/ESCP to the S+R Administrator to update the SRMP, and MBTA PM for record.

Refer to LEED v4/v4.1 SS Prerequisite *Construction Activity Pollution Prevention*.

A.1.1.6.7 Post-design Commissioning

Commissioning (Cx) is the process of subsystem integration by a subject matter expert who reviews individual subsystems, and also the interrelationships of the different systems. Operations and maintenance staff must have training and be receptive to learning new methods for optimizing system performance so that efficient design is carried through to efficient performance.

Given the increasing complexity and interdependency of building systems, a deficiency in any one system can have a significant impact to the overall efficient operation and reliable performance of other systems therefore affecting facility sustainability, and in some cases, resilience. The operational team must be completely trained for all building systems functionality at the component and system levels. It is critical to the mission of the MBTA that a process for seamlessly transitioning capital projects from construction to full operational control is implemented.

Construction Phase

- Cx Site Observation During Rough-in: During the construction phase, especially when building systems are being installed, it is important for key members of the Cx team to have a regular onsite presence.
- O&M Documentation Cx Review: The coordination of O&M documentation is often left to the end of the project and can have a negative impact on how the systems operate over the life of the building. Early review of these documents results in improved quality and useful tools.
- Warranty Documentation Cx Review: Given the importance of proper system operation over the life of the buildings, ensuring that equipment warranties meet the O&M team's requirements is of critical importance.

- Enterprise Asset Management System (EAMS)/Computerized Maintenance Management System (CMMS) Integration and Building Automation System (BAS): The Cx process should verify that all assets are fully integrated into the EAMS/CMMS and BAS. This process includes:
  - Verify the asset tagging information to confirm that the EAMS/CMMS and/or BAS tag aligns with all other documentation associated with a particular asset. Ideally, the naming protocol is established early in the project so that it can be carried forward throughout the design and construction process.
  - Observe actual asset tag locations and content while onsite is beneficial to confirm consistency.
  - Ensue the maintenance practices incorporated in the EAMS/CMMS and BMS represent industry best practices for that particular asset and not just boilerplate O&M data.
  - Verify warranty information is properly captured in the EAMS/CMMS and BMS can prevent unintentional repairs on equipment that is under warranty.
  - Ensure proper end-use reporting to the BMS and that the BMS can effectively control applicable assets.
- Pre-Functional Testing: Pre-functional checklists (PFCs) are used to ensure the equipment and systems are installed and operational in accordance with the contract documents and that Functional Performance Testing (FPT) may proceed without unnecessary delays. The Cx team prepares the PFCs that address asset labeling, equipment delivery, installation, start-up, and BAS configuration for all systems and equipment being commissioned.
- Equipment Start-up: The first chance to observe the equipment in its operating condition and an essential part of the Cx process.
- Testing, Adjusting, and Balancing (TAB) Review: TAB is a critical element of the Project delivery process. The commissioning authority (CxA) should work with construction team to coordinate their activities of the TAB contractor for each project.
- Training Planning: As part of the training planning process, the training requirements should be reviewed against the expectations and requirements of the O&M team. Training should include understanding of automated and manual responses to disruptions.

Testing and Training

- Attend Planning Meetings: The Cx team schedules, organizes, leads, and supervises the FPT, with the involvement of the installing contractors to operate systems. Testing and training planning sessions should be coordinated with Project meetings. Sessions will cover all systems to be commissioned.
- FPT: This is the dynamic testing of systems under full operation.
  - An FPT only commences when the pre-functional testing and checklists are complete and approved by the CxA and O&M team.
  - Systems are tested under various modes (such as during low loads, high loads, component failures, unoccupied, varying outdoor conditions, alarm conditions, and utility failures). The systems are run through all the Energy Management Control System (EMCS) sequences of operation and components are verified to be responding as intended. When systems do not pass a test, issues are clearly documented in an issues log. Items in the log are reviewed and closed through the issue resolution process. Systems are then re-tested.

- The results of this phase establish the operational baseline for the systems and their components. The O&M team time commitment can be significant, particularly for a large project. O&M team participation during FPT is possibly the best method of introducing building systems to those responsible for operating them. Systems to be commissioned include the following:
    - Building envelope
    - Conveyance/vertical transportation
    - Electrical, including renewable energy systems
    - Energy and water utility metering systems and submeters
    - Energy Management and Control Systems
    - Fenestration control systems
    - Irrigation
    - Life safety (fire protection and fire alarm system)
    - Low voltage
        - Security
        - Mass notification
        - Distributed antennae
        - Synchronized clock system
    - Mechanical
    - Metering of all systems
    - Plumbing

- Integrated Systems Testing (IST): The building systems' interoperability is verified under a number of failure scenarios. In critical facilities, this is an industry standard best Cx practice. The primary test is when the normal power supply to the building is "turned off" and the team observes how the building systems respond. During this test, not only are generators, fuel systems, and transfer switching tested, but many other integrated systems are verified for performance under these conditions. While on normal power and emergency power, the team needs to verify that the EMCS, fire alarm, security, and other systems continue to operate as designed regardless of power source or power switching. It is common to find some systems do not perform correctly when switching to emergency power or back to normal power. The IST process is the first time the O&M team will be exposed to emergency management procedures related to the new facility and the lessons learned are extremely valuable. The results of this testing often drive institutional standard operating procedures (SOPs) and utility management plans.
- Corrective Action: Corrective Issue Reports are generated by the CxA when issues or problems arise during the Cx process. The report will describe the problem condition along with any related reference information and issued to the construction team for corrective action. When the necessary corrections have been completed, the actions taken are documented and the item is closed in the issues log. Depending on the nature of the issue or problem, the CxA, along with the Project stakeholders, will determine if re-testing of the equipment or system is necessary. It is important to have the O&M team engaged during the corrective issues process, so the issue is clearly understood by all parties, and everyone understands the resolution.

- Owner Training: Training is one of the most important aspects of turning the Project over to the O&M team. As-built documents, O&M manuals, and all approved submittals should be turned over to the O&M staff prior to any training. The delivery of closeout materials should be verified by the CxA. The training must include both component/equipment level and integrated system level sessions. All training sessions should follow the pre-approved agendas and plans, all attendees should sign the attendance sheet during the sessions, and a follow-up evaluation is performed to verify the trainees were provided with the pertinent information to properly operate and maintain the facility. All training materials should be captured and translated into a format, such as PowerPoint, that allows for new hire training as well as continuous training of current staff. Training sessions are only effective if attended by the appropriate personnel. At this point in the transition to operational control, there should be representation from each responsible shift attending the training sessions for each building system. This is another critical step in the delivery process.

Post-construction

- Finalize SOPs: One of the keys to achieving operational functionality is having clear, concise documentation on how the integrated building systems function as a whole. As part of the systems manual, SOPs for all potential conditions should be provided. These should be developed to allow for the documents to be laminated and placed on or near the primary system components and control points. In a “critical to mission” environment, being able to respond to an unplanned incident quickly and effectively can have a direct impact on mission readiness and being prepared for such an event is the best way to mitigate that risk. During the development of the SOPs, the Cx/O&M team plays a vital role where they need to define their team composition and provide input to the level of detail desired for each system.
- Seasonal/Deferred Testing: Despite all the efforts of the Cx team members to complete all verification testing prior to Project closeout and occupancy, identify any systems that cannot be tested at this juncture because of Project phasing and/or weather conditions. Any seasonal verification issues will be well documented, and the appropriate Cx team members will need to be convened to carry out these tests. The need for O&M team involvement is crucial because the facility is now occupied and under their control. These tests will need to be closely coordinated to ensure occupant comfort and overall life safety is not impacted.
- Warranty Item Review and Verification: Ideally, 10 months into the 12-month warranty period the team returns to meet with the specific O&M personnel. This process should include and be recorded in the Final Cx Report:
    - Review of O&M experience in operating various systems
    - Recommendations for improvement
    - Warranty claims registered during the first months of operation
    - Record documentation of any warranty items that require follow-up
    - Summary of O&M personnel recommendations for system performance enhancements
    - O&M staff requests for additional and/or supplementary training sessions
    - Suggestions for improvements in the Cx process to be implemented on future projects
- Measurement and verification (M&V) Implementation: To ensure that energy performance goals are achieved, incorporating measurement and verification elements into the Project delivery process is essential. Even though the facilities will be brand new, the design phase began several years ago and there may be opportunities for further energy consumption savings. Throughout construction, the team may identify additional measures that should be considered for future savings.

- M&V should be implemented during the warranty phase and after a full year of occupancy.
- The energy performance of the facilities should be observed, and the performance documented. Since full occupancy may be well beyond the initial warranty period, the operational team should review the performance after a full year of occupancy to verify that the true targeted goals are being achieved and to identify any additional measures that may be implemented.
- The entity that performs the M&V body of work will vary from project to project. The contracting responsibility should be decided during the planning phase.

- Final EMCS Training: Several training sessions prior to occupancy will help the O&M staff establish baseline knowledge. The final training will focus on system level operations within the occupied facility.
- Long-term Training: A long-term training planning should address core competency requirements that align with the building systems in place. With an ongoing training plan in place, the O&M team will be able to operate the facilities safely, efficiently, and effectively under all operating conditions.
- Develop Monitoring-based Cx Program: A continuous process to resolve operating issues, improve comfort, and optimize energy use. Using the successfully commissioned systems as the baseline, all the operating parameters and sequences of operation are recorded. Through the EMCS, “trigger” points are identified, and alarms are initiated when a system is performing out of its optimized range. These points can include efficiency rating (kilowatts per ton), a setpoint (static pressure), or total runtime (hours) – individually or in a combination. Monthly reports should be generated that allow the O&M team to search for anomalies. This process verifies that the building and systems performance are optimized to meet the current operating requirements, which ultimately extends the useful life of an asset and reduces the operating costs.

The specific requirements for each project will vary but must incorporate all of the elements noted in this section, from planning and design phase through post-construction activities.

Refer to LEED EA Prerequisite and Credit, *Fundamental Commissioning and Verification* and *Enhanced Commissioning*.

A.1.2 Local and Regional Sustainability and Resilience Initiatives

Each Project Team must review the requirements applicable to a project’s municipality as well as the overall requirements laid out here for incorporation as appropriate; it is anticipated that the mandates will continue to develop and progress as well as expand into neighboring cities in the coming years. Project teams must also research similar project requirements in other municipalities not listed in **Table A-2** to determine if additional criteria exist and applies.

Table A-2. Local and Regional Sustainability and Resilience Initiatives

Document	Description
Massachusetts Commission on Clean Heat[a]	Includes a set of policy recommendations to meet the mandate put forth to sustainably reduce the use of heating fuels and minimize the greenhouse gas emissions from buildings while ensuring the costs and opportunities arising from such reductions are distributed equitably.
Statewide Climate Resilience Design Standards and Guidelines for the Resilient Massachusetts Action Team (2020)[b]	Recommended design standards and guidelines on how to use them to incorporate climate resilience into projects with physical assets. MBTA is part of the RMAT and a key stakeholder in this resource.

Document	Description
Boston Planning and Development Agency's Coastal Flood Resilience Design Guidelines (2019)[c]	Additional guidance for properties in the City of Boston on how to adhere to the requirements and guidelines in the City. May be applicable to projects outside of Boston located in coastal areas. Provides in-depth technical considerations for buildings.
Medford Climate Vulnerability Assessment (2019)[d]	Designers may look at the plan for a preliminary view of areas that are modeled urban heat islands, prone to flooding, and at risk of coastal flooding due to sea-level rise. The plan contains information on vulnerabilities of critical infrastructure that may impact operations of the facility in addition to socially vulnerable populations that should be considered.
SHMCAP (2018)[e]	This plan, the first of its kind to comprehensively integrate climate change impacts and adaptation strategies with hazard mitigation planning, also complies with current federal requirements for state hazard mitigation plans and maintains the Commonwealth's eligibility for federal disaster recovery and hazard mitigation funding.
Boston Public Works Department Climate Resilient Design Standards & Guidelines for Protection of Public Rights-of-Way (2018)[f]	Guidelines for designing flood protection within the City of Boston and for impacts to the public right of way
Boston Planning & Development Agency Climate Change Checklist (2017)[g]	Required online Climate Resiliency Checklist Reporting Form, per Boston Zoning Code Article 37 Green Buildings and the Resiliency Policy, for all development projects subject to Boston zoning Article 80. • Large projects (adding more than 50,000 square feet) • Small projects (greater than 20,000 square feet) • Planned development areas (new overlay zoning districts for Project areas larger than 1 acre) • Institutional master plans (projects relating to academic and medical campuses) The Checklist form may be complementary to the forms provided in this set of guidelines.
Climate Ready Boston (ongoing)[h]	Designers can view mapping of coastal flooding, stormwater flooding, heat island, and social vulnerability in the City of Boston and consider ongoing projects that may provide protection. Neighborhood plans provide short, mid, and long-term actions that may be applicable.
Cambridge Climate Plans and Reports: **Climate Change Vulnerability Assessment** **Part 1 (2015)[i]** **Part 2 (2017)[j]** **Resilient Cambridge Plan (2021)[k]**	Part 1: Focuses on the vulnerability of assets to increased precipitation, heat, and the social and economic impacts of climate change Part 2: Focuses on sea-level rise and coastal storm surge impacts on critical infrastructure, community resources, and social vulnerabilities The Resilient Cambridge Plan includes a section on buildings and infrastructure that may be of use to designers.
State-wide Resilience Master Plan for the DCAMM (2016)[l]	Alternative, but similar, process for identifying how your facility is at risk and selecting design guidelines for electrical, mechanical, structural, architectural, and exterior building systems and components.
Massachusetts Global Warming Solutions Act (2008)	This Act required the MassDEP to establish mandatory greenhouse gas reporting regulations. All facilities regulated under Title V of the federal Clean Air Act and MassDEP regulation 310 CMR 7.00: Air Pollution Control, are required to report GHG emissions under the Massachusetts Greenhouse Gas Emissions Reporting Program.[m]
Metropolitan Boston Climate Preparedness Commitment (2016)[n]	Commitment to help the region integrate existing local efforts related to climate resilience and mitigation and coordinate future work, including advocacy efforts, to ensure the region's responses to threats of climate change are cohesive and complementary.

Document	Description
Carbon Free Boston[o]	This is the City of Boston's initiative to become carbon neutral by 2050 by reducing GHG emissions to contribute to climate change.
Zero Waste Boston[p]	This is the City of Boston's initiative to transform Boston into a zero-waste city (i.e., reducing, repairing, and reusing materials), through planning, policy and community engagement. Toolkits and resources have been established for businesses and institutions to reduce solid waste, by business type and waste streams. As the facilities plan their operations, they can review these tools to help minimize their waste.
Resilient Boston Harbor Plan[q]	A plan to protect Boston's neighborhoods from sea-level rise and flooding due to climate change. The plan includes strategies for adapted infrastructure, protecting waterfront parks and utilizing elevated harbor walks.
Cambridge 2020 Climate Action Plan[r]	The goal of this action plan is to reduce GHGs by 80% between 2002 and 2050 in the City of Cambridge. The have established local actions to reduce GHG emissions through the City of Cambridge Climate Protection Plan.
Cambridge Net Zero Action Plan[s]	This action plan includes best practices designers can review that support the City of Cambridge's goal to be carbon neutral by 2050.
Somerville's Community Climate Change Plan[t]	This plan includes policies, programs and strategies that outline implementable actions designers that are planning projects in the City of Somerville can review to reduce Somerville's contribution to climate change and prepare for the impacts of climate change.
SomerVision 2040[u]	The SomerVision 2040 Comprehension Plan includes a topic chapter focusing specifically on Climate and Sustainability. Potential tasks are included in the plan for addressing climate change mitigation and adaptation, resilience, energy efficiency, waste reduction, environmentalism, renewable energy, carbon neutrality, and pollution prevention and mitigation within the Somerville locality.

[a] Commonwealth of Massachusetts, 2022a.

[b] Commonwealth of Massachusetts, 2020a.

[c] Boston Planning & Development Agency, 2019.

[d] Metropolitan Area Planning Council, 2020.

[e] Commonwealth of Massachusetts, 2018.

[f] Boston Public Works Department, 2018.

[g] Boston Planning & Development Agency, 2020.

[h] Greenovate Boston, 2020.

[i] City of Cambridge, 2015.

[j] City of Cambridge, 2017.

[k] City of Cambridge, 2021.

[l] DCAMM, 2016.

[m] MassDEP, n.d.

[n] Metropolitan Area Planning Council, 2015.

[o] City of Boston, 2020b.

[p] City of Boston, 2020d.

[q] City of Boston, 2020c.

[r] City of Cambridge, 2020a.

[s] City of Cambridge, 2020b.

[t] City of Somerville, 2020.

[u] City of Somerville, 2018.

Document	Description

Notes:
DCAMM = Massachusetts Division of Capital Assets Management and Maintenance
RMAT = Resilient Massachusetts Action Team
SHMCAP = Statewide Hazard Mitigation and Climate Adaptation Plan

Depending on location, size, and/or locally specific agreements, projects may be required to either design to or certify at a certain level of LEED (or other third-party certification program) certification or provide a pathway to achieve net zero energy or carbon by the year 2050. These standards intend to enable compliance and success aligned with the region's sustainability goals. This document proactively makes accommodations for those plans that the cities are slowly implementing, focused on building performance, prioritizing renewable energy, and waste management in line with the cities' and the MBTA's goals.

