BUS FACILITY MODERNIZATION

Design Guideline for Bus Maintenance Facilities

First Edition

December 2020

Prepared for

Massachusetts Bay Transportation Authority

Prepared by

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0	December 2020	First Edition	Erik J. Stoothoff, P.E., Chief Engineer 02/11/2021

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ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
AHJ	Authorities Having Jurisdiction
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASTM	American Society for Testing and Materials International
ATS	automatic transfer switch
A/V	audiovisual
BEB	battery electric bus
BOD	basis of design
CO2	carbon dioxide
EACS	electronic access control system
EC	engine coolant
ECM	energy conservation measures
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FTA	Federal Transit Administration
GFCI	ground-fault circuit interrupter
gpm	gallons per minute
HVAC	heating, ventilation, and air conditioning
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America
IMC	International Mechanical Code
IP	Internet Protocol
IT	information technology
LAN	Local Area Network
LEED	Leadership in Energy and Environmental Design
M.G.L.	Massachusetts General Law
MassDEP	Massachusetts Department of Environmental Protection
MassDOT	Massachusetts Department of Transportation
MBTA	Massachusetts Bay Transportation Authority

MC-FRM	Massachusetts Coast Flood Risk Model
MHz	megahertz
MEPA	Massachusetts Environmental Policy Act
MV	medium voltage
MWRA	Massachusetts Water Resource Authority
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NOAA	National Oceanic and Atmospheric Administration
PA	Public Address
PLC	programmable logic control
PM	Project Manager
psi	pounds per square inch
PSIM	Physical Security Information Management
RMAT	Resilient MA Action Team
S+R Admin	Sustainability and Resilience Administrator
S+R Coordinator	Sustainability and Resilience Coordinator
SCADA	Supervisory Control and Data Acquisition
SHMCAP	State Hazard Mitigation and Climate Adaptation Plan
SRMP	Sustainability and Resilience Management Plan
SWAN	Security Wide Area Network
TIA	Traffic Impact Assessment
UL	Underwriters Laboratories
UPS	uninterruptable power supply
USGBC	U.S. Green Building Council
WAN	Wide Area Network
V	volt
VAV	variable air volume
VFD	variable frequency drives
VoIP	Voice over Internet Protocol

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 first edition of the Design Guideline outlines design criteria for running repair or preventative 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 shall be reflected in the facility design. (A subsequent edition of the Design Guideline will incorporate design criteria specific to bus heavy maintenance facilities.) The Design Guideline pertains to both new construction and major rehabilitation projects.

1.1 Compliance

The Designer of Record shall comply with all codes, standards, and manuals relevant to the content herein, including but not limited to those referenced within this document. It is the responsibility of the designer to validate the codes and standards referenced within to ensure the latest version in force and effect is used to develop the facility design. The designer is also responsible for reviewing and complying with MBTA's Engineering Directives,[1] Design Standards and Guidelines,[2] and other Design and Construction Policy and Procedure Manuals, as applicable. If there are discrepancies in codes, standards, or directives, the designer shall identify the discrepancy and allow MBTA to review for approval (in general, the stricter requirement will apply).

1.2 Deviations

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

- The Designer of Record shall 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 shall 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 Bus Facility Modernization Program Director (who would coordinate review by other members of the Office of the Chief Engineer as needed) and other stakeholder departments.
- All waivers shall be approved by the Chief Engineer or designee.

1.2.1 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 shall include the following:

- Waiver request number (to be established with Office of the Chief Engineer)

[1] https://www.mbta.com/engineering/directives
[2] https://www.mbta.com/engineering/design-standards-and-guidelines

- 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
- 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

1.2.2 Tracking

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

1.3 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.

1.4 Organization

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

Section 2. General Design Principles

This section provides guidance and requirements on overarching elements of the facility design and operation as follows:

2.1 Bus Maintenance Facility Workflows—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.

2.2 Fleet Changes—Considerations related to bus fleet makeup (e.g., vehicle size, propulsion type) and anticipated or potential future changes to the bus fleet as they impact operational requirements shall be accounted for in the facility design.

2.3 Facility Asset Management—The facility and its components shall be designed to maintain optimal performance and condition in a cost-effective manner over the life-cycle of the facility.

2.4 Sustainability and Resilience (and **Appendix A Supplement**)—MBTA facilities shall be designed and constructed to balance the utilization of resources that go into facility operations and maintenance for improved sustainability and to incorporate resilient systems able to recover from disruptions.