A.1.2.1 MBTA Sustainability and Resilience Plans and Policies

Transportation infrastructure and energy consumption in buildings contribute to GHG emissions, which influence the local and regional climate with incremental climate changes resulting in extreme weather events. The MBTA is committed to minimizing their impact on the environment as well addressing their vulnerabilities as climate change related events occur.

The MBTA has taken steps to reduce their greenhouse gas (GHG) emissions, energy use, and resource consumption as outlined in the following reports and directives, published by the MBTA or their memberships:

- APTA Sustainability Commitment & Guidelines (APTA 2016)
- SWPPP (MBTA 2015a)
- 2015 Design of Permanent Construction Directive (MBTA 2015b)
- 2015 Construction Specification Development Directive (MBTA 2015c)
- MBTA 2017 Sustainability Report & Program (MBTA 2017)
- 2019 Design Directive (MBTA 2019a)
- MBTA Flood Resiliency Design Directive (2019b)
- 2019 Material Selection Directive (MBTA 2019c)
- 2020 Energy Management Program (MBTA 2020)
- 2020 Construction Monitoring Programs Directive (MBTA 2020)

To date, the MBTA has also made significant progress addressing how their facilities and operations adapt to climate change, including investments in coastal erosion control and flood protection systems, prioritizing energy efficiency strategies, and centralizing utility data (MBTA 2022).

In the future, the MBTA aims to assess facility vulnerabilities according to current and future climate trends, quantify and minimize their impact on the environment through technology-based pollution prevention systems and a process of continuous improvement and stakeholder transparency, and continue to inventory their GHG emissions annually to support these efforts, in coordination with the Conservation Law Foundation's Transit Industry Best Practices. Designers must coordinate with the

Energy and Environmental Affairs Department. Refer to the MBTA Climate Change Resiliency website for applicable requirements (MBTA 2022).

A.1.2.2 Leading by Example

The Massachusetts Department of Energy Resources runs the LBE Program, which "facilitates and promotes state government clean energy and sustainability initiatives" (Commonwealth of Massachusetts 2020c) that reduce the environmental impacts of state government operations. The program was established in 2007 via Executive Order (EO) 484 and focuses on advancing energy efficiency, clean energy production, and reducing greenhouse gas emissions associated with climate change. The program additionally addresses waste reduction, water conservation, green buildings, alternative fuels, efficient transportation, and recycling.

Under the current version of EO 484 and 594, all state construction must comply with the most recent performance and tracking requirements (project teams must confirm the most current program requirements at the time of design and comply as stated). The program requires the tracking and reporting of facility energy data to monitor progress by the required participating entities, including the MBTA. To assist in this effort, the electrical and mechanical engineers must use the LBE Tracking Form to report on and provide the data to the MBTA, including the following:

- Electricity data for all the sources that apply to the Project including onsite renewable energy, Renewable Energy Certificates (RECs), and Alternative Energy Credits purchased or sold separate from the DCAMM state contract, if applicable.
  - Related, if the Project purchases any RECs and/or carbon offsets, the Project must follow the LBE guidance on power purchase agreements, preserve all documentation, and provide all information to the MBTA as part of the SRMP.
- Energy data associated with all building fuels except for electricity and onsite generation at buildings. Provide all consumption information for all non-electric building energy use, including natural gas, oil, propane, etc.
- Information about electric vehicle (EV) charging stations as outlined in the form.

Additional team members must also populate the LBE Tracking Form as appropriate for Project aspects, including:

- Architect and/or PM to provide information on recycling services being accommodated (office and maintenance area programs)
- Plumbing engineer to provide information on annual total water use (occupant and maintenance practices)
- Civil engineer and/or landscape architect to provide information on landscaping activities and sustainable landscaping efforts, including any added site material resilience precautions

If requested, the Project Team must additionally assist the MBTA in pursuit of grant funding for clean energy feasibility studies and/or solar photovoltaic canopies, as applicable. Project design requirements related to energy metering and analytics are provided in the *Design Guideline for Bus Maintenance Facilities* Section 3.5.2.5, Metering Energy Systems.

The S+R Admin must facilitate team compliance and assist the team in collecting the required information.

A.1.2.3 Resilient Massachusetts Action Team and MBTA

The MBTA is also a member of the statewide RMAT, which is an inter-agency team led by the Executive Office of Energy and Environmental Affairs and the Massachusetts Emergency Management Agency. The RMAT has established Statewide Climate Resilience Design Standards & Guidelines. The Climate Resilience Design Standards are grounded in scientific methodology, using the best available climate science data in Massachusetts, which will predictably and regularly improve over time to incorporate new science, additional or changing climate hazards, and ongoing stakeholder feedback. The focus of the RMAT Climate Resilience Design Standards & Guidelines is to integrate climate resilience in projects with physical assets owned and maintained by state agencies. The recommended Climate Resilience Design Standards & Guidelines supplement existing practices, regulatory requirements, or codes and provide consistent climate resilience standards across agencies and municipalities.

Designers will be able to use the outputs from the Tool and Guidelines to calculate the primary thresholds for design of MBTA bus maintenance facilities and consider/document design considerations. Please refer to the Mass.gov for more detailed information regarding the Statewide RMAT Climate Resilience Design Standards & Guidelines.

A.2 GENERAL SUSTAINABILITY REQUIREMENTS

A.2.1 LEED Requirements

Table A-3 indicates LEED Prerequisites and Credits available to projects, identifies which are required by MBTA, responsible parties, and additional notes, including recommended pursuits in order to enable each facility to reach Gold certification range. The required items are typically achievable, either in part or in whole, for maintenance facility projects in the greater Boston area. Levels of achievement within each Credit will vary per project; it is the responsibility of the S+R Admin to facilitate the Project-specific conversations with the Project Team and MBTA necessary to achieve all points for which the Project is reasonably eligible.

Table A-3. LEED Project Responsibility Tracker

LEED v4 for BD+C:
New Construction
Project Responsibility Tracker
MBTA Bus Maintenance Facilities

Design or Construction	#	Prerequisite/Credit Name	Required by MBTA	Primary Responsibility	Notes
Design	Form 1	Project Information Form	YES	S+R Admin	
Integrative Process					
Design	Credit 1	Integrative Process	YES	Team	S+R Admin to facilitate information consolidation.
Location and Transportation					
Design	Credit 1	LEED for Neighborhood Development Location	N/A	N/A	NOTE: You are either eligible for Credit 1 or Credits 2–8, but not both. Total points available for this category are 16. Projects are rarely eligible for Credit 1.
Design	Credit 2	Sensitive Land Protection		Civil/ Landscape Architect	Recommended as applicable.
Design	Credit 3	High Priority Site			Recommended as applicable.
		Option 1: Historic District		S+R Admin/ Architect	
		Option 2: Priority Designation		S+R Admin	
		Option 3: Brownfield Remediation		Civil/Contractor	
Design	Credit 4	Surrounding Density and Diverse Uses		S+R Admin	Recommended as applicable.
Design	Credit 5	Access to Quality Transit	YES	S+R Admin	
Design	Credit 6	Bicycle Facilities	YES	Civil/Architect	
Design	Credit 7	Reduced Parking Footprint	YES	Civil	
Design	Credit 8	Green Vehicles	YES	Civil/Electrical	
Sustainable Sites					
Construction	Prerequisite 1	Construction Activity Pollution Prevention	YES	Civil/Contractor	

LEED v4 for BD+C:
New Construction

Project Responsibility Tracker
MBTA Bus Maintenance Facilities

Design or Construction	#	Prerequisite/Credit Name	Required by MBTA	Primary Responsibility	Notes
Design	Credit 1	Site Assessment		Civil/Landscape Architect	Recommended as applicable.
Design	Credit 2	Site Development-Protect or Restore Habitat			
		Option 1: Onsite Restoration		Civil/Landscape Architect	
		Option 2: Financial Support		S+R Admin	
Design	Credit 3	Open Space		Civil/Landscape Architect	
Design	Credit 4	Rainwater Management	YES	Civil/Landscape Architect	
Design	Credit 5	Heat Island Reduction	YES	Civil/Architect	
Design	Credit 6	Light Pollution Reduction	YES	Electrical	
Water Efficiency					
Design	Prerequisite 1	Outdoor Water Use Reduction	YES	Landscape Architec	
Design	Prerequisite 2	Indoor Water Use Reduction	YES	Plumbing	
Design	Prerequisite 3	Building-Level Water Metering	YES	Plumbing/ Landscape Architect	
Design	Credit 1	Outdoor Water Use Reduction	YES	Landscape Architect	
Design	Credit 2	Indoor Water Use Reduction	YES	Plumbing	
Design	Credit 3	Cooling Tower Water Use		Mechanical	
Design	Credit 4	Water Metering	YES	Plumbing	
Energy and Atmosphere					
Construction	Prerequisite 1	Fundamental Commissioning and Verification	YES	CxA	
Design	Prerequisite 2	Minimum Energy Performance	YES	Mechanical	
Design	Prerequisite 3	Building-Level Energy Metering	YES	Mechanical/ Electrical	
Design	Prerequisite 4	Fundamental Refrigerant Management	YES	Mechanical	
Construction	Credit 1	Enhanced Commissioning	YES		
		Option 1, Path 1: Enhanced Commissioning		CxA	
		Option 1, Path 2: Enhanced and Monitoring-based Commissioning		CxA	

LEED v4 for BD+C: New Construction

Project Responsibility Tracker

MBTA Bus Maintenance Facilities

Design or Construction	#	Prerequisite/Credit Name	Required by MBTA	Primary Responsibility	Notes
		Option 2: Envelope Commissioning		Building Envelope Commissioning Agent	Envelope commissioning (Cx) services are often either subcontracted by the Owner or CxA, but not required to be separately contracted.
Design	Credit 2	Optimize Energy Performance	YES	Mechanical	
Design	Credit 3	Advanced Energy Metering	YES	Mechanical/ Electrical	
Construction	Credit 4	Demand Response		Mechanical/ Electrical	
Design	Credit 5	Renewable Energy Production		Electrical	
Design	Credit 6	Enhanced Refrigerant Management	YES	Mechanical	
Construction	Credit 7	Green Power and Carbon Offsets	YES	Mechanical/ S+R Admin	
Materials and Resources					
Design	Prerequisite 1	Storage and Collection of Recyclables	YES	Architect/ MBTA	
Construction	Prerequisite 2	Construction and Demolition Waste Management Planning	YES	Contractor	
Construction	Credit 1	Building Life-Cycle Impact Reduction	YES		
		Option 4: Whole-Building Life-Cycle Assessment		Architect/ Structural	Will need a team member to provide embodied carbon modeling.
Construction	Credit 2	Building Product Disclosure and Optimization - Environmental Product Declarations		Team/ Contractor	Recommended as feasible. Includes Architect, Civil, Landscape Architect, MEP, Interiors.
Construction	Credit 3	Building Product Disclosure and Optimization - Sourcing of Raw Materials		Team/ Contractor	Recommended as feasible. Includes Architect, MEP, Interiors
Construction	Credit 4	Building Product Disclosure and Optimization - Material Ingredients		Team/ Contractor	Recommended as feasible. Includes Architect, Civil, Landscape Architect, MEP, Interiors.
Construction	Credit 5	Construction and Demolition Waste Management	YES	Contractor	
Indoor Environmental Quality					
Design	Prerequisite 1	Minimum Indoor Air Quality Performance	YES	Mechanical	
Design	Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	YES	Architect/MBTA	Coordinate with signage.

LEED v4 for BD+C:
New Construction

Project Responsibility Tracker
MBTA Bus Maintenance Facilities

Design or Construction	#	Prerequisite/Credit Name	Required by MBTA	Primary Responsibility	Notes
Design	Credit 1	Enhanced Indoor Air Quality Strategies	YES	Mechanical/ Architect	
Construction	Credit 2	Low-Emitting Materials	YES	Team/ Contractor	
Construction	Credit 3	Construction Indoor Air Quality Management Plan	YES	Contractor	
Construction	Credit 4	Indoor Air Quality Assessment	YES	Contractor/ MBTA	
Design	Credit 5	Thermal Comfort		Mechanical/ MBTA	
Design	Credit 6	Interior Lighting	YES		
		Option 1: Lighting Control		Electrical/ Lighting	
		Option 2: Lighting Quality		Architect/ Interiors	
Design	Credit 7	Daylight	YES	Architect/ Electrical	Will need a team member to provide daylight modeling.
Design	Credit 8	Quality Views	YES	Architect/Interiors	
Design	Credit 9	Acoustic Performance		Architect/Interiors / Acoustics	Will likely need an acoustics expert or consultant.
Innovation					
Design/Construction	Credit 1	Innovation		To be determined based on targeted strategies	Recommended as feasible. To earn all five points, a project must have at least one Pilot Credit, at least one Innovation Credit, and no more than two Exemplary Performance Credits. Refer to Design Guideline content for several suggested strategies for consideration.
Construction	Credit 2	LEED Accredited Professional	YES	S+R Admin	

A.2.1.1 Site-related Requirements

For additional design considerations, the S+R Admin should review the following LEED Innovation and Pilot Credits, available in the LEED Credit Library:

- Community Outreach and Involvement
- Walkable Project Site
- Parksmart Measures
- Solar Access to Green Space
- Offsite Rainwater Management
- Offsite Financial Support for Habitat Protection

A.2.1.2 Toward Net Zero Carbon

Much of the design and construction industry is focusing on carbon emissions associated with both facility operational carbon and embodied carbon. Operational carbon is defined as the greenhouse gas (GHG) emissions associated with the energy required to condition and power the building, including (but not limited to) lighting, service water heating, plug loads, heating, and cooling. Note that this does not include the energy required to charge EV's, whether they are battery electric buses (BEBs), fleet vehicles, or employee vehicles. Embodied carbon is defined as the emissions associated with the full life-cycle (cradle to grave) of all building materials used to construct the facility, including the construction process itself.

MBTA projects also acknowledge their contribution to carbon emissions and take actions to raise awareness while lowering generation though evaluation of the embodied carbon of their facilities; as part of this effort, the project teams will document efforts toward meeting the goals.

For projects that are unable to meet the net zero carbon thresholds outlined in this section due to site or operational constraints, the designer must demonstrate due diligence in seeking to apply the strategies detailed within by providing justification for the level of achievement for each criterion as part of the stated documentation requirements.

A.2.1.2.1 Carbon Reduction Plan

Develop a CRP to achieve net zero carbon (or as close to net zero carbon as feasible with the specific requirements for each project) that considers both operational and embodied carbon to align with the requirements of EO 594.

The Project will use the International Living Future Institute (ILFI) Zero Carbon Certification guidance as a model of how to implement appropriate strategies. The CRP must include the following strategies for optimal energy performance and reductions in carbon emissions:

- Operational Carbon: Identify strategies employed to reduce carbon emissions and provide energy modeling simulations that calculate the operational carbon reduction. The strategies should include the following:
  - Provide a clear description and a determination of Energy Use Intensity (EUI) baseline, based on ASHRAE 90.1-2010. The 2010 version is identified here as the appropriate baseline as referenced by ILFI. More recent versions of ASHRAE Standard 90.1 may be used, though it must be noted that the same performance thresholds may not apply equally to newer versions. Superior energy efficiency must be achieved in building operations prior to offsetting the associated emissions. The Project Team must use the most appropriate baseline available at the time of design; any adjusted performance thresholds must be reviewed with, and approved by, the MBTA.
  - Provide energy modeling simulations with results of predicted operational energy use, described in terms of annual energy use and EUI.
  - Provide confirmation that operational design strategies reduce emissions 25% or more below ASHRAE 90.1 2010 baseline.
  - Provide a description of carbon reduction strategies identifying how they contribute to overall carbon reduction effort.
- Zero Combustion: Eliminate onsite combustion of any fossil fuel source for any purpose, including but not limited to heating, service water heating, cooking or other ancillary use. Emergency standby power can be included as an exception, but efforts must be made to minimize the capacity of the standby power system and to limit the burning of fossil fuels.

- Embodied Carbon - Primary Materials: Identify strategies used and provide calculations to demonstrate reductions of embodied carbon to meet the target reduction of 10% or more for Primary Materials – defined as foundations, structure, and enclosure systems, compared to a baseline building of equivalent size, function and energy performance.
- Total Embodied Carbon: The total embodied carbon of primary materials, in the foundation, structure and building enclosure along with interior materials may not exceed 500 kilograms of carbon dioxide equivalent per square meter.
- Solar-ready Design: It is recognized that installation of solar photovoltaic panels as part of the Project scope is not always desired or feasible; however, it is required that new buildings are designed to be "solar-ready". Solar system costs continue to decline while grid power costs, in contrast, continue to escalate. Solar-ready design enables the future installation of a solar array, typically in a rooftop application, without the need for significant building modifications; this strategy also allows the facility to engage a third-party provider to install and maintain the systems rather than the owner. The Project Team must discuss and determine a preferred path with the MBTA for each project. If solar-ready design is chosen, the following requirements must be met:
  - Orientation: Orient the building to provide a south facing roof where solar modules can be located without being shaded.
  - Roof Design: Design the roof structure to accommodate the loads of a future solar array as quantified through ASCE 7 analysis. Uplift forces due to winds are a significant consideration.
    - The roof space for solar equipment should be maximized by limiting the amount of mechanical equipment located on the roof.
  - Electrical Chases: Provide penetrations and conduits from the roof to an electrical room for routing of power.
  - Electrical Layout: Consider locations for DC combiner boxes, inverters, rapid shut down switch and disconnect switches. Rooftop and electrical rooms are the typical locations.
  - Electrical Panel: Provide adequate capacity in the electrical panel, as required by the local jurisdiction, for the connection of the solar array to a circuit breaker.

The CRP must also include reference to the following ongoing operational strategies to confirm ongoing compliance with carbon reduction strategies:

- Disclosure of the actual energy consumption of the building. Incorporate metering and tracking infrastructure to facilitate reporting of actual usage data in operation.
- Offset of all carbon emissions associated with the Project, both embodied and operational carbon. Offsets should be accomplished through implementation of onsite renewable energy generation and procurement of renewable energy, carbon-sequestering materials, and carbon offsets. The plan should reference MBTA's contract for 100% clean energy to operate its facilities and transit systems.

A.2.1.2.2 Operational Carbon Reductions

Orientation and Massing: Orientation and massing can be challenging due to property lines, views, traffic management and zoning, but it is very important that optimal orientation and massing be achieved to support energy efficiency and renewable energy goals. A building with a long east-west axis provides opportunities to optimize daylighting and manage solar radiation through shading on the southern façade and the minimization of glazing on the east and west facades. Glazing on western facades is particularly problematic due to solar heat gain on warm afternoons. The north façade can provide largely glare free daylighting without shading. Optimal orientation and roof framing provides opportunities for rooftop solar to maximize onsite renewable energy generation. Combine solar heat gain management and optimal daylighting to produce a very meaningful impact HVAC system loads and sizing.

These guidelines reference Passive House (PHIUS+) as a source of industry best practices for aggressive energy use and carbon reduction and their overlap with cost effectiveness; PHIUS+ is focused on the use of passive measures, specifically. The Project Team must use the most current version available at the time of Project design for reference in determining the following aspects:

- Building Envelope: Optimization of the building envelope should significantly reduce the heating and cooling loads on the building, and this can be combined with management of internal loads to result in reduced dependence on active systems. A well air sealed, thermally broken, well insulated envelope is only successful as part of an integrated approach to the building science of internal and external heat flows, moisture management, and an attention to indoor air quality through controlled outside air management and energy recovery. Meet or exceed building envelope performance characteristics as identified in US PHIUS+ requirements.
  - Assembly U-Values: Optimize envelope insulation to meet PHIUS+ standards. Focus attention on whole assembly calculations, limiting or eliminating thermal bridging, and providing continuity of thermal insulation. There is no prescriptive U-value for any given project – all performance values must be calculated on a per-project basis to optimize the envelope for minimal external gains.
  - Building Assembly Analysis: In order for a building to be sustainable, it must be durable. For a building to be durable, it must be designed to prevent the accumulation of moisture in building assemblies since moisture accumulations can create mold and corrosion. The first step is to provide a very tight building envelope with air barrier performance that meets or exceeds the requirements of PHIUS+ for the Project scale and construction. Verify envelope airtightness through post-construction/preoccupancy whole-building blower-door airtightness test. This air barrier performance must greatly reduce the amount of warm air that can carry moisture into the building envelope where it can condense on cool surfaces. A second way that moisture can enter the building is at material junctions where two different material systems come together. To address this concern, special attention must be paid to detailing and installation of exterior enclosure systems. Building assembly performance must be verified using a hygrothermal simulation tool to address condensation risks.

    A tool often used for this type of study is called “WUFI” from the Freihofer Institute. WUFI stands for “heat and moisture transiency” in German (Wärme Und Feuchte Instationär).
  - Windows and Glazing: Meet or exceed window performance for Climate Zone 5 as identified on PHIUS Certified Data for Window Performance Program website (PHIUS 2020). These requirements are identified to meet thermal comfort requirements and avoid condensation risk.
- Energy Recovery/Ventilation: The HVAC system should be designed to decouple the space heating/ cooling and ventilation loads to improve overall system efficiency. They system should also include energy recovery as an additional energy efficiency measure.
- Building Systems: Project team to identify building systems required to meet thermal comfort and ventilation requirements. Mixed mode systems include differing methods of operation to meet distinct challenges based on seasonal change. Team to identify and diagram systems and components in SRMP tracker, identifying operating modes to address active cooling, active heating, passive shoulder seasons, and fan-assisted ventilation as applicable to project and program.

- Lighting and Controls: Project team to identify lighting systems and controls to meet light level requirements incorporating daylight dimming, occupancy and time-of-day controls, integrated into automated shading devices as applicable.

CRP and SRMP content must include descriptions of integrated envelope, systems, controls, and schedule.

A.2.1.2.3 Embodied Carbon

Project team to identify primary foundation, structure, and enclosure materials for a baseline building. Specific measures must be identified and undertaken to reduce the embodied carbon of these materials, including but not limited to the following strategies:

- Reduced material quantities: Design to reduce the quantity or volume of materials required. Design an efficient structure that uses less concrete or steel than a typical structure serving the same purpose.
- More efficient material characteristics: Design the foundation, structural, and enclosure materials with alternative materials or alternative formulations of materials to reduce carbon intensity of the Project. For example, the use of alternative cementitious materials in lieu of Portland cement, or alternative manufacturing processes, contribute to reduced embodied carbon impact for a concrete mix. The use of sustainably forested wood products in a mass timber structure in lieu of steel structural elements can contribute to reduced embodied carbon impact of that structural system.
- Carbon-entraining materials: Design or implementation of carbon-entraining materials or landscaping/natural materials that naturally sequester carbon can reduce the embodied carbon of a typical design.
- For projects involving hardscape and vegetation, the Pathfinder Tool developed by Climate Positive Design provides data on carbon intensity of materials and carbon sequestration capacity by vegetation. This tool enables project teams to track the Project carbon footprint and have the opportunity to account for Project life-cycle carbon sequestration from revegetation on the Project site.

Helpful resources for projects are the following, both of which provides a myriad of resources for all project materials:

- ILFI’s Zero Carbon certification resources page
- Boston Society of Architecture’s Embodied Carbon in Buildings resource page

Plans addressing the carbon exploration and any potential change must be included in the CRP in narrative format. Project teams should track, document, and clearly explain their methodology for calculating material intensity. Some material/product-related content may also be included in the MPP.

The resulting CRP composition must be provided to the Project S+R Admin for inclusion in the SRMP and to the MBTA PM for record.

CRP content must demonstrate compliance with design targets for reduction of embodied carbon. Tools for Calculating embodied carbon (i.e. performing a life-cycle assessment [LCA]) include the following:

- Athena Impact Estimator Whole Building LCA tool
- One Click LCA Web-based Whole Building LCA tool
- TallyLCA Revit-based Whole-Building LCA tool

- eTool Web-based Whole Building LCA tool
- Embodied Carbon in Construction Calculator (EC3) tool: A tool for carbon evaluation of product specific environmental product declarations

Refer to *ILFI Zero Carbon Certification*, Passive House (PHIUS+) Certification (ILFI 2022; PHIUS 2020).

Refer to *LEED BD+C v4/4.1: MR Pilot Credit 132 Procurement of Low Carbon Construction Materials* (USGBC 2020e).

A.2.1.3 Energy Efficiency Performance

A.2.1.3.1 Demand Response

In addition to energy efficiency at the individual project level, each project should evaluate participation in a demand response program consistent with LEED v4.1 EA Cr 4 Grid Harmonization, pending MBTA approval. Demand response programs provide an opportunity for entities like MBTA to capture financial incentives by volunteering to reduce their electrical load during periods of peak demand. This allows the New England Independent System Operator to match generation to load and maintain grid stability. This can be achieved by reducing lighting levels, changing HVAC set points, shutting down process loads or dispatching battery energy storage. Demand Response strategies should be designed into the BAS to facilitate participation. The design team must coordinate with MBTA operations staff on implementation of demand response as one aspect of energy-efficient design.

A.2.1.3.2 Life-cycle Cost Analysis

Independent of an LCA (as described previously), an LCCA is a method for assessing the total cost of facility ownership. It considers all costs of acquiring, owning, and disposing of a building or building system. LCCA is especially useful when Project alternatives that fulfill the same performance requirements but differ with respect to initial costs and operating costs, have to be compared to select the one that maximizes net savings. For example, LCCA will help determine whether the incorporation of a high-performance HVAC or glazing system, which may increase initial cost but result in dramatically reduced operating and maintenance costs, is cost-effective or not.

The LCCA must be performed early in the design process while there is still time in the Project schedule to refine the design to ensure a reduction in life-cycle costs. Design teams must strive for the best possible life-cycle cost-effective performance, which may be significantly better than the baseline, be it ASHRAE 90.1, MA Stretch Code, or other. The purpose of the LCCA methodology is to identify and compare life-cycle cost-effective building systems that will in total achieve the energy goals and requirements of the Project. LCCA and whole-building energy simulation work together to inform the resulting savings and provide the information for the required narrative.

An LCCA is required for the following:

1. Systems contributing to energy footprint of the building/Project. Energy-consuming systems include, but are not limited to, the major systems impacting the whole-building/Project energy simulation, HVAC, lighting, service water heating, process/equipment use, and the building envelope.
2. Renewable energy generating systems (for example, photovoltaic panels).
3. LCCAs comparing at least three individual component or system alternatives must use 40 years from the beginning of beneficial use. Include the appropriate replacement and salvage values for each of the other alternatives. Acceptable alternatives must not degrade the overall building performance. They must be sound technical alternatives that are comfort-compatible, are reliable,

locally serviceable, user friendly, ensure safety and at a minimum are neutral regarding occupant productivity and design aesthetics.

4. The LCCA must treat the entire building as a system so that the interactions among the building enclosure, the lighting system, the plug and process loads, and the HVAC system are properly accounted for. The goal is to optimize the building envelope and daylighting to allow for the simplification and downsizing of mechanical and electrical equipment to reduce life-cycle costs.

Perform this analysis based on the actual conditions expected over the life of the facility including anticipated occupancies, scheduled hours of operation, and process loads. Include the following:

- Actual location utility costs and utility escalation rates for the actual sources used
- Realistic energy usage and efficiencies
- Realistic operations, maintenance, repair, and replacement costs
- All costs or savings associated with recovered energy, solar thermal, solar photovoltaic energy, and other renewable or waste heat applications
- Credit any alternative funding such as rebates, incentives, etc. in the LCCA

Design team must provide the LCCA to the S+R Admin for inclusion in the SRMP and to the MBTA PM for record. The electrical and mechanical engineers must contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to LEED BD+C v4/4.1: EA Prerequisite, *Fundamental Commissioning and Verification, and EA Credit: Enhanced Commissioning; EA Credit: Optimize Energy Performance.*

A.2.1.3.3 Energy Metering

The Project must install metering devices in accordance with LEED Energy & Atmosphere Prerequisite for Energy Metering as well as the Credit for Advance Metering. Systems metering is in alignment with MBTA goals for monitoring facility energy and water use. Meters must link to the MBTA BAS and the Enterprise Energy Management System, ultimately contributing to the overall MBTA Energy Scorecard. Energy metering will be installed for the building's whole-building energy sources as well as any circuit *and/or* individual energy end use that represents 10% or more of the total annual consumption of the building.

Additional metering requirements are identified in Section 3.5, Electrical, and Section 3.6, Plumbing, in the main *Design Guideline for Bus Maintenance Facilities*.

Refer to LEED BD+C v4/4.1: EA Credit, *Optimize Energy Performance; EA Prerequisite: Building-Level Energy Metering and Credit: Advanced Energy Metering*.

A.2.1.3.4 Energy Simulation and Energy Conservation Report

For all energy-consuming projects, design teams must provide an ECR that summarizes the building/Project anticipated energy consumption and describes the energy conservation measures (ECMs) considered for the Project. The ECR is related to but separate from the CRP described in **Section A.2.1.2.1**. Descriptions of the ECMs must include relevant calculations showing anticipated savings as well as the reasoning for any strategies not implemented. Content must be inclusive of all site and building design measures that contribute to overall savings, both passive and active. Planning for and tracking of the ECMs will enable the MBTA to expand their energy-saving strategy and empower successive projects to benefit from a collection of best practices and lessons learned.

The design team must provide the ECR to the S+R Admin for inclusion in the SRMP and to the MBTA PM for record.

Refer to LEED BD+C v4/4.1: EA Credit, *Optimize Energy Performance*.

A.2.1.4 Water Performance

WPP: This plan must highlight strategies engaged to reduce demand for and further conserve potable water by the Project as well as address quality concerns, and must include but is not limited to the following:

- Exterior Water Use
- Sanitary fixtures
- Process water use, by HVAC equipment and by vehicle wash systems

The WPP must identify potential, viable alternative sources, including rainwater, cooling coil condensate capture, and recycling of wash water.

The plan should be organized to show water balance between supply sources and demands and compare building water balance with a baseline code-compliant building. Design team members must contribute to the documentation; the S+R Admin is responsible for guiding the process.

A.2.1.5 Commissioning Activities (Design Phase)

Cx is often discussed in the context of the construction phase of a project; there are many crucial aspects of Cx, however, that must occur during the planning and design phases of a project to maximize benefits for the Project Team, and especially long-term for the owner. Early engagement of a CxA contributes to the Project's overall integrative process and ensures that the architects' and engineers' designs meet the OPR. Each project must engage a third-party CxA (independent of the design and construction teams) by or before the 30% design phase; ideally, the CxA would work with the MBTA prior to design team engagement to best identify specific Project design and performance requirements. It must be noted that early engagement of a CxA is a requirement for projects pursuing LEED certification.

Prior to or during the preliminary design phase, the CxA must do the following:

- Develop the OPR: Include the overall goals of the Project; quality standards; operational and warranty requirements; training expectations (BOD, equipment level, and system level); cost considerations; and measurable performance criteria.
- Develop the BOD: Describe how each element of the Operating Performance Report will be implemented in the design.
- Participate in Focused Design Review: Determine if there are systematic errors and to ensure that training and warranty requirements meet expectations, not to fully check the design accuracy of the design team.
- Develop Cx Specification: Define the administrative requirements of the Cx process and the CxA involvement with the contractor and is typically included in the General Conditions. Design teams must edit specification content to fit the Project. Fully independent third-party CxA must be used. All systems that require Cx must be included in the Project specification.
- Develop the Cx Plan: Describe responsibilities of the Cx team members, schedule, and activities through each phase of the Project delivery, documentation requirements, communication channels, and procedures for documenting and resolving situations when verification does not meet the

Owner's Project Requirements. Cx plan includes identification of systems to be checked during prefinal and final inspection.

- Develop the M&V Plan: Define the method for evaluating and tracking the building energy performance. Define system performance indicators, system alerts, and actions needed to ensure ongoing sustainable and resilient system performance.

Refer to *LEED EA Prerequisite and Credit for Fundamental Commissioning and Verification and Enhanced Commissioning*.

A.2.1.6 Materials and Resources Performance

The design team must identify a pool of qualifying materials and products from which the contractor can choose in alignment with Project procurement regulations. The MPP must contain tracking mechanisms developed by the design team as appropriate to each project. The working files must be provided to the contractor for use throughout construction. As part of construction closeout, the tracking information—including supporting vendor/manufacturer product documentation like cut sheets, website snapshots, manufacturer letters, and certificates—must be provided in electronic format in the final MPP (unless the Project authority dictates otherwise) to the S+R Administrator for inclusion in the SRMP and the MBTA PM for record.

The MPP must address each of the topics in **Sections A.2.1.6.1** through **A.2.1.6.6**.

A.2.1.6.1 Use of Recycled Materials

Design teams must incorporate recycled materials use into drawings and specifications for the contractors to implement. Using recycled, reused, and renewable materials and products—including existing structures and materials onsite—reduces demand for virgin materials and the embodied carbon emissions and environmental degradation attributed to their extraction and processing. Using these materials also reduces waste and supports the market for recycled and reused materials, especially at local levels.

Refer to *Envision Sustainable Infrastructure Framework (v3), RA1.2 Use Recycled Materials; RA1.5 Balance Earthwork On-Site;* and LEED BD+C v4/4.1: MR Cr. 3 *Building Product Disclosure and Optimization - Sourcing of Raw Materials*.

A.2.1.6.2 Material Content, Product Transparency, Responsible Sourcing, and Reuse Potential

Design teams must provide narratives in the MPP describing how they have enabled the contractor to meet requirements and goals as described in the following list. Documentation must identify and track qualifying material criteria identified and specified during the design phase; the contractor must then revise the MPP content to identify how they intend to execute the design criteria.

For all products, the MPP must give preference to products that can robustly demonstrate the optimum combination of the following:

- Project teams must provide a plan for consideration of the following additional measures, and implement product use when determined it is not otherwise detrimental to the Project; these attributes may overlap with other requirements and goals, and may be included in multiple tracking categories if the product displays multiple attributes:
  - At least 50% (by cost) of all materials and products in the Divisions identified should, in combination, conform to one or more of the following:
    - At end of life, are more readily reusable or recyclable per manufacturer's documentation.