2.5 Environmental Protection and Enhancement—Facility design shall prioritize preserving, protecting, enhancing and promoting environmental resources and environmental policies of MBTA, state and federal policies, and alignment with sustainability and resilience goals.

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, structural, mechanical, and electrical engineering, plumbing, intelligent systems, site landscape, and architectural.

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. Appendix B, Facility Program Matrix, 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 shall be verified with MBTA unless specifically indicated on the room card. Appendix E provides supplemental information on maintenance lift equipment to aid in the design process.

Appendixes

Appendix A – Sustainability and Resilience Supplement

Appendix B – Facility Program Matrix

Appendix C – Exterior Finishes Supplement

Appendix D – Optional Standby Power Generator Equipment

Appendix E – Maintenance Lift Supplement

2 GENERAL DESIGN PRINCIPLES

2.1 Bus Maintenance Facility Workflows

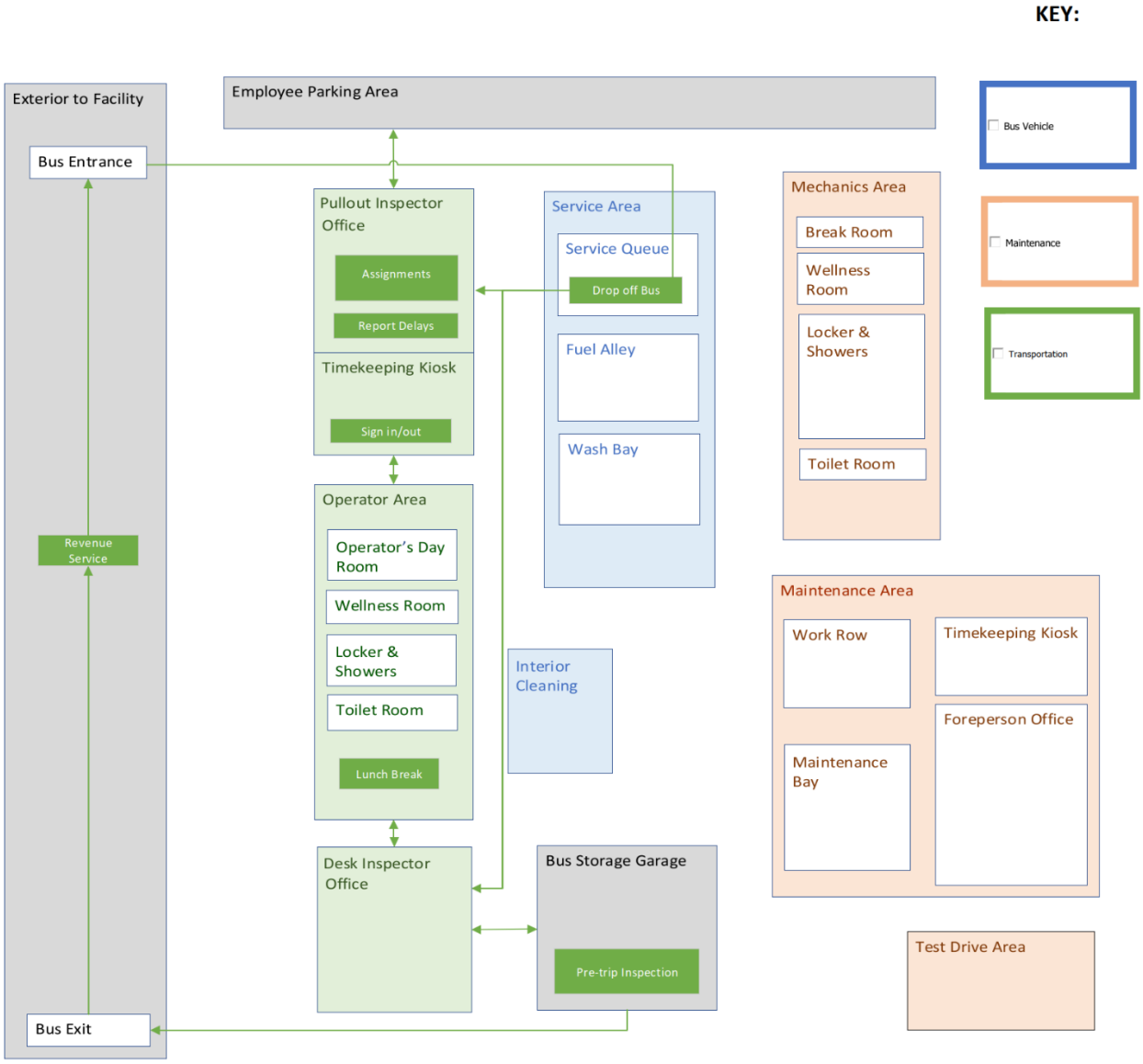
MBTA bus maintenance facilities shall be designed to effectively support and enable all operations within a fully enclosed building. (Employee parking need not be enclosed.) The three diagrams below visualize the primary people and vehicle movements and activities (arrows color coded according to corresponding legend) that occur within and around the building on site for the following groups:

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

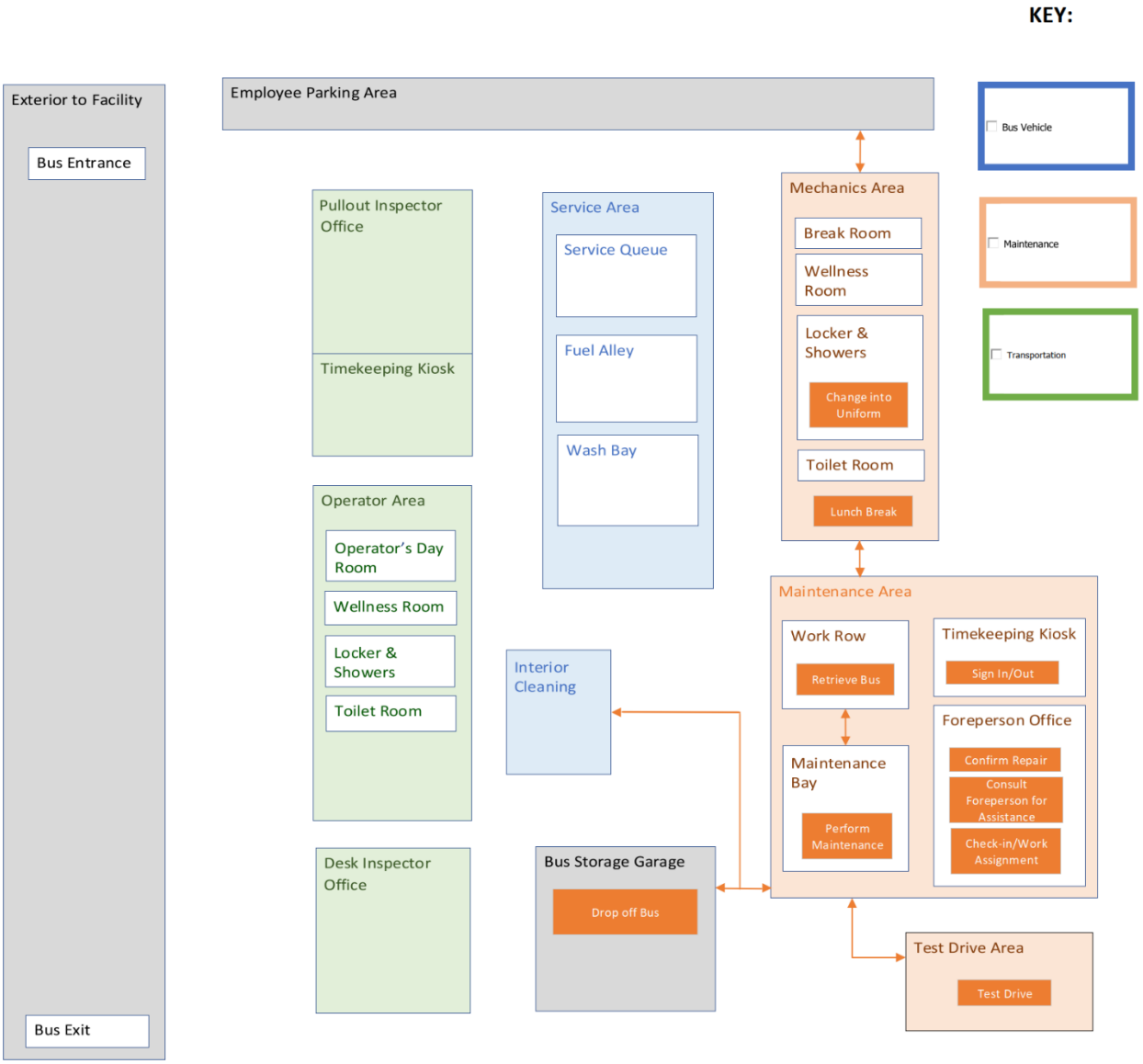
Bus vehicle movements inside the building and within the site shall be one-way, forward movements in a counterclockwise direction (required for 60-foot buses, preferred for 40-foot buses).