- Can be comprehensibly sourced locally within 500 miles of the Project site, with supporting documentation of material extraction, manufacturing, and purchase locations. Meeting this requirement must not conflict with any applicable Federal Transit Administration procurement regulations.
- For timber (and timber based) products, the MPP must give preference to products that can robustly demonstrate one of the following:
  1. Forest Stewardship Council certification
  2. Programme for the Endorsement of Forest Certification scheme
  3. Sustainable Forestry Initiative certification
  4. American Tree Farm System
  5. CSA Sustainable Forest Management Standard Z-809
  6. Another certification/assurance that is accepted nationally as an acceptable alternative to one of these goals
- Environmental Product Declarations that conform to ISO 14025, 14040, 14044, and EN 15804 or ISO 21930 and have at least a cradle-to-gate scope
- The end-use product has a published, complete Health Product Declaration with full disclosure of known hazards in compliance with the Health Product Declaration Open Standard
- Responsible Stone Sourcing: All dimensional stone products used within the Project must be certified under the Natural Stone Council ANSI/NSC 373 Standard by quarries and/or manufacturers, per Living Building Challenge v4 – p 53.

A.2.1.6.3 Reduce Volatile Organic Compounds (Low-emitting Materials)

The Project Team must specify materials and products that have obtained certifications or include labels that demonstrate compliance with cited minimum requirements of LEED BD+C v4/4.1 IAQ Credit for Low-Emitting Materials.

Project teams must include targeted materials and tracking mechanisms in the MPP to enable the contractor to meet the requirements. Project teams are encouraged to exceed the minimum requirements. Individual product waivers may be pursued by the contractor as appropriate for specialty applications with limited product availability. Requests for variances must include original requirements, description of reason for variance including reasonable efforts made to identify compliant product, product substitution options, and final approval from the S+R Administrator and MBTA PM.

A.2.1.6.4 Hazardous Material Reduction

The Project Team must specify indoor and outdoor materials, products, and installation processes that reduce or eliminate exposure to hazardous heavy metals and phthalates (e.g., lead, mercury, cadmium, chromium IV, and antimony) found in building materials.

For all newly installed building materials, at minimum 20% (by cost) of the following building products and material types contain less than 100 parts per million (ppm) added lead:

- Doors and door hardware
- Ductwork
- Conduits
- Metal studs

- Mirrors/glass
- Roofing or flashing
- Brass cooler drains, pumps, motors, and valves
- Vinyl blinds or wallcovering

For all newly installed furnishings and furniture (including textiles, finishes and dyes), all components that constitute at least 5% (by weight) furniture or furnishing assembly meet the following thresholds for material content:

- Mercury less than 100 ppm
- Cadmium less than 100 ppm
- Antimony less than 100 ppm
- Hexavalent chromium in plated finishes less than 1,000 ppm

All newly installed electrical components: fire alarms, meters, sensors, thermostats, and load break switches, meet the following maximum concentration value per listed substance:

- Lead (Pb): less than 1,000 ppm
- Mercury (Hg): less than 1,000 ppm
- Cadmium (Cd): less than 100 ppm
- Hexavalent Chromium: (Cr VI) less than 1000 ppm

A.2.1.6.5 Embodied Carbon Materials

MPP must also identify materials cross-referenced with the materials portion of the CRP.

A.2.1.6.6 Materials and Product Plan Summary

The resulting composition must be provided to the Project S+R Administrator for inclusion in the SRMP and MBTA PM for record. The construction team will add documentation of actual materials installed and coordinate updates with the S+R Coordinator.

Refer to *Envision Sustainable Infrastructure Framework (v3)*, *RA1.1 Support Sustainable Procurement Practices*; and LEED BD+C v4/4.1: MR Cr 1 *Building Product Disclosure and Optimization – Environmental Product Declarations*; MR Cr 2 *Building Product Disclosure and Optimization – Sourcing of Raw Materials*; MR Cr 3 *Building Product Disclosure and Optimization - Material Ingredients;* MR Cr 4 *Building Product Disclosure and Optimization - Material Ingredients*.

A.2.1.7 Indoor Environmental Quality Performance

A.2.1.7.1 Indoor Air Quality Performance

Real-time air monitoring is necessary to address deviations in indoor air quality metrics and minimize occupant exposure to pollutants. Air quality monitoring and quality control education can help individuals identify deviations and correct air quality issues as they arise. Indoor air monitors must be implemented with the following requirements:

1. Monitors measure at least three of the following within a regularly occupied or common space in the building:
   a. Particulate matter $(PM)_{2.5}$ or PM_{10} (accuracy 5 micrograms per cubic meter [μg/m³] + 15% of reading at values between 0 and 50 μg/m³).
   b. Carbon dioxide (accuracy 50 ppm + 3% of reading at values between 400 and 2,000 ppm).
   c. Carbon monoxide (accuracy 1 ppm at values between 0 and 10 ppm).
   d. Ozone (accuracy 10 parts per billion [ppb] at values between 0 and 100 ppb).
   e. Nitrogen dioxide (accuracy 20 ppb at values between 0 and 100 ppb).
   f. Total VOCs (accuracy 20 μg/m³ + 20% of reading at values between 150 and 2000 μg/m³).
   g. Formaldehyde (accuracy 20 ppb at values between 0 and 100 ppb).
2. Monitor density is minimum one per floor or one every 3,500 feet, whichever is more stringent. Monitors are sited at locations compliant with the following requirements:
   a. Between 3.6 to 5.6 feet above the finished floor at locations where occupants would typically be seated or standing.
   b. Sampling points must be at least 3.3 feet away from doors, windows, and air supply/exhaust outlets.
3. Measurements are taken at intervals of no longer than 10 minutes for particulate matter and carbon dioxide and no longer than one hour for other pollutants.
4. Data are analyzed for regularly occupied hours (e.g., median, mean, 75th, 95th percentile) and documented.
5. Monitors are recalibrated or replaced annually, with documentation attesting to their calibration or replacement.

Environmental Measures Display

Real-time display of air pollutants measured by air quality monitors mentioned in **Section A.2.1.7.1** must be made available to occupants through one of the following:

1. At least one display is prominently positioned at a height of 3.6 to 5.6 feet per 10,000 sf of regularly occupied space.
2. Required data are hosted on a website or phone application accessible to occupants. At least one visible sign is positioned per 10,000 sf or regularly occupied space indicating where the data may be accessed.

Air Quality Education

A labeling system (e.g., colors or symbols) must be clearly displayed next to each monitor screen used for air quality monitoring. Information about health effects must be shown in relation to a range of concentrations of air pollutants monitored as listed in **Section A.2.1.7.1**. An explanation of the labeling system must be provided.

Design team members must contribute to the documentation; the S+R Admin is responsible for guiding the process. This information must be included in the overall SRMP and submitted to the MBTA PM for review and approval.

A.2.1.7.2 Daylight and Views

Compile all daylighting and views documentation and submit in final electronic format to the S+R Administrator for inclusion in the SRMP, and MBTA PM as part of the design closeout phase. Include a summary narrative outlining the outcomes of these exercises.

Refer to LEED BD+C v4/4.1: IEQ Credit: *Daylight; IEQ Credit: Quality Views*

A.2.1.8 Interior and Exterior Quality of Life

A.2.1.8.1 Accessible, Inclusive, Universal Design

All projects must refer to the following best practice guidance as applicable to each project type; the design team must include considerations for both temporarily and permanently affected individuals, those with both seated and standing height challenges, and other disabilities that can affect individuals in varying ways or at varying times:

- International Organization for Standardization (ISO) 21542:2011, Building Construction: Accessibility and Usability of the Built Environment
- BS 8300-1:2018, Design of an Accessible and Inclusive Built Environment, Part 1: External Environment: Code of Practice
- BS 8300-2:2018, Design of an Accessible and Inclusive Built Environment, Part 2: Buildings: Code of Practice
- Draft prEN 17210, Accessibility and Usability of the Built Environment, Functional Requirements
- Building for Everyone: A Universal Design Approach, Centre for Excellence in Universal Design, 2012

The following features must be integrated to the maximum extent possible as appropriate to each project type after projects have met required minimum project criteria from the Americans with Disabilities Act Accessibility Guidelines and the MAAB 521 CMR:

1. Accessibility features related to horizontal and vertical site circulation:
   - Include resting areas with seating at various heights, including seating with back rests and without arm rests
   - Provide accessible routes 43 inches in width, at minimum
   - Design the site with open sight lines to and from entries
2. Accessibility features related to the use of a facility:
   - Doors (regularly used pedestrian entry) and elevators, window blinds, indoor lighting controls, trash/recycling bins: Offer hands-free operation (through foot, voice, sensor or personal electronic device) or implement other design strategies to avoid hand operation
   - Install 36-inch wide doors, at minimum, in all occupied spaces
   - Provide circulation paths 20% wider than required, at minimum
   - Increase clear floor space at appliances and fixtures to 30 by 52 inches, at minimum
   - Increase the size of turning space to 72 inches in diameter, at minimum

3. Accessibility features related to sanitary accommodation:
   - Restroom(s) with an assistance alarm accessible by those who use wheelchairs, at least one of which is a gender-neutral facility.
   - All water bottle fillers, water faucets, soap and paper towel dispensers: Offer hands-free operation (through foot, voice, sensor or personal electronic device) or implement other design strategies to avoid hand operation.
4. Orientation and wayfinding:
   - Clear information and legible and easily understood signage, including availability in different languages where appropriate to the asset location.
   - Use of visual contrast and color to facilitate orientation and navigation, to provide warnings about potential hazards, and to facilitate reading of information and signs.
5. Assistive technologies:
   - Hearing enhancement system(s) (such as induction loop) at service or reception counters and in rooms and spaces used for meetings, lectures, classes, or films.
   - Audible information systems.
   - Visual alarm systems.
   - Height adjustable desks, adjustable height counters (with fixtures, where applicable), and accessible height sales and service counters.
   - Voice or touch screen operated controls for devices and systems affecting occupancy of the space and user comfort, including but not limited to, lighting, window shades, and thermostats.

Through thoughtful incorporation of accessible and Universal Design, projects can establish an inclusive and enabling community where people of all abilities can effectively and easily access, use, and engage with a space.

Compile all Universal Design documentation mentioned in this section and submit in final electronic format to the S+R Administrator for inclusion in the SRMP, and MBTA PM as part of the design closeout phase. Design team members must contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to LEED BD+C v4/4.1: *Pilot Credits, Inclusive Design* (USGBC 2020f).

A.3 GENERAL RESILIENCE REQUIREMENTS

The general resilience project requirements are structured as follows:

Section A.3.1: Resilience framework for bus maintenance facility design

Section A.3.2: Identified disruptors (natural hazards) that can impact physical assets and infrastructure, operational capacity, public health and safety, financial stability, and environmental quality and affect the ability for bus maintenance facilities to maintain critical functionality

Section A.3.3: Overall resilience performance goals to protect assets/infrastructure and minimize disruption under specific conditions or thresholds

Section A.3.4: Framework for designers to evaluate operational capacity to meet performance goals and establish acceptable downtime with MBTA stakeholders

Section A.3.5: Sample resilience adaptation strategies that designers can incorporate into both physical design and operational considerations to meet performance goals

A.3.1 Resilience Framework

The resilience framework (**Figure A-1**) for MBTA bus maintenance facilities design focuses on strengthening and maintaining critical functionality today and in the future by using physical strategies and operational processes. An existing system (non-resilient) and a resilient system will function differently before and after being affected by a disruptor, such as a natural hazard or pandemic. Refer to **Section A.3.2** for descriptions of disruptors. A resilient system will maintain critical functionality, have a reduced recovery time during and after the disruption, or have the ability to adapt and improve over time. In contrast, a non-resilient system is at risk of reduced functionality and lengthy disruption as a result of prolonged system downtime and recovery.

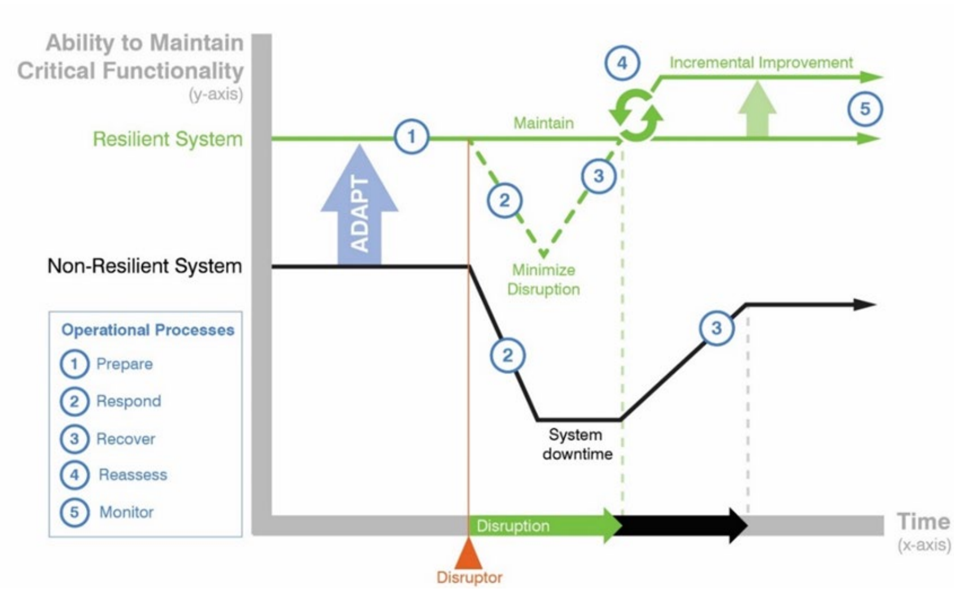


Figure A-1. Resilient Framework—System Ability to Maintain Critical Functions/Minimize Disruption

As shown on **Figure A-1**, a resilient system is adapted so that it has a higher ability to maintain critical functionality before, during, and after disruptions (natural hazard, pandemic, etc.). The performance goals and specific conditions under which critical functions will be maintained are defined in **Section A.3.3, Resilience Performance Requirements and Goals**, for each disruptor. If the design threshold to a disruptor is exceeded, a resilient system will still manage the effects from the disruptor such that downtime is minimized with a quick recovery. This is discussed further in **Section A.3.4, Identifying Acceptable Downtime and Operational Capacity**, and **Section A.3.5, Resilience Adaptation Strategies**.

Adapting to a resilient system is often accomplished during design of the asset, but designers will also consider the resulting operational processes that affect the ability to maintain critical functionality as part of design decisions:

Prepare the system for different disruptors and disruption scenarios

Respond to the disruptor to minimize damages and system downtime

Recover assets/infrastructure to pre-disruptor functionality

Reassess performance and identify areas for improvement post disruption

Monitor operational capacity and update processes as needed.

A resilient system will also consider how the design may adapt to future conditions incrementally over time. Physical adaptation strategies and operational processes can provide an **incremental improvement** over the original design, to help manage the uncertainty associated with future disruptors and conditions.

A.3.1.1 "Design Beyond Site" or "Interdependency"

Bus maintenance facilities operate within a wider system of bus routes, transportation corridors, the public realm, and service provision for all users, particularly vulnerable populations[1] as they are often most reliant on bus service. The critical functionality of a bus maintenance facility as a single asset is important on its own, but more so, due to its interdependency on the transportation system. Because the critical functionality of a single asset depends on and influences other aspects of the system, it also impacts services to passengers and employees across multiple municipalities and regions. A resilient system recognizes design and operational considerations and context beyond the site and emphasizes how a single asset interacts with the system. It provides tools to limit disruption to maintenance facilities, the broader system, and ultimately, to the users it serves.

A.3.2 Resilience Disruptors

Bus maintenance facilities are vulnerable to disruptors, which include natural hazards like extreme storms, precipitation, and temperatures and coastal flooding, as well as manmade disasters and disease outbreaks or pandemics. Many natural hazards are predicted to intensify and occur more frequently with climate change. As bus maintenance facilities are anticipated to function for decades, climate change considerations must be incorporated into the design.

Major resilience disruptors are summarized in **Table A-4.** Natural and climate hazards are divided into four main categories (extreme storms, coastal flooding, extreme precipitation, and extreme temperatures) with several types of extreme weather events falling into each. The Disease/Pandemic category includes preparations for possible occurrence of future disease outbreaks and pandemics that can be folded into design and operational plans by considering different types of transmission pathways and reducing possible exposure. Before or during design, several datasets may be useful to gather and inform the design alternatives.

The Massachusetts SHMCAP is the main source for the Historic Frequency and Increased Exposure Areas columns in **Table A-4**. Although the information provided is for statewide occurrences, it is also relevant to MBTA service areas. The historic frequency of a disruptor at a particular site may be higher or lower based on the geographic location. Some of the Increased Exposure Areas listed may specifically overlap with the MBTA bus service areas, but since resilience requires a regional approach, areas with increased exposure outside of the bus service areas have been also included. A regional resilience consideration could be the need to use buses as a commuter rail backup and the commuter rail extends beyond the regular bus service area. For more information on the historic frequency, statewide impacts, regional climate change trends, and other data related to natural hazards, please refer to The Massachusetts Climate Change Clearinghouse (Resilient MA).

[1] The SHMCAP (2018) states that a range of factors can result in the increased vulnerability of certain populations. Individuals who have less physical and socioeconomic resiliency due to factors such as age, mobility, access to transportation, income level, race, or health status are more vulnerable to the impacts of natural hazards and climate change. Vulnerable populations include Environmental Justice populations, which include communities that have an annual median household income that is equal to or less than 65 of the statewide median ($62,072 in 2010); or 25% or more of the residents identify as a race other than white; or 25% or more of households have no one over the age of 14 who speaks English only, or very well.

Table A-5 outlines impact categories and corresponding considerations linked to the major resilience disruptors that must be addressed in the facility design. Natural hazards and disease outbreaks can impact physical assets and infrastructure, operational capacity, public health and safety, financial stability, and environmental quality. At times, the impacts are interlinked and cumulative. For example, equipment damage to physical assets may cause operational capacity disruptions.[1]

Table A-4. Resilience Disruptors – Historic and Future Trends

Categories and Icon	Subtypes	Historic Frequency Estimates—Statewide[a]	Regional Climate Change Trends[a]	Increased Exposure	Data Source
Extreme Storms	• Snowstorms • Ice storms • Tornado • Nor'easter • Wind • Hurricane	• 63 tropical storms/hurricanes between 1842 and 2016 • 1 disaster declaration from severe storm every 9 years • 1 to 2 tornadoes per year • 44 high wind events per year on average from 2008 to 2017 • 20-30 thunderstorm days per year • Nor'easters occur annually • 1 high-impact snowstorm per year	• Increased intensity and severity	• Coastal storms: East-facing coastal areas • Snow: Boston has experienced significant snowfall (e.g., 2015)	• SHMCAP Maps • Local Hazard Mitigation Plans • NOAA Storm Center Database[b]
Coastal Flooding	• Sea-level rise • Coastal surge	• 1 day of coastal flooding per year on average from 1950 to 2017	• 4.3 feet of sea-level rise by 2070[c]	• Coastal areas • Climate Ready Boston Map Explorer[d] – view High Tide and Coastal Flood Risk Maps	• FEMA FIRMs • MC-FRM[c]
Extreme Precipitation	• Riverine flooding • Stormwater • Urban flooding	• State experienced a disaster declaration flood event once every 3 years based on events from 1954 to 2017 • Stormwater flooding frequency is site-specific and may correspond to impervious cover or undersized/outdated infrastructure	• Increase in extreme precipitation events • Increase in high intensity, short duration rainfall events	• FEMA Flood Zones • Areas with high amounts of impervious cover or undersized drainage • Climate Ready Boston Map Explorer[d] – view Stormwater Flooding	• FEMA FIRMs • NOAA Atlas 14 precipitation data • Localized Constructed Analogs
Extreme Temperatures	• Heat waves/days over 90 degrees • Polar vortex/cold snaps/days under 32°F	• 1.5 extreme cold events (-15°F for at least 3 hours) and 2 extreme heat events (3 days over 90°F) annually per year on average in the last 2 decades	• Increase in days above 90°F annually • Fewer days below 32°F, but still at risk for polar vortex	• Urban heat islands • Climate Ready Boston Map Explorer[d] – view Heat	• NOAA National Climatic Data Center • Multivariate Adaptive Constructed Analogs

Categories and Icon	Subtypes	Historic Frequency Estimates—Statewide[a]	Regional Climate Change Trends[a]	Increased Exposure	Data Source
Disease/ Pandemic[d]	• Not applicable	• Zoonotic/ vector transmission • Airborne transmission • Direct contact transmission • Contamination	• Undocumented at this time	• Confined areas • High contact surfaces	• Center for Disease Control

[a] Commonwealth of Massachusetts, 2018.
[b] NOAA, n.d.
[c] Massachusetts Coast Flood Risk Model (MC-FRM)
[d] City of Boston, 2020a.
[e] Information not provided in SHMCAP (Commonwealth of Massachusetts 2018).

Notes:
°F = degree(s) Fahrenheit
FEMA = Federal Emergency Management Agency
FIRM = Flood Insurance Rate Map
MC-FRM = Massachusetts Coast Flood Risk Model
NOAA = National Oceanic and Atmospheric Administration

Table A-5. Resilience Disruptors – Physical and Operational Considerations

Impact	Example Risks	Example Consequences from Impacts	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Assets and Infrastructure Threats	Equipment Damage	• Critical assets' condition, location, power source, and elevation • Critical component replacements and storage locations	Yes	Yes	Yes	Yes	No
	Loss of Power Supply	• Typical/average energy demand • Peak energy demand • Critical asset energy usage • Energy transmission points • Backup power supply options (generators, fuel sources, uninterruptable power supply, batteries, etc.)	Yes	Yes	Yes	Yes	No
	Accelerated Deterioration of Assets	Equipment prone to overheating	No	No	No	Yes	No
		Possible structural damages from exceeded loads	Yes	No	No	No	No
		Corrosion of critical assets	Yes	Yes	Yes	Yes	No
Operational Capacity Threats	Reduced Workforce Capacity	Trained staff availability and capacity to reach site	Yes	Yes	Yes	Yes	Yes
		Preparation time and available resources (deploy flood barriers, move buses from parking lot, etc.)	Yes	Yes	Yes	Yes	No
		Response time and resources (bring in supplies/ batteries as needed, de-ice, snow removal, additional cleaning)	Yes	Yes	Yes	Yes	Yes
		Recovery time and resources (decontaminate, fix damages)	Yes	Yes	Yes	Yes	Yes

Impact	Example Risks	Example Consequences from Impacts	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Operational Capacity Threats (continued)	Service Discontinuity	• Backup service plans (use other maintenance facilities, operate at reduced capacity) • Additional capacity to support other facilities that are offline • Manual backup plans for critical functions during loss of power	Yes	Yes	Yes	Yes	No
		Snow removal site/plan	Yes	No	Yes	No	No
		Supplies to charge extra batteries or more frequently charge batteries during peak demand or during periods of reduced battery life	Yes	No	No	Yes	No
	Communication Breakdown	• Backup communications and controls	Yes	Yes	Yes	Yes	Yes
Public Health and Safety Threats	Employee Safety	Languages spoken	Yes	Yes	Yes	Yes	Yes
		Material choice (easy to clean)	No	Yes	Yes	No	Yes
		• Sanitizer placement • Ventilation systems with fresh air, filtration, ultraviolet disinfection, etc. • Contactless options	No	No	No	No	Yes
		MBTA employee data and emergency contact information	Yes	Yes	Yes	Yes	Yes
		• Emergency response access • Evacuation routes out of facility • Storm shelter room • Shelter in place preparation	Yes	Yes	Yes	No	Yes
	Mobility	• Backup service • Nearby bikeshare locations • Options for people with disabilities • Existing bike/ped options	Yes	Yes	Yes	Yes	Yes

Impact	Example Risks	Example Consequences from Impacts	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Financial Threats	Maintenance Costs	Increased maintenance as a result of more frequent disruptors	Yes	Yes	Yes	Yes	Yes
	Operating Costs	• Increased cleaning costs • Overtime hours • Utility cost spikes	Yes	Yes	Yes	Yes	Yes
	Emergency Costs	• Increased Insurance costs • Repair costs • Reduced revenue	Yes	Yes	Yes	Yes	Yes
Environmental Threats	Contamination	• Hazardous material storage locations • Impacted building materials • Impacted groundwater/vapor intrusion	Yes	Yes	Yes	No	Yes
	Water Quality	• Site drainage/soil types • Standing water potential	No	Yes	Yes	No	Yes

A.3.3 Resilience Performance Requirements and Goals

The MBTA has faced disruptors in the recent past, including extreme snowfall in 2015, coastal flooding from nor'easters in 2018, and the COVID-19 pandemic in 2020. These events caused damages and downtimes for MBTA services, and future bus maintenance facilities will be designed to be prepared for similar and future events based on climate change trends.

New bus maintenance facilities will be built to current codes and in general are anticipated to function during current extreme weather with minimal damage to the facilities, or minimal disruption to operations fully sheltered inside the buildings, even when conditions outside the buildings are unsafe for staff. The resilience performance requirements are intended to assist designers in creating a resilient facility with little to no disruption to its critical functionality and that is able to quickly recover under future climate conditions. The ability to function under future climate conditions may not be covered under the current codes and going beyond code is expected. In Massachusetts, the RMAT has provided Statewide Climate Resilient Design Standards and Guidelines for designing physical assets. The MBTA is a member of RMAT and was a key stakeholder in developing these statewide recommendations. The S+R Admin will refer to the most recent version of those standards and guidelines by visiting the Resilient MA website and compare the recommended standards to those that are provided in this section, as the RMAT Statewide Climate Resilience Design Standards and Guidelines may be updated over time.

Critical functionality assumes the following overall performance goals are met and may vary based on site-specific needs for structural, electrical, mechanical, plumbing, fire safety, civil/landscaping, and architectural design features:

- A safe workplace (no employee injuries, serious illnesses, and/or deaths)
- A well-informed, trained workforce available to maintain critical functionality
- Minimum building systems stay operational to maintain critical functionality and BAS can function without staff intervention where possible
- Clear, transparent communication to other MBTA facilities and public (as needed)

The specifics surrounding the minimum trained workforces and building systems needed to maintain critical functionality will be established during the design process with input from key MBTA stakeholders. Defining the critical assets and functionality, as well as performance goals and requirements, may follow a similar process as outlined in **Section A.3.4, Identifying Acceptable Downtime and Operational Capacity**, and will be documented in the SRMP. Critical assets and infrastructure are features of the facility necessary to function to support these performance goals, as well as any additional assets or infrastructure identified by the design team and MBTA. These may vary based on the site and design features.

The resilience performance requirements are structured around two thresholds for maintaining critical functionality based on the framework in **Section A.3.1, Resilience Framework**. The specific conditions for each threshold are organized by disruptors as identified in **Section A.3.2, Resilience Disruptors**.

1. The primary threshold is the condition under which critical assets/infrastructure will be designed so that there are minimal or no damages to the asset and critical functionality is maintained with little to no disruption. The primary thresholds are generally based on the standards recommended in RMAT Statewide Climate Resilience Design Standards and Guidelines.
2. The secondary threshold assumes the primary threshold has been exceeded. It is intended to minimize system downtime with limited damages and quick recovery time. Recommended secondary thresholds are provided in the guidelines in **Sections A.3.3.1** through **A.3.3.10** by

disruptor. The acceptable downtime durations and level of critical functionality affected may vary based on the site and role of the facility in the larger MBTA system. The acceptable downtime durations and level of critical functionality will be established as part of the design process with input from key MBTA stakeholders following the guidance in **Section A.3, General Resilience Requirements**. Designers will also need to follow guidance from the MBTA Risk Council and any other guidance specific to a particular facility as provided by the MBTA.

These performance goals and thresholds do not supersede environmental regulations or Massachusetts State Building Codes; where regulations are applicable, the more stringent criteria will govern design. The primary and secondary threshold design values will be documented in the SRMP.

A.3.3.1 Extreme Storms

Critical assets and infrastructure will be designed so that they are not damaged and remain functional before, during, and after extreme storm events, including snowstorms, ice storms, nor'easters, hurricanes, and extreme wind. The Massachusetts SHMCAP provides information on these hazards, some of which are included in the disruptors **Section A.3.2, Resilience Disruptors**. These extreme storms are predicted to intensify and occur more frequently with climate change. As bus maintenance facilities are anticipated to function for decades, the design of critical assets and infrastructure will consider the intensity and frequency of these events today, as well as throughout their projected service life. The RMAT Statewide Climate Resilience Design Standards and Guidelines do not currently provide recommendations for designing for future extreme storms (such as wind or snow), but there are several existing resources that are referenced for the performance thresholds outlined in this section. The most recent editions will be used when available of the following:

- Code Amendments for Sustainability: Modifications to the International Building Code, 2012 Edition, *CAS-B12* (Szoke and Skalko 2015). This resource provides recommended increases in importance factors for wind and snow loads to enhance resilience of structures.
- Massachusetts SHMCAP (Commonwealth of Massachusetts 2018). This resource provides descriptions of damages from snow and hurricanes that were used to identify thresholds for maintaining critical functionality.
  - Referenced in the SHMCAP is the NOAA-produced Regional Snowfall Index. The Regional Snowfall Index includes scaled categories for the severity of snowstorm impacts, which also corresponded to snowfall thresholds. The thresholds for snowfall based on magnitude of snowstorm impact were used in these design guidelines as a basis for resilience performance requirements.
  - Referenced in the SHMCAP are general assessments of damage and risk to public infrastructure due to hurricanes. The damage thresholds for hurricane categories were used in these design guidelines as a basis for resilience performance requirements.

A.3.3.2 Snow, Ice Storms, and Nor'easters

The following performance thresholds will be met in the design of critical assets and infrastructure and operations and maintenance planning with respect to snow/ice storm events and nor'easters:

- **Primary Threshold:** Design critical assets/infrastructure to prevent damages and disruption in critical functionality under the following conditions:
  - Increase design snow and ice loads using the importance factor as outlined in **Table A-6** by American Society of Civil Engineers (ASCE) 7 Risk Category

- 5 inches or less of snowfall within a 24-hour period and/or a commercial power outage lasting the duration of backup generation fuel supply and/or battery systems.

Table A-6. Snow and Ice Importance Factors

ASCE 7 Risk Category	Snow Importance Factor	Ice Importance Factor
I	0.95	0.95
II	1.20	1.20
III	1.25	1.40
IV	1.30	1.40

Source: Szoke and Skalko, 2015.

- **Secondary Threshold:** Design critical assets/infrastructure so that critical functionality is restored within a specific amount of downtime as determined through the process on how to establish disruption times as presented in **Section A.3.5, Resilience Adaptation Strategies**.
  - 10 inches of snowfall within a 24-hour period
  - 30 inches of snowfall within a 72-hour period

A.3.3.3 Extreme Wind and Hurricanes

The following performance thresholds will be met in the design of critical assets and infrastructure and operations and maintenance planning with respect to extreme wind and hurricanes; refer to extreme precipitation for rainfall depths:

- **Primary Threshold:** Design critical assets/infrastructure to prevent damages and disruption in critical functionality during Category 3 hurricane wind speeds.
- **Secondary Threshold:** Design critical assets/infrastructure so that critical functionality is restored within a specific amount of downtime (disruption time) as determined in **Section A.3.5, Resilience Adaptation Strategies**, under Category 4 Hurricane wind speeds.

A.3.3.4 Coastal Flooding

Critical assets and infrastructure will be designed so that they remain functional before, during, and after coastal flooding events. Coastal flooding is predicted to intensify and occur more frequently with climate change. As bus maintenance facilities are anticipated to function for decades, the design of critical assets and infrastructure will consider the intensity and frequency of these events today as well as throughout their service life.

If the site is exposed to coastal flooding based on the RMAT Statewide Climate Resilience Design Standards and Guidelines preliminary climate risk screening output, the following performance thresholds apply in the design of critical assets and infrastructure and operations and maintenance planning:

- **Primary Threshold:** Design critical assets/infrastructure to prevent damages and disruption in critical functionality under the following conditions:
  - Current and future (2070 planning horizon) design flood elevation and duration for a 1% annual exceedance probability coastal flood with at least 2 feet of freeboard

- **Secondary Threshold:** Design critical assets/infrastructure so that critical functionality is restored within a specific amount of time (disruption time) as determined in **Section A.3.4, Identifying Acceptable Downtime and Operational Capacity**, under the following conditions:
  - Current and future (2070 planning horizon) design flood elevation and duration for a 0.2% annual exceedance probability coastal flood
- If wave heights are recommended based on the RMAT Statewide Climate Resilience Design Standards and Guidelines climate standards output, the design flood elevation will include the estimated wave heights, and critical assets will consider current and future wave loads in design.
- If scour and erosion are recommended based on the RMAT Statewide Climate Resilience Design Standards and Guidelines climate standards output, critical assets will consider current and future flood velocities in design.

A.3.3.5 Extreme Precipitation

Critical assets and infrastructure will be designed so that they remain functional before, during, and after extreme precipitation events. Extreme precipitation events are projected to intensify and occur more frequently with climate change, which may result in both stormwater/urban and riverine flooding, depending on the location. As bus maintenance facilities are anticipated to function for decades, the design of critical assets and infrastructure will consider the intensity and frequency of these events today, as well as throughout their service life.

A.3.3.6 Stormwater Flooding

The following performance thresholds will be met in the design of critical assets and infrastructure and operations and maintenance planning:

- **Primary Threshold:** Design critical assets/infrastructure to prevent damages and disruption in critical functionality under the following conditions:
  - Current and future (2070 planning horizon) 24-hour rainfall depth and peak intensity for a 25-year (4% annual exceedance probability) design storm.
- **Secondary Threshold:** Design critical assets/infrastructure so that critical functionality is restored within a specific amount of time (disruption time) as determined in **Section A.3.4, Identifying Acceptable Downtime and Operational Capacity**, under the following conditions:
  - Current and future (2070 planning horizon) 24-hour rainfall depth and peak intensity for a 100-year (1% annual exceedance probability) design storm.

A.3.3.7 Riverine Flooding

If the site is exposed to riverine flooding based on the RMAT Statewide Climate Resilience Design Standards and Guidelines preliminary climate risk screening output, the following performance thresholds apply in the design of critical assets and infrastructure and operations and maintenance:

- **Primary Threshold:** Design critical assets/infrastructure to prevent damages and disruption in critical functionality under the following conditions:
  - Current and future (2070 planning horizon) peak flood elevation and duration for a 1% annual exceedance probability riverine flood with at least 2 feet of freeboard

- **Secondary Threshold:** Design critical assets/infrastructure so that critical functionality is restored within a specific amount of time (disruption time) as determined in **Section A.3.4, Identifying Acceptable Downtime and Operational Capacity**, under the following conditions:
  - Current and future (2070 planning horizon) peak flood elevation and duration for a 0.2% annual exceedance probability riverine flood
- If scour and erosion are recommended based on the RMAT Statewide Climate Resilience Design Standards and Guidelines standards output, critical assets will consider current and future riverine flood velocities in design.