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** indicate spatial relationships and connections between the areas included in the workflow diagrams. The designer shall validate the design with MBTA to ensure provisions for all required activities are incorporated.

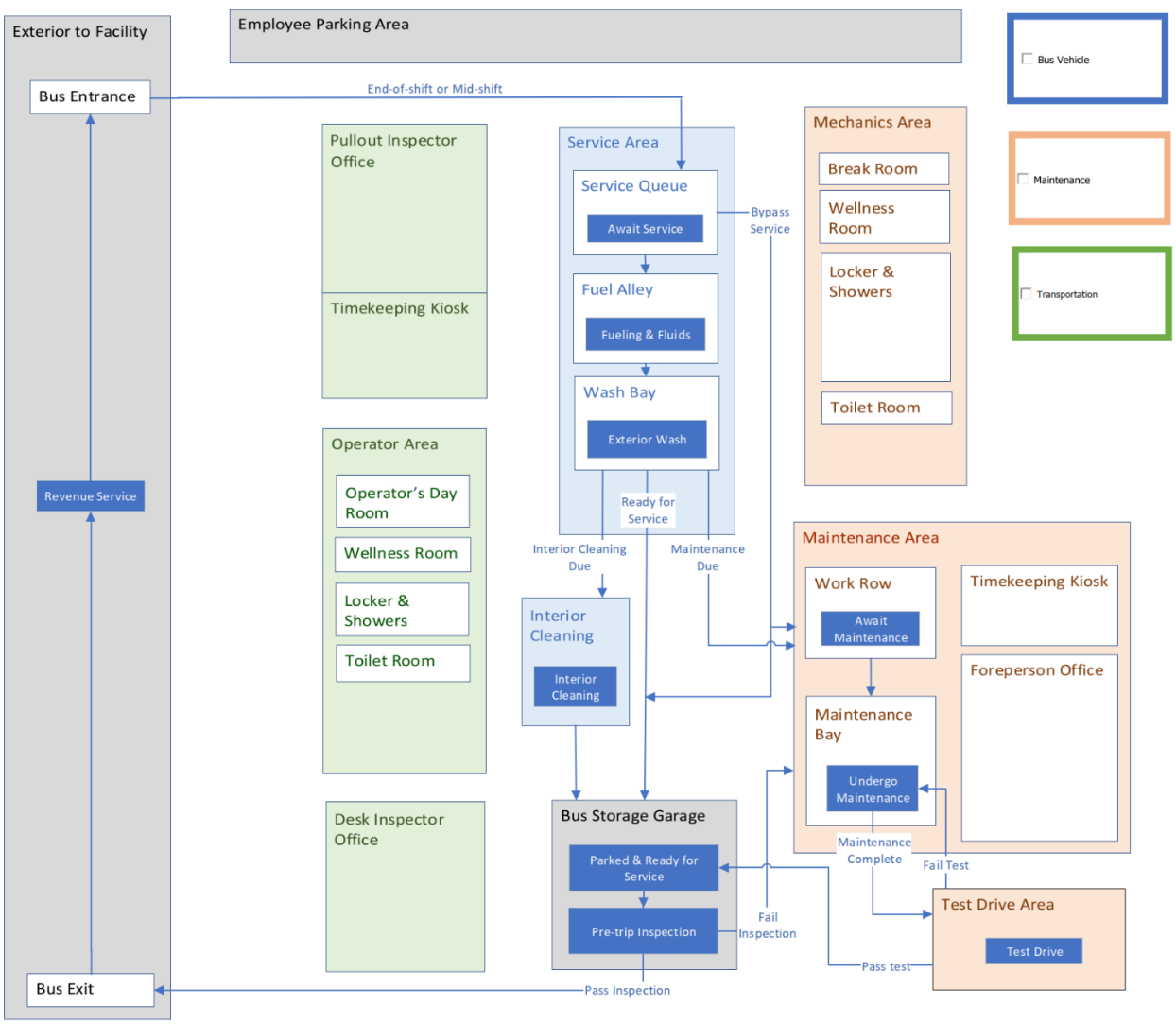
Bus Maintenance Facility
Transportation Workflow Diagram



Bus Maintenance Facility
Maintenance Workflow Diagram



Bus Maintenance Facility
Bus Vehicle Workflow Diagram



2.2 Fleet Changes

This section describes the guidelines on preparedness and capabilities for accommodating future technology and fleet changes. MBTA's most significant fleet change at this time is the intended transition to battery-electric buses (BEBs) with diesel-electric hybrid buses as the near-term or interim transition vehicle. Facility design shall anticipate that fleet changes in the future may not only involve electrification, but also changes in fleet sizing, bus sizes, and maintenance requirements.