A.3.3.8 Extreme Temperatures

Critical assets and infrastructure will be designed so that they remain functional before, during, and after extreme temperature events, both heat and cold induced. Temperatures, including days over 90°F, are predicted to increase with climate change, but bus maintenance facilities will still be subjected to cold snaps due to the polar vortex in the future. As bus maintenance facilities are anticipated to function for decades, the design of critical assets and infrastructure will consider the intensity and frequency of these events today as well as throughout their service life. Extreme temperatures also affect employee and ridership health and safety, so the conditions will also consider occupancy and environment. It is likely that the extreme temperature coincides with demand response request from the electrical power utility. Demand response will require either a temporary reduction in facility electrical consumption or use of onsite backup power supply.

The following performance thresholds will be met in the design of critical assets and infrastructure, areas that are occupied by employees, and operations and maintenance planning:

- **Primary Threshold:** Design critical assets/infrastructure to prevent damages and disruption in critical functionality, during a demand response event, under the following conditions:
  - Current and future (2070 planning horizon) heatwave annual frequency and average duration.
  - Current and future (2070 planning horizon) cooling degree days and heating degree days.
  - Current and future (2070 planning horizon) days over 90, 95, and 100°F.
  - Current and future (2070 planning horizon) days below 32°F.
- **Secondary Threshold:** Design critical assets/infrastructure so that critical functionality is restored within a specific amount of time (disruption time) as determined in **Section A.3.4, Identifying Acceptable Downtime and Operational Capacity**, under the following conditions:
  - Current and future (2070 planning horizon) events that exceed the primary thresholds for days over 90, 95, and 100°F and days below 32°F by up to 10%.
  - Current and future (2070 planning horizon) cooling degree days and heating degree days that exceed the primary thresholds by up to 10%.

A.3.3.9 Diseases/Pandemic

Critical assets and infrastructure will be designed to remain functional before, during, and after pandemics, such as the COVID-19 virus. Globally, public health risks are expected to increase with climate change.

Please refer to the current and future orders from the Governor’s Office and recommendations from the Center for Disease Control for acceptable performance requirements under pandemic conditions, as well as different phases.

A.3.3.10 Cumulative Disruptions

When one or more disruptors occur simultaneously or consecutively, the consequences may be greater. The ability to maintain critical functionality and to recover may be hindered if multiple disruptions occur simultaneously or consecutively. The design of the facility will consider the ability of the system to maintain critical functionality under the following conditions:

- Two or more disruptors' primary thresholds have been met either simultaneously or consecutively (for example, snowfall exceeding 5 inches in 24 hours followed by extreme rainfall resulting from the 25-year 24-hour design storm depth, or ongoing pandemic/disease risks during a natural hazard event).
- A disruptor's primary threshold condition is met or exceeded over a series of smaller events. For example, snowfall of 4 inches in 24 hours for several days.
- The design team will confer with stakeholders on setting acceptable downtimes and developing plans for cumulative disruptor events that exceed primary thresholds. Please refer to **Section A.3.4, Identifying Acceptable Downtime and Operational Capacity**, for guidance.

A.3.4 Identifying Acceptable Downtime and Operational Capacity

- Operational capacity is defined herein as the availability of workforce and equipment to maintain critical functionality, operate systems, and prepare, respond, and recover from disruptors. Operational capacity is key in establishing acceptable downtime due to a disruptor and creating a plan to effectively mitigate consequences associated with that downtime. The MBTA has several existing resources on operational capacity that will be referenced, such as any guidance provided by the MBTA Risk Council (pending release scheduled after the release of these guidelines). Designers will use the most recent versions of these plans, as they may have been updated since the publication of this document and confer with the MBTA on any other guidance specific to a particular facility.
- The MBTA Snow and Ice Operations Plan (2019-2020) was developed by the MBTA to prepare for, respond to, and recover from winter weather and storms. This plan ties together the policies, resources, and practices of all MBTA departments and packages them into a functional reference used to implement snow and ice related activities. By planning and implementing an organized, detailed, and flexible approach to snow and ice operations, the MBTA aims to mitigate, and where possible eliminate, winter weather service and safety impacts to customers and employees.
- The purpose of the MBTA Severe Weather Operations Plan (2020) is to provide information, resources, and references that will enable the MBTA to effectively prepare for a hurricane or similar severe weather event. This includes MBTA operational department preparedness, response, and recovery activities.
- The purpose of the COVID-19 Pandemic Operational Guidance (FEMA 2021) is to describe the anticipated challenges to disaster operations posed by COVID-19 and the planning considerations in light of these challenges.

Following review of these existing documents, designers will undertake the following steps to identify acceptable downtime and operational capacity to inform selection of design strategies to meet the performance goals under the secondary threshold conditions:

1. **Identify Key Stakeholders**: This may include MBTA staff from operations and control center, bus maintenance, bus operations, security and emergency management, environment and energy, engineering, and other departments, as necessary. This may also include private, local, and regional partners that support emergency preparedness, response, and/or recovery efforts.

2. **Identify existing operational capacity**: Designers will identify the existing available workforce and equipment necessary to maintain critical functionality under fair-weather conditions, as well as the primary and secondary threshold conditions defined within **Section A.3.3, Resilience Performance Requirements and Goals**. This information will be assembled and documented for MBTA review, and will likely include but is not limited to the following types of questions:
   a. **Workforce:** What is the minimum workforce needed to maintain critical systems at the bus maintenance facility? What is the potential risk to the workforce from the disruptors? What type of training is necessary to maintain critical systems? What is the availability of the trained workforce under both fair-weather and disruptor conditions?
   b. **Equipment:** What is the minimum equipment needed to maintain and operate critical systems? What is the potential risk to equipment from the disruptors? What backup equipment is available to maintain and operate critical systems if the equipment is damaged/inoperable? What is the availability and capacity of the backup equipment? How soon can the backup equipment be deployed?
   c. **Communications:** What are the proposed communication systems necessary to maintain and operate critical systems? What is the potential risk to communications from disruptors? What backup communications are available in the event of an emergency?
   d. **Plans**: What are the existing plans for emergency preparedness and response? How do the plans relate to the proposed design of the bus maintenance facility and disruptors? Do other facilities rely on the bus maintenance facility in the event of an emergency? Does the bus maintenance facility rely on other facilities in the event of an emergency?
   e. **Identify the consequences associated with disruption of critical functionality**: Designers will work with key stakeholders to identify the range of consequences associated with disruption of critical functionality for the bus maintenance facility. Refer to **Table A-7** for example consequences. Designers will identify the maximum acceptable downtime based on these consequences and associated disruptors.

Establish acceptable downtime conditions for disruptors: Following review of operational capacity considerations, designers will propose acceptable downtime conditions for disruptors for MBTA review and acceptance. Designers will then continue to identify design strategies as outlined in **Section A.3.5, Resilience Adaptation Strategies**, that meet the primary and secondary threshold performance requirements.

A.3.5 Resilience Adaptation Strategies

- Both operational and physical design strategies will be considered to meet the performance goals identified in **Section A.3.3, Resilience Performance Requirements and Goals**. The resilience adaptation strategies presented in this section are categorized into operational and physical as follows: **Operational Strategies**: Prepare, Respond, Recover, Reassess, Monitor
- **Physical Strategies**: Protect, Accommodate, Retreat

Physical strategies are focused on assets and infrastructure associated with the bus maintenance facility design, while operational strategies focus on the considerations to protect the safety of MBTA system users and workers surrounding disruptor events. The two will be considered together in design and communicated in the SRMP and Cx activities. Physical and operational strategies are linked by the concept of adaptation, through which systems become more resilient to and better prepared for future conditions over time. Physical strategies will still consider the prepare, respond, recover, reassess, and monitor steps of the Resilience Framework. For example, a physical flood barrier will be inspected before and after a flood event. Each adaptation strategy is also linked to a hazard discussed in **Section A.3.2, Resilience Disruptors**.

Strategies can and will mitigate multiple hazards where possible for maximum effectiveness. Adaptation strategies can also help manage the uncertainty of planning for additional unknown disruptors in the future in providing flexible pathways and incremental approaches to design. For example, a flood barrier could be designed to accommodate additional levels of protection over time. Please refer to the RMAT *Statewide Climate Resilience Design Standards and Guidelines* for additional considerations associated with planning flexible and adaptive designs.

A.3.5.1 Physical Resilience Strategies

When considering design strategies, refer to the resilience performance requirements and goals in **Section A.3.3, Resilience Performance Requirements and Goals**. Practitioners will refer to discipline-specific guidelines related to structural; civil/landscape; mechanical, electric, plumbing; landscape architecture; and facility layout in Section 3, Site and Building Requirements, of the main *Design Guideline for Bus Maintenance Facilities*, to meet discipline-specific requirements and recommendations for operations.

In addition to meeting the performance goals, the strategies can also provide co-benefits related to societal, environmental, and economic considerations. Refer to **Section A.3.5.3, Resilience Co-Benefits**, for more information on representative co-benefits. **Table A7** shows the physical resilience strategies by disruptor.

Table A-7. Physical Resilience Strategies by Disruptor

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Retreat	General	Relocate assets out of flood zones and vulnerable locations if possible.	Yes	Yes	Yes	No	No
		Elevate critical assets above design flood elevations.	Yes	Yes	Yes	No	No
Protect	General	Secure elements that could erode or become debris and damage other assets or impact operations due to a storm event.	Yes	Yes	Yes	No	No
		Seal and insulate elements that are common conduits for air and water entry.	Yes	Yes	Yes	Yes	Yes
		Install adequate shading structures and shelter for site occupants.	No	No	No	Yes	No
	Site/Civil	Implement backflow preventer valves and sump pumps with water level sensors.	No	Yes	Yes	No	No
		Design for overland relief away from critical civil/site features for extreme flows in excess of storm conveyance system capacity.	No	Yes	Yes	No	No
		Design site plan for incorporation of increased sanitary stations and space for social distancing.	No	No	No	No	Yes
	Architectural	Storm shelter rooms per International Code Council: Standard for the Design and Construction of Storm Shelters (ICC 500).	Yes	No	Yes	No	No
		FEMA Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms (P-361).	Yes	No	Yes	No	No
		Include redundancy in design to prevent further compromising critical functionality of mechanical, electrical, and communication systems.	Yes	No	No	No	No
		Building features that are not located above the base flood elevation will be designed to withstand the corresponding hydrostatic pressure or protected from the flood hazard.	No	Yes	No	No	No

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Protect (continued)	Architectural (continued)	Design mitigation for airborne pathogens as part of air flow and space usage strategy. Improving health performance is allowed to take precedence over energy efficiency.	No	No	No	No	Yes
	Structural	Provide permanent site perimeter protection from floodwater.	No	Yes	Yes	No	No
		Reinforce exposed structural elements to resist direct flood action and hydrostatic pressures.	No	Yes	No	No	No
		Design and construct deep foundations in flood zone.	No	Yes	No	No	No
		Dry floodproof and reinforced walls.	No	No	Yes	No	No
		Install permanent flood barriers around site to block flooding.	No	No	Yes	No	No
	Mechanical	Provide redundancy in mechanical systems through standby units as needed.	Yes	Yes	Yes	No	No
		Building features that are not located above the design flood elevation will be designed to withstand the corresponding hydrostatic pressure or protected from the flood hazard.	Yes	Yes	No	No	No
		Wet floodproof critical systems with waterproof membranes or sealants.	No	No	Yes	No	No
		Design air handling units with heat recovery.	No	No	No	Yes	No
		Install electrical condensate evaporation and/or supplemental evaporative cooling for HVAC systems.	No	No	No	Yes	No
		Provide redundancy in mechanical systems through standby units.	No	No	No	Yes	No
		Design mitigation for airborne pathogens as part of HVAC design strategy. Improving health performance is allowed to take precedence over energy efficiency. Cost of HEPA filtration will be considered.	No	No	No	No	Yes

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Protect (continued)	Electrical	Provide redundancy in backup battery supply for buses in storage and extra charging capacity.	Yes	Yes	No	No	No
		Install heat exchangers in enclosed systems to dissipate heat.	No	No	No	Yes	No
		Install electrical distribution equipment in well ventilated areas.	No	No	No	Yes	No
		Provide cast coil transformers with fans for the distribution system.	No	No	No	Yes	No
Accommodate	General	Consider corrosive resistant materials.	No	Yes	No	No	No
		Consider reflective materials and solar facades.	No	No	No	Yes	No
		Select easy to clean materials and surfaces.	No	No	No	No	Yes
	Site/Civil	Design green infrastructure features that are more resilient to deterioration from natural hazards over time.	No	No	No	No	No
		Design landscaping for synergy with storm resistance (e.g., depressed landscaping areas and vegetated species resistant to wind and temporary inundation).	Yes	No	Yes	No	No
		Provide pavement sections that will adequately withstand adverse weather impacts.	Yes	No	Yes	No	No
		Design green infrastructure with salt-tolerant vegetated species that are resistant to extreme temperatures.	No	Yes	Yes	Yes	No
		Consider destratification fans-internal circulation to eliminate thermal stratification.	No	No	No	Yes	No
	Architectural	Consider thermic barriers and zones to reduce building energy demand and provide safe zones during extended temperature extremes.	No	No	No	Yes	No
		Consider passive cooling techniques, such as enhanced natural ventilation, using solar energy and evaporative cooling to reduce building energy consumption and increase indoor thermal comfort.	No	No	No	Yes	No
		Resilient roofing design with heating pads to de-ice and remove snow.	Yes	No	No	No	No

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Accommodate (continued)	Structural	Design breakaway walls in coastal flood areas for storm surge.	Yes	Yes	No	No	No
		Resilient roofing design, blue/white roofs to temporarily store water and mitigate extreme heat, and green/white roofs to mitigate stormwater flooding and extreme heat.	No	No	Yes	Yes	No
		Install hydrostatic relief valves in the floor slabs and sub-floor trenches.	No	Yes	Yes	No	No
		Dry-flood proof entrances that lead to mechanical rooms.	No	Yes	Yes	No	No
	Mechanical	Install floor guard connections to floor drains and under slab drains in mechanical room to prevent backflow and flooding; consider backflow preventers.	No	Yes	Yes	No	No
		Install an exterior duplex pump system to remove water in sub-floor trenches.	No	No	Yes	No	No
		Consider emergency alternatives and shut-off pathways for air flow.	No	No	No	No	Yes
		Consider sanitation and cleaning requirements in mechanical system design.	No	No	No	No	Yes
		Provide power supply for both critical functions and for full operations through charging stations, transmission systems, and diverse energy sources including utility scale and distributed generation assets such as microgrids equipped with renewable energy and battery storage devices. Recommended minimum of three power supply sources for redundancy.	Yes	Yes	Yes	Yes	No

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Accommodate (continued)	Electrical	Provide extra battery supply for buses in storage and extra charging capacity.	Yes	Yes	Yes	Yes	No
		Provide feeders and raceways resilient to flooding.	No	Yes	Yes	No	No
		Consider alternate fuel sources for standby power.	Yes	Yes	Yes	Yes	No
		Consider using submersible exterior transformers and substations.	No	Yes	Yes	No	No
		Consider submersible sump pumps with water level sensors.	No	Yes	Yes	No	No
		Provide enclosures rated for the extreme environments with heating and ventilation.	Yes	No	Yes	No	No
		Consider thermic barriers and zones to reduce building energy demand and during extended temperature extremes.	Yes	No	No	Yes	No
		Provide touchless (motion sensor) lighting.	No	No	No	No	Yes

Note:
HEPA = high-efficiency particulate air

A.3.5.2 Operational Resilience Strategies

Operational strategies will support the physical design of the bus maintenance facility assets and infrastructure. The strategies, as shown in **Table A-8**, are structured for different stages of planning for a disruptor.