MBTA currently operates a mixed fleet manufactured by Neoplan USA and New Flyer Industries of diesel, diesel-hybrid (battery electric and electric trolley), electric trolley, compressed natural gas, and BEBs. MBTA's five BEBs are 60-foot New Flyer XE60s with plug-in charging, delivered in 2019 and currently undergoing evaluation on the Silver Line. The evaluation program is in place to identify the advantages and constraints of BEBs within the MBTA's operating environment in preparation for larger deployments in the future.

2.2.1 Fleet Electrification

2.2.1.1 Facility Electrification

To ensure that facilities could accommodate an electric bus fleet, a detailed evaluation of existing spatial assets and required utility improvements is needed for both existing facility modifications and new proposed sites. New facility designs shall provide spatial flexibility in accommodating current electric fleet charging and maintenance standards and shall anticipate for future changes such as varied methods of service, fleet typology, and bus sizing.

MBTA will work 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. The utility will likely need to install or upgrade substations, install new circuits and transformers, possibly 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 shall occur in the early stages of the project design.

2.2.1.2 Site and Building Impacts

Key considerations when designing facilities to transition to an electrified fleet include the following:

- Site planning shall accommodate adequate contingencies for potential upsizing requirements of electrical equipment (e.g., switch gears, transformers, Supervisory Control and Data Acquisition [SCADA] rooms, and generators). Significant area (likely in the thousands of square feet of space) will need to be dedicated to site electrical equipment.
- Facility electrification will require adequate space for additional electrical rooms, charging stations, fleet operations/charge control room, charging dispensers, and additional circulation. Specific maintenance needs, such as large battery storage, battery testing bays, possible need for a load bank to test batteries, pantograph maintenance, maintenance bay configurations for different bus types and vendor types, and other powertrain provisions, shall be considered in the facility layout.
- Service lanes will no longer be used for fueling, but will continue to be used for daily cleaning, bus data collection, and fare pull (until MBTA transitions to the planned cashless automated fare collection system [AFC 2.0], at which point fares will not be pulled but accommodations shall be made in the facility design for data to be downloaded either while the bus is in the service lane or another location in the facility). The automatic bus wash system will not be affected.

- Diesel dispensers and tanks will continue to be used for auxiliary heaters and could also be used for diesel storage for new generators to backup charging infrastructure.
- Older bus batteries with many cycles may no longer be fit for bus service but could serve as a short-term energy storage for the facility. Future consideration for space and connectivity of the older batteries could be a useful strategy.
- An all-electric fleet will have less maintenance fluids distributed to the service area and maintenance bays (reels, dispensers, and piping); only coolant and window wash fluid will be needed in service lanes and chassis grease for maintenance bays. There will be no engine oil and transmission and brake fluid replacement will only occur every 80,000 to 90,000 miles, possibly eliminating the need for bulk storage and piping onsite.
- The roof framing members of the bus storage and maintenance areas need to accommodate the additional loadings associated with overhead charging contacts, wiring, and conduit. Currently, it is envisioned that electric buses will use folding pantograph for charging at MBTA facilities. Plug connection, such as a Society of Automotive Engineers (SAE) J1772, will be needed at the maintenance bays to avoid use of pantograph connections (SAE J3105) where they will conflict with lifts and hanging equipment.
- Based on currently available technology, there will be a large space requirement for charging stations and associated hardware.
- MBTA operational requirements are such that charging equipment shall be elevated above bus circulation (approximate 12-foot clearance) and away from work areas for safety. Chargers, substations, and other critical components shall be located at the mezzanine level where possible to meet resilience performance thresholds. There shall be a de-energizer or rapid disconnect switch at ground level on a structural column in the event of emergency. Feeder lines shall be set in slab with specific distribution within the facility determined during the design process.
- Transitioning to an all-electric fleet will reduce maintenance costs, but battery maintenance and electronic component exchange are likely to increase. Overall, the need for the number of maintenance bays may be reduced. Shop areas for interchangeable component repair could be located at the extra maintenance bays or on a mezzanine level above the maintenance or shop area.
- An all-electric fleet will reduce the general building ventilation needs within maintenance and storage spaces, but only if there are no fossil fueled vehicles allowed in the facility. A vehicle engine exhaust system is not required in the maintenance bays if the fleet is all electric.