Table A-8. Operational Resilience Strategies by Disruptor

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Prepare	Plans	Plan for sharing facilities and/or buses with public and private partners	Yes	Yes	Yes	No	No
		Plan for snow removal to designated storage sites	Yes	No	Yes	No	No
		Plan for multiple evacuation routes in the event of flooding, obstacles, or blockages	Yes	Yes	Yes	No	No
		Plan for site infrastructure inspection and maintenance, such as stormwater management systems to maintain proper working conditions	Yes	No	Yes	No	No
		Storm shelter in place plans and supplies for critical staff to stay at the building during an extreme event	Yes	Yes	Yes	Yes	Yes
		Develop an emergency communication plan and update contacts annually	Yes	Yes	Yes	Yes	Yes
	Equipment	Where possible, relocate potentially vulnerable portable assets to protected locations in advance of a storm/temperature extreme	Yes	Yes	Yes	Yes	No
		Test emergency equipment regularly. Confirm that equipment has not been damaged in storage and that parts have not been lost	Yes	Yes	Yes	Yes	No
		Accommodate demand response and plan to delay electrical loads such as battery charging during peak power demands such as extreme daytime heat or nighttime cold	Yes	No	No	Yes	No
		Have available emergency alternatives to typical equipment, assets, and infrastructure	Yes	Yes	Yes	Yes	No

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Prepare (continued)	Workforce	Provide regular training for staff who would provide emergency support and develop protocol for preparation, response, and recovery	Yes	Yes	Yes	No	Yes
		Designate area and supply storage for sheltering in place	Yes	Yes	Yes	No	Yes
		Assemble staff and supplies for response and recovery	Yes	Yes	Yes	No	Yes
Respond	Equipment	Adjust BAS equipment to save energy and continue operations during power outages	Yes	Yes	Yes	Yes	No
		Deploy emergency response equipment	Yes	Yes	Yes	No	No
		Provide and resupply hand sanitizer stations, PPE	No	No	No	No	Yes
	Communication	Alert external media/communication contacts and internal employee emergency contacts	Yes	Yes	Yes	Yes	Yes
		Share emergency messages in all languages spoken	Yes	Yes	Yes	Yes	Yes
	Workforce	Provide adequate time, staff, and materials for response	Yes	Yes	Yes	Yes	Yes
Recover	Equipment	Clean facilities and equipment after an extreme event and clear debris	Yes	Yes	Yes	No	No
		Identify and address damage to facilities and equipment	Yes	Yes	Yes	No	No
		Move buses and any temporarily relocated equipment back to facility	Yes	Yes	Yes	No	No
	Communication	Alert external media/communication contacts and internal employee emergency contacts	Yes	Yes	Yes	Yes	Yes
		Share emergency messages in all languages spoken	Yes	Yes	Yes	Yes	Yes
	Workforce	Provide adequate time, staff, and materials for recovery	Yes	Yes	Yes	Yes	Yes

Design	Design Component	Strategy	Extreme Storms	Coastal Flooding	Extreme Precipitation	Extreme Temperatures	Disease/ Pandemic
Reassess	Plans	Update operations and maintenance plan for emergency equipment	Yes	Yes	Yes	Yes	Yes
	Workforce	Consider additional staffing, training, equipment, or communications needs	Yes	Yes	Yes	Yes	Yes
Monitor	Plans	Continue to review existing plans and changes to the natural environment that may affect them	Yes	Yes	Yes	Yes	Yes
	Equipment	Continue to maintain equipment and review changes to the natural environment that may affect equipment performance	Yes	Yes	Yes	Yes	Yes
	Workforce	Continue to evaluate staffing and training needs and changes that may affect workforce availability	Yes	Yes	Yes	Yes	Yes
	Communication	Continue to evaluate communications needs and changes that may affect existing systems	Yes	Yes	Yes	Yes	Yes

A.3.5.3 Resilience Co-Benefits

In addition to meeting the performance goals, the strategies identified in the previous sections can also provide co-benefits related to societal, environmental, and economic considerations. Evaluating the benefits of various strategies can assist in prioritizing and selecting a final resilience strategy. **Table A-9** summarizes representative examples of co-benefits.

Table A-9. Representative Examples of Co-Benefits

Strategy Type	Design	Design Component	Strategy	Co-Benefit
Physical	Accommodate	Structural	Resilient roofing, including green roofs to mitigate stormwater flooding and extreme heat	Environmental co-benefits of improving air and water quality, combined sewer overflow reductions in urban areas, introducing pollinators, and urban farming. Societal co-benefit of mitigating urban heat island effects
		Site/Civil	Design green infrastructure and low-impact development for stormwater management.	Environmental co-benefits of improving air and water quality, and stormwater volume reductions. Societal co-benefit of mitigating urban heat island effects
Operational	Prepare	Equipment	Where possible, relocate potentially vulnerable portable assets to protected locations in advance of a storm/temperature extreme	Economic co-benefit of reducing maintenance costs

A.3.5.4 Incremental Improvement

Adaptation to future hazards is a critical component of the resilience process to adapt and improve the resilience of facilities over time. Bus maintenance facilities will be able to function under current climate conditions as well as future climate conditions through the recommended planning horizon, and beyond.

Where possible the design approach will embrace strategies that adapt over time and respond to changing conditions. Designers will consider conditions beyond the recommended 2070 planning horizon identified in the performance goals, since climate change is still a concern beyond an asset's intended useful life. There may be opportunities to build in adaptability to future climate conditions, such as over-designing a foundation to allow for a flood wall height to be increased in the future and/or preparing for future stormwater pumps to be added by designing extra wet wells and supporting infrastructure. Designs will also consider exposure and risk through an asset's useful life to identify flexible approaches to achieve the performance goals recommended herein and meet the recommended RMAT Statewide Climate Design Standards and Guidelines.

A.4 SAMPLE RESILIENCE FORMS

The resilience forms in **Sections A.4.1** through **A.4.3** provide an example of the information necessary to document how a design team would meet resilience goals and performance requirements and applied design strategies for a bus maintenance facility. The information focuses on the design of physical assets at the bus maintenance facility, required operations and maintenance activities associated with new construction, rehabilitation, or repair.

As presented, these forms are intended to serve as example formats and reflect the type of documentation that the MBTA will review related to resilience with design submittals. Designers may select a different format or presentation, but the forms and content should reflect the guidelines outlined in **Section A.3**. These forms should be used to supplement the forms provided in the RMAT Statewide Climate Resilience Design Standards and Guidelines (Commonwealth of Massachusetts 2020a).

There are three sample forms provided in this section:

1. **Critical Asset List**: Identify each critical asset as determined by the MBTA and design team. This is intended as a succinct list of the most critical assets on the site, which may vary based on the needs of the site. This should be closely coordinated with the MBTA and members of the design team. This list will serve as the basis for additional forms that are recommended. *Please note that these forms do not ask about offsite assets that may have interdependencies with this facility; for example, offsite power transformers that supply the site with power or mobile generators at other facilities that this site may rely on*.
2. **Design and Performance Thresholds**: These forms have two components. The first part of the forms is intended to document the design values for the primary and secondary threshold conditions for the overall design. These are categorized by disruptor (e.g., Extreme Storm, Coastal Flooding, Extreme Precipitation, Extreme Temperature, Disease/Pandemic). The second part should be completed for each critical asset listed in the previous section, and document if primary and secondary threshold conditions were met in the design of the asset.
3. **Applied Design Strategies**: These forms document the proposed design strategies for each critical asset to achieve the conditions documented in the previous section. These are categorized by the guidelines discipline categories (Structural, Electrical, Mechanical, Civil and Landscape, Architectural). These forms should be completed based on the discipline category identified for the critical asset.

A.4.1 Critical Asset List Form

Complete this form for each critical asset. Add additional rows as necessary. Refer to notes section following the form for definitions and to incorporate suggested inclusions. Note that not all columns may apply to the identified asset.

	Critical Asset (Discipline)	Elevation	Location and Access	Condition and Age	Power Source	Backup Power Source
1	e.g., Architectural, Civil, Electrical, Fire Protection, Mechanical, Plumbing, Structural					
2						
3						
4						
5						

Notes:

- **Critical Asset** – Name of onsite system component and associated discipline (e.g., mechanical, structural, architectural, electrical, plumbing, civil, fire).
- **Elevation** – Include the elevation relative to MBTA datum.
- **Location and Access** – Describe the asset's location onsite and access plans/considerations.
- **Condition and Age** – If applicable (such as rehabilitation of existing facility), use State of Good Repair System.
- **Power Source** – If applicable, describe the fuel type and connection.
- **Backup Power Source** – If applicable, describe the backup fuel type and connection.

A.4.2 Design and Performance Thresholds Forms

A.4.2.1 Overall Design

Complete this form for the overall design of the Bus Maintenance Facility Project. For coastal flooding, extreme precipitation, and extreme temperatures, please reference the RMAT Statewide Climate Resilience Design Standards and Guidelines for the methodologies to estimate future design values.

Resilience Disruptor	Primary Threshold	Design Value	Secondary Threshold	Design Value
Extreme Storms (Snow, Ice Storms, Nor'easters)	Increase design snow and ice loads using the importance factor as outlined by ASCE 7 Risk Category (CAS-B12, 2015)		10 inches of snowfall within a 24-hour period	
	5 inches or less of snowfall within a 24-hour period and/or a commercial power outage lasting the duration of backup generation fuel supply and/or battery systems		30 inches of snowfall within a 72-hour period	
	Category 3 hurricane wind speeds		Category 4 hurricane wind speeds	
Coastal Flooding	Current and future (2070 planning horizon) design flood elevation and duration for a 1% annual chance probability coastal flood with at least 2 feet of freeboard	Current	Current and future (2070 planning horizon) design flood elevation and duration for a 0.2% annual chance probability coastal flood	Current
		Future		Future
Extreme Precipitation (Stormwater Flooding, Riverine Flooding)	Current and future (2070 planning horizon) 24-hour rainfall depth and peak intensity for a 25-year design storm	Current	Current and future (2070 planning horizon) 24-hour rainfall depth and peak intensity for a 100-year design storm	Current
		Future		Future
Extreme Temperatures	Current and future (2070 planning horizon) heatwave frequency and duration	Current	N/A	
		Future		
	Current and future (2070 planning horizon) cooling degree days and heating degree days	Current	Events that exceed the primary threshold by cooling degree days and heating degree days up to 10%	
		Future		
	Current and future (2070 planning horizon) days over 90°F, 95°F, and 100°F	Current	Events that exceed the primary threshold for days over 90°F, 95°F, and 100°F by up to 10%	
		Future		
	Current and future (2070 planning horizon) days below 32°F	Current	Events that exceed the primary threshold for days below 32°F by up to 10%	
		Future		
Disease/ Pandemic	Please refer to current and future orders from the Governor's Office or recommendations from the Center for Disease Control (CDC) for acceptable performance requirements under pandemic conditions, as well as different phases		Please refer to current and future orders from the Governor's Office or recommendations from the CDC for acceptable performance requirements under pandemic conditions, as well as different phases.	

A.4.2.2 Critical Asset Design

Please copy this form and complete for all critical assets identified in the Critical Asset List form.

Asset 1: (Identify Asset and Discipline here)

Resilience Disruptor	**Primary Threshold** The primary threshold is the condition under which critical assets/infrastructure should be designed so that there are no damages and critical functionality is maintained with little to no disruption. Please refer to the design values listed in **Section A.4.2.1**.			**Secondary Threshold** The secondary threshold assumes the primary threshold has been exceeded; this is intended to minimize downtime with limited damages and quick recovery time. Downtime assumes total duration of disruption (including the natural hazard event). Recovery time is only after the natural hazard event has ended (i.e., snow has stopped falling, coastal stormwater has receded). These may be the same, or they may be different, depending on the facility and operations. Acceptable times for the secondary thresholds should be established as part of the design process with input from key MBTA stakeholders (refer to the following page for questions to support establishing acceptable downtime duration). Please refer to the design values listed in **Section A.4.2.1**.					
	Design **meets** current and future design values	Design meets current design value and **can be adapted over time** to the meet future design value	Design **does not meet** future design value	Design **meets** current and future design values	Design meets current design value and **can be adapted over time** to the meet future design value	Design **does not meet** future design value	Acceptable downtime (hours)	Acceptable recovery time (hours)	Critical reduced functionality consequences and/or replacement considerations
Extreme Storms	☐	☐	☐	☐	☐	☐			
Coastal Flooding	☐	☐	☐	☐	☐	☐			
Extreme Precipitation	☐	☐	☐	☐	☐	☐			
Extreme Temperatures	☐	☐	☐	☐	☐	☐			
Disease/ Pandemic	☐	☐	☐	☐	☐	☐			

Primary Threshold Explanation: For those assets which do not meet the future design values (including can be adapted over time), please provide a statement and necessary reasoning in the following box.

Acceptable Disruption Time Documentation for Secondary Threshold: Secondary thresholds should be established as a part of the design process with input from key MBTA stakeholders. The following offers guiding questions for reference and more space to detail downtimes, conditions, and consequences. Describe the operational activities—to prepare, respond, recovery, reassess, and monitor—that are associated with meeting the design values and under the secondary threshold condition in the Applied Design Strategies forms.

Identify key stakeholders. *This may include MBTA staff from operations and control center, bus maintenance, bus operations, security and emergency management, environment and energy, engineering, and other departments, as necessary. This may also include private, local, and regional partners that support emergency preparedness, response, and/or recovery efforts.*
Identify existing operational capacity. *Designers should identify the existing operational capacity necessary to maintain critical functionality under fair-weather conditions, as well as the primary and secondary threshold conditions defined within.*
• **Workforce** - What is the minimum workforce needed to maintain criticality systems at the bus maintenance facility? What is the potential risk to the workforce as a result of the disruptors? What type of training is necessary to maintain critical systems? What is the availability of the trained workforce under fair-weather and disruptor conditions? • **Equipment -** What is the minimum equipment needed to maintain and operate critical systems? What is the potential risk to equipment as a result of disruptors? What backup equipment is available to maintain and operate critical systems if the equipment is damaged/inoperable? What is the availability and capacity of the backup equipment? • **Communications -** What are the proposed communication systems necessary to maintain and operate critical systems? What is the potential risk to communications as a result of disruptors? What backup communications are available in the event of an emergency? • **Plans** (include review plan agency/organization, title, and year) - What are the existing plans for emergency preparedness and response? How do the plans relate to the proposed design of the bus maintenance facility and disruptors? Do other facilities rely on the bus maintenance facility in the event of an emergency? Does the bus maintenance facility rely on other facilities in the event of an emergency?
Identify consequences associated with disruption of critical functionality. *Designers should identify the range of consequences associated with disruption of critical functionality for the bus maintenance facility. Designers should identify the maximum acceptable downtime and recovery time based on these consequences and associated disruptors and include in the Critical Asset Design form.*

A.4.3 Applied Design Strategies Forms

Please copy this form and complete for all critical assets identified in the Critical Asset List form. Only complete the form for the discipline identified for the critical asset. For "Other," Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.

A.4.3.1 Discipline: Structural

Asset 1: (Identify Asset and Discipline here)

Disruptor	Disruptor Consequence	Structural Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Storms	Accelerated deterioration of structural elements (roofing, building envelope, foundations, etc.)	☐ Select corrosion resistant materials ☐ Other		
Extreme Storms	Possible structural damages due to exceeded snow, ice, and wind loads	☐ Secure elements that could become debris during an extreme storm ☐ Resilient roofing design with heating pads to de-ice and remove snow ☐ Design breakaway walls in coastal flood areas for storm surge due to nor'easter events ☐ Other		
Coastal Flooding	Accelerated deterioration and possible structural damages due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment. **Extreme Precipitation**	☐ Elevate critical structural features above design flood elevation ☐ Relocate out of flood zones, as possible ☐ Provide permanent site perimeter protection from floodwater ☐ Reinforce exposed structural elements to resist direct flood action and hydrostatic pressure ☐ Implement breakaway walls ☐ Design and construct deep foundations in flood zone ☐ Other		
Extreme Precipitation	Accelerated deterioration (rot, buckling, etc.) and possible structural damages to building foundations, columns, trusses, beams, and other structural elements	☐ Select corrosion resistant materials ☐ Elevate structural elements out of design flood elevations ☐ Secure elements that could become debris during flooding ☐ Resilient roofing, blue roofs to temporarily store water, and green roofs to mitigate stormwater flooding ☐ Select corrosion resistant materials ☐ Other		
Extreme Precipitation	Flooding of basement facilities	☐ Dry floodproof and reinforced walls ☐ Install permanent flood barriers around site to prevent flooding ☐ Other		

Disruptor	Disruptor Consequence	Structural Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Temperatures	Thermal expansion of exposed columns, trusses, beams, and structural materials	☐ Install adequate exterior shading structures ☐ Consider reflective materials and solar facades ☐ Consider resilient green roof design to mitigate extreme heat and/or urban heat island effects for general building envelope and site ☐ Identify structural members that are sensitive to thermal expansion and develop operations and maintenance plan for mitigating heat impacts ☐ Other		

A.4.3.2 Discipline: Mechanical

Asset 1: (Identify Asset and Discipline here)

Disruptor	Disruptor Consequence	Mechanical Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Storms	Accelerated deterioration due to impact from extreme storm debris	☐ Select corrosion resistant materials ☐ Other		
Extreme Storms	Possible system damages due to exceeded snow, ice, and wind loads	☐ Seal, insulate, and secure elements (intake and exhaust louvers and dampers, exposed ductwork, etc.) ☐ Provide redundancy in mechanical systems through standby units as needed ☐ Other		
Coastal Flooding	Accelerated deterioration and possible damages to HVAC and mechanical systems due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment	☐ Elevate mechanical systems above design flood elevation ☐ Relocate critical mechanical systems out of flood zones as possible ☐ Design building features that are not located above the design flood elevation to withstand the corresponding hydrostatic pressure or protect from the flood hazard ☐ Seal, insulate, and secure elements (intake and exhaust louvers and dampers, exposed ductwork, etc.) ☐ Provide redundancy in mechanical systems through standby units as needed ☐ Other		

Disruptor	Disruptor Consequence	Mechanical Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Precipitation	Water in HVAC systems can cause short/long-term air quality issues, leakage into occupied spaces, and potential equipment failure.	☐ Elevate mechanical rooms above design flood elevation ☐ Dry-floodproof entrances that lead to mechanical rooms ☐ Install floor guard connections to floor drains and under slab drains in mechanical room to prevent backflow and flooding ☐ Install an exterior duplex pump system to remove water in sub-floor trenches ☐ Seal, insulate, and secure elements (intake and exhaust louvers and dampers, exposed ductwork, etc.) ☐ Wet floodproof critical systems with waterproof membranes or sealants ☐ Redundancy in mechanical systems through standby units as needed ☐ Backflow preventers ☐ Install hydrostatic relief valves in the floor slabs and sub-floor trenches ☐ Other		
Extreme Temperatures	Accelerated deterioration of mechanical systems, leading to higher maintenance demands and shorter service life. Evaporative-cooled systems will require greater amounts of water. High ambient humidity will result in larger amounts of interior condensate and may stress drainage systems. Reduced efficiency of cooling cycles and additional energy requirements to operate.	☐ Design air handling units with heat recovery ☐ Install electrical condensate evaporation and/or supplemental evaporative cooling for HVAC systems ☐ Provide redundancy in mechanical systems through standby units as needed ☐ Dedicated outside air systems to directly address the outside environment entering the building ☐ Incremental approach (splitting the design load between multiple pieces of equipment) to ensure equipment operates in its most efficient zones when temperatures are not elevated ☐ Other		
Extreme Temperatures	Public health emergency	☐ Design mitigation for airborne pathogens as part of HVAC design strategy. Improving health performance is allowed to take precedence over energy efficiency ☐ Consider emergency alternatives and shut-off pathways for air flow ☐ Consider sanitation and cleaning requirements in mechanical system design ☐ Provide a holistic plan for air movement paying attention to air migration and space pressurization ☐ Consider disinfection alternatives such as ultraviolet and bipolar-ionization ☐ Other		

A.4.3.3 Discipline: Electrical

Asset 1: (Identify Asset and Discipline here)

Disruptor	Disruptor Consequence	Electrical Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Storms	Accelerated deterioration of electrical equipment (exterior systems and generators, etc.).	☐ Provide underground utilities with multiple feeders where available ☐ Consider locations for louvers and ventilation for exterior enclosures ☐ Other		
Extreme Storms	Possible system failure due to exceeded snow, ice, and wind loads. Equipment failure due to wet or damp equipment.	☐ Seal, insulate, and secure elements (conduits, tubing, vents, etc.) ☐ Provide redundancy in power and battery supply ☐ Extra battery supply for buses in storage and extra charging capacity ☐ Provide power supply for both critical functions and for full operations through charging stations, transmission systems, and diverse energy sources. Recommend minimum of three power supply sources for redundancy ☐ Other.		
Coastal Flooding	Accelerated deterioration and possible damages to electrical systems and equipment due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment. Replacement of equipment damaged during an extreme flooding incident.	☐ Provide feeders and raceways resilient to flooding ☐ Elevate mechanical systems above design flood elevation ☐ Relocate critical mechanical systems out of flood zones as possible ☐ Provide redundancy in backup battery supply for buses in storage and extra charging capacity ☐ Other		
Coastal Flooding	Fuel requirements for standby power If the site is exposed to current and/or future coastal flooding.	☐ Consider alternate fuel sources for standby power ☐ Other		
Extreme Precipitation	Accelerated deterioration and possible damages to electrical equipment (generators switchgears, insulation, circuitry, fuses, controllers, capacitors, etc.) due to flooding. Potential for corrosion, short circuits, and equipment failure from inundation and infiltration through unsealed system pathways.	☐ BEB charging equipment, transformers, backup generators, switchgears and circuit panels, and other critical electric systems above design flood elevation ☐ Consider using submersible exterior transformers and substations ☐ Consider submersible sump pumps with water level sensors ☐ Seal transformer manholes to prevent water run-off infiltration/intrusion into manholes ☐ Seal electrical conduits at exterior manholes and points of entry into building ☐ Consider temporary flood barriers around generators for emergency scenarios ☐ Provide enclosures rated for the extreme environments with heating and ventilation ☐ Other		

Disruptor	Disruptor Consequence	Electrical Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Temperatures	Overheated electrical equipment, increasing risk of fire, explosion, personal injury, and more. Sustained extreme ambient temperatures may also result in electrical equipment operating at temperatures above the safe operating range. Damages to assets may require replacement of equipment.	☐ Install heat exchangers in enclosed systems to dissipate heat ☐ Provide extra battery supply for buses in storage and extra charging capacity ☐ Consider thermic barriers and zones to reduce building energy demand and during extended temperature extremes ☐ Install electrical distribution equipment in well ventilated areas ☐ Provide cast coil transformers with fans for the distribution system ☐ Other		

A.4.3.4 Discipline: Civil and Landscaping

Asset 1: (Identify Asset and Discipline here)

Disruptor	Disruptor Consequence	Civil/Landscaping Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Storms	Accelerated deterioration of pavement design, pathways, aboveground utility connections, and slopes. Damages to aboveground utility connections that service the bus maintenance facilities. Potential for erosion of slopes.	☐ Provide pavement sections that will adequately withstand adverse weather impacts ☐ Design landscaping for synergy with storm resistance (e.g., depressed landscaping areas and vegetated species resistant to wind and temporary inundation) ☐ Use preferred design of subsurface utilities ☐ Other		
Extreme Storms	Physical obstruction to paths of travel such as roadways, sidewalks, parking lots, etc.	☐ Secure elements that could erode or become debris and damage other assets or impact operations during an extreme storm event ☐ Other		
Extreme Storms	Potential for insufficient capacity of stormwater drainage infrastructure if storm is too intense or if network is not maintained or serviced appropriately, such as localized flooding	☐ Develop operation and maintenance plan for site infrastructure like the stormwater management systems to maintain proper working conditions ☐ Design green infrastructure features that are more resilient to deterioration from natural hazards over time ☐ Other		
Coastal Flooding	Accelerated deterioration of civil/site features due to flooding and exposure to salt-water inundation	☐ Design green infrastructure with salt-tolerant vegetated species; consider coastal wetlands or marshes ☐ Allow for coastal vegetation migration upslope with sea-level rise ☐ Other		

Disruptor	Disruptor Consequence	Civil/Landscaping Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Coastal Flooding	Physical obstruction to paths of travel such as roadways, sidewalks, parking lots, etc.	☐ Elevate or adjust site grading/design to raise above design flood elevations, which is the best option if feasible ☐ Other		
Coastal Flooding	Site flooding from tailwater elevations exceeding design criteria	☐ Implement backflow preventer valves and sump pumps with water level sensors ☐ Other		
Coastal Flooding	Damages to aboveground utility connections that service the bus maintenance facilities	☐ Elevate or adjust site grading/design to raise above design flood elevations, which is the best option if feasible ☐ Design for overland relief away from critical civil/site features for extreme flows in excess of storm conveyance system capacity ☐ Other		
Extreme Precipitation	Accelerated deterioration of pavement design, sidewalks and employee pathways, and other traffic networks. Potential for erosion.	☐ Design landscaping for synergy with storm resistance (e.g., depressed landscaping areas and vegetated species resistant to wind and temporary inundation) ☐ Provide pavement sections that will adequately withstand adverse weather impacts ☐ Other		
Extreme Precipitation	Physical obstruction to paths of travel such as roadways, sidewalks, parking lots, etc.	☐ Elevate or adjust site grading/design to raise above design flood elevations – provided impacts from diverted stormwater are mitigated ☐ Secure elements that could erode or become debris and damage other assets or impact operations during a storm event ☐ Other		
Extreme Precipitation	Potential for insufficient capacity of stormwater drainage infrastructure if storm is too intense or if network is not maintained or serviced appropriately, such as localized flooding	☐ Design for overland relief away from critical civil/site features to extreme flows in excess of storm conveyance system capacity. ☐ Follow operation and maintenance plan for site infrastructure like the stormwater management systems to maintain proper working conditions. ☐ Implement backflow preventer valves and sump pumps with water level sensors. ☐ Design green infrastructure features that are more resilient to deterioration from natural hazards over time. ☐ Other		
Extreme Temperatures	Increased surface temperature of impervious surfaces and accelerated deterioration of civil/site features due to overheating	☐ Design civil/site features with reflective or non-absorptive materials. ☐ Design green infrastructure to include vegetated species that are resistant to temperature extremes. ☐ Other		
Extreme Temperatures	Human health impacts	☐ Adequate shade/shelter for workforce and site occupants. ☐ Other		
Disease/ Pandemic	Human health impacts	☐ Design site walkways for incorporation of sanitary stations and space for social distancing. ☐ Other		

A.4.3.5 Discipline: Architectural

Asset 1: (Identify Asset and Discipline here)

Disruptor	Disruptor Consequence	Architectural Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Storms	Accelerated deterioration to architectural features (windows, doors, and overall building envelope) due to impact from extreme storms such as snow, ice, and wind loads and wind debris. Possible architectural damages due to exceeded snow, ice, and wind loads. Potential for impact damage from wind debris.	☐ Secure elements that could become debris during an extreme storm event ☐ Storm shelter rooms and safe rooms per ICC 500 and P-361 ☐ Include redundancy in design to prevent further compromising critical functionality of mechanical, electrical, and communication systems ☐ Resilient roofing design with heating pads to de-ice and remove snow ☐ Other		
Extreme Storms	Accumulation of snow and ice may create direct hazards to site access	☐ Include redundancy in design to prevent further compromising critical functionality of mechanical, electrical, and communication systems ☐ Other		
Coastal Flooding	Possible damages to critical architectural features due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment. Accelerated deterioration due to salt-water exposure.	☐ Elevate critical architectural features above design flood elevation ☐ Relocate out of flood zones as possible ☐ Building features that are not located above the base flood elevation should be designed to withstand the corresponding hydrostatic pressure or protected from the flood hazard ☐ Consider corrosive resistant materials ☐ Other		
Extreme Precipitation	Accelerated deterioration of architectural features due to flood-born debris during extreme precipitation events	☐ Elevate critical entryways architectural features above flood zone ☐ Storm shelter rooms and safe rooms per ICC 500 and P-361 ☐ Other		
Extreme Precipitation	Potential for mold, mildew, general air quality issues, and subsequent human health issues with exposure to water	☐ Consider enhanced sealing from for water entry (perimeter of doors, windows and other openings, control, and expansion joints, plus drainage and utility connections, etc.) ☐ Other		

Disruptor	Disruptor Consequence	Architectural Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Temperatures	Increased indoor ambient air temperatures; extended temperature ranges throughout the year	☐ Seal and insulate elements common pathways for air entry (perimeter of doors, windows, windows and other openings, control, and expansion joints, plus drainage and utility connections, etc.). ☐ Install adequate exterior shading structures. ☐ Consider destratification fans-internal circulation to eliminate thermal stratification. ☐ Consider thermic barriers and zones to reduce building energy demand and provide safe zones during extended temperature extremes. ☐ Consider passive cooling techniques, such as enhanced natural ventilation, using solar energy and evaporative cooling to reduce building energy consumption and increase indoor thermal comfort. ☐ Other		
Extreme Temperatures	Increased surface temperature of impervious surfaces (urban heat island effect) with potential human health concerns	☐ Consider reflective materials and solar facades. ☐ Other		
Disease/Pandemic	Increased risk and vulnerability to MBTA workforce and site occupants at bus maintenance facilities	☐ Design mitigation for airborne pathogens as part of air flow and space usage strategy. Improving health performance is allowed to take precedence over energy efficiency. ☐ Design easy to clean materials and surfaces; consider antimicrobial materials. ☐ Other.		

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APPENDIX B
MAINTENANCE LIFT SUPPLEMENT

CONTENTS

B.1 PURPOSE

The purpose of this memorandum is to describe various vehicle lifts available for bus operations and how they are best used to maintain vehicles. No one lift fits all maintenance requirements. Cost varies depending on lift type, and what type of controls and structural slab or foundation it needs. In addition, there are specific building code requirements that should be followed to meet to assure lifts supplied meet industry standards and can be operated safely.

B.2 VEHICLE LIFT TYPES

Vehicle lifts will provide access to the bus undercarriage and wheels transmissions, brakes, and come in three forms. Each lift will have unique advantages for various maintenance operations. No single lift is ideal for all maintenance procedures. Most modern bus maintenance facilities for function, efficiency, and flexibility employ all three. It is assumed that the Quincy facility will not maintain nonrevenue service vehicles, so other types of lifts designed for smaller vehicles will not be considered.

B.2.1 Inground Post Axle Engaging Lifts

These fixed lifts require a pit or cassette below grade. The consist of a fixed post and a moving post to adjusted for different wheel axle dimensions. Modern lifts are self-contained within a concrete foundation pit or metal cassette so there is no danger of leaks outside the pit. The design allows complete replacement of the lift with new components without affecting the foundation. Post Lifts are most common in full maintenance bay positions and engage lifts to replace tires, work on breaks, and undercarriages without additional jacks. These lifts come in both two and three post lift configurations. Three post lifts are used for articulated buses but can also be designed to handle 40-foot buses as well in the same bay.

B.2.2 Platform Lifts

These fixed lifts raise vehicles up on a drive on ramp platform at either side of the vehicles. They require additional jacks to replace tires or work on brakes, so they are not ideal for this use. They tend to be a faster way to raise and position vehicles then the post lifts. Older versions of these lifts required longer bays because the lift raised by moving forward as the raised offsetting the position. Newer versions use a scissors type motion that raise vehicle straight up and are preferred because they save space. These lifts can be waterproofed and work well for chassis wash or steam bays for cleaning. They also provide quick inspection in existing conditions or where pits cannot be used. Control station will be at front of bay with wiring below the slab to the lift. These units can be placed on existing slabs without a recess or pit but require a short ramp on the access side. They can also be recessed in the slab to be flush with the floor in new facilities.

B.2.3 Portable Lifts

These can easily be moved within bays or to different bay locations in facility by one person. within a maintenance garage. They are most often used in flat bays to provide capability of lifting but also allow a bus to be pulled into a bay for fast turnover work orders. These are a fraction of the cost of the other two types of lifts and are good Value Engineering decision for at least some bays or where a flat open bay without any recess, or pit cover is needed. They come in sets of 4, for 40-foot buses or six for articulated buses and are synchronized to lift together wirelessly so there are no cables between units. Battery operated units also eliminates any power cords, which was an issue with older portable systems. The battery units can be charged with standard outlets when not in use.

B.3 VENDORS

There are two main vendors in the United States for bus lifts in all configurations described previously. These vendors include Stertile-Koni and Rotary. There are other vendors that supply portable, and platform lifts suitable for buses such as Mohawk, but any purchase should make sure that the lifts meet current building code requirements described in the next section. Lifts are designed to support the weight of the bus and transfer the load to the foundations. Foundations and floor slabs; however, must be designed by a registered structural engineer based on point and uniform loads provided by the manufacturer.

B.4 SUMMARY OF CURRENT BUILDING CODES AND INDUSTRY STANDARDS

Current building codes, industry standards, and Occupational Safety and Health Administration (OSHA) regulations regarding lifts have been re-examined. The International Code Council's (ICC) International Building Code (IBC) is primarily a building code specific to building type, occupant egress, construction type, structural requirements for stability of the building and its built-in components under normal loading, and seismic events. The IBC also addresses lifting equipment such as hoist cranes and vehicle lifts.

B.4.1 Code Interpretation from ICC

The IBC sets building size, construction type, structural requirements, occupancy, building access and egress. It deals with elevators and conveying systems and components in Chapter 30. This includes automotive lifts and industrial scissor lifts as listed in IBC table 3001.3. In paragraph 3001.3, the code specifically requires the design, construction, installation, and repair to meet the following standards: the American National Standards Institute (ANSI)/Automotive Lift Institute (ALI) Automotive Lift Construction, Testing, and Validation (ALCTV) standards and for automotive lifts and ANSI/American Society of Mechanical Engineers MH29.1 for scissor lifts.

The ALI is an industry manufacturers association that sets standards for design, manufacturing, installation, certification, and safe operations of all types of vehicle lifts. ALI developed the first commercial standards for vehicle lifts in 1947. ALI has developed a certification program for manufactures, specific lift models, types, applications, and installation. The certification program and accumulated work is found in ALI Standard documentation, Safety Requirements for Construction, Testing, And Validation, 2017. The ALI ALCTV requires the design of lifts for all dead and live loads with synchronized raising and lowering of pistons, jacks, and locking features. Safety of operations of lifts is its primary focus. The development of the standard is in association with OSHA and the National Bureau of Standards and covers the following elements:

- Design criteria and analysis methods
- General construction requirements for electrical components, control devices, speeds, wireless controls, and strength of drive components
- Specific construction requirements for several lift components such as columns, runways, ramps, swing arms, and load-holding devices
- Manufacturer quality assurance systems and procedural requirements
- Lift testing procedures

These standards also state the responsibilities of users and owners. There are no other references or requirements regarding automotive or platform lifts in Chapter 30 or the rest of the IBC. Therefore, the IBC directly confirms the need for such lifts to meet ALI and ANSI requirements. Commentary by ICC has confirmed that automotive lifts and industrial scissor lifts would cover all vehicle lifts (including bus lifts) installed in a building.

To fully comply with the ALI certification program supporting the standard, all lift models must be tested by one of three approved, third-party, OSHA accredited Nationally Recognized Testing Laboratories.

Testing includes electrical systems and the structural capacity, function, controls, lowering speed, and mechanical overload safety. In addition, the manufacturers production facility must meet requirements in the standard for fabrication of such lifts. Also, lift models are certified separately.

B.4.2 Industry Standards and Other Requirements

The American Public Transportation Association and other industry organizations have provided white papers and presentations regarding lift safety. Much this covers good industry practices that include the following:

- Daily inspection of lift prior to use
- Annual lift (experienced inspector or ALI-certified)
- Annual training and recording for mechanics and technicians
- Maintain written documentation for lifts, training, inspection, and service
- Use of manufacturer-approved and -certified accessories and replacement parts
- Facility emergency plan for emergency events, such as storm, seismic, and power outages for staff and operations
- Mechanics aware of proper vehicle spotting methods for a particular lift and check that all equipment and people are clear before raising or lowering
- Proper housekeeping procedures