2.3 Facility Asset Management

Transit Asset Management is a business model that uses the performances and condition of assets to guide the optimal prioritization of funding and maintain a State of Good Repair. Asset management optimizes performance, risk, and cost over the entire life-cycle of an asset.

State of Good Repair

The condition in which a capital asset is able to operate at a full level of performance. A capital asset is in a state of good repair when that asset:

1. Is able to perform its designated function,
2. Does not pose a known unacceptable risk, and
3. Its life-cycle investments shall have been met or recovered.

The goal of applying asset management principles to facility design and construction phases is to build structures that will be operated, maintained, and eventually retired and replaced in the safest, most efficient, and cost-effective manner. In general, the designer shall design a facility that aims at minimizing life-cycle costs and risks of operating and maintaining the facility and its component systems and assets.

This section provides an overview of asset management requirements related to bus facilities, as well as guidance and requirements for the designer to facilitate MBTA's implementation of facility asset management practices.

2.3.1 Overview of Federal Asset Management Reporting Requirements

In 2016, the Federal Transit Administration (FTA) published the Transit Asset Management Rule to help achieve and maintain a State of Good Repair for the nation's public transportation assets. The rule applies to all transit operators that receive federal funds to support the provision of transportation services, including MBTA, and requires annual reports to FTA's National Transit Database that include information relevant to bus maintenance facilities, such as an asset inventory that catalogs data (e.g., facility name, address, and square footage), as well as condition assessment and performance results.

2.3.2 Overview of the MBTA Enterprise Asset Management System

The MBTA is implementing an enterprise asset management system aimed at supporting MBTA staff to manage its physical assets, including bus maintenance facilities and their components. The enterprise asset management system is designed to inform MBTA staff of maintenance and operational activities while producing performance and condition data to support decision-making of future maintenance activities and capital renewal activities.

The enterprise asset management system conforms to the MBTA asset inventory hierarchy framework as set forth in the MBTA Asset Data Standard and the MBTA Asset Definitions and Data Dictionary Document (AD4) for Facilities. The MBTA maintenance facility asset hierarchy is based on the ASTM International (ASTM) Uniformat II classification and aligns with FTA's classification framework as described in the FTA Transit Asset Management Facility Performance Measure Reporting Guidebook: Condition Assessment Calculation (March 2018), which categorizes facility components into the following primary levels:

1. Substructure
2. Shell
3. Interiors
4. Conveyance
5. Plumbing
6. Heating, ventilation, and air conditioning (HVAC)
7. Fire Protection
8. Electrical
9. Equipment
10. Site

MBTA conducts periodic condition assessments of its facilities using a process outlined in the MBTA Facility Condition Assessment Methodology. The condition assessment is primarily intended to assess the overall physical condition of the facility and components listed above to support maintenance prioritization and capital investment decisions. Facilities under construction are exempt from condition assessment requirements but reporting requirements will take effect following commissioning of the facility.

2.3.3 Design Requirements to Support Asset Management Activities

The designer shall 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.

The facility design team shall ensure visibility and/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 shall 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 shall allow easy access for maintenance, upgrades, and replacements.

2.4 Sustainability and Resilience

This section (with supplemental material provided in Appendix A) guides design teams in preparing design plans and project documents that provide enhanced levels of achievement in sustainability and resilience. Both the design and construction teams shall provide documentation of sustainable and resilient project features as described in this section. The following subsections and associated Appendix A define the requirements for sustainable and resilient MBTA bus maintenance facility design.

MBTA bus maintenance facility designs shall address sustainability from a holistic approach, being simultaneously environmentally responsible, socially equitable, operationally achievable and economically viable. They shall 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 and high winds shall be considered. For many weather-related disruptors, the resilience challenges are secondary; the loss of power, potable water, and other utilities that follows an extreme event are generally more challenging than the weather event, itself.
The sustainability and resilience guidelines herein protect employees, avoid environmental degradation, improve surrounding neighborhoods, facilitate financial responsibility, and maintain critical functionality and efficiency in operations (critical functionality is further defined in Section 2.4.4.3, Resilience Performance Requirements and Goals, and is determined on a facility-by-facility basis using the guidance in Section 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity).

MBTA defines sustainability in its Sustainability Report (MBTA 2017) as “the ability to be maintained at a certain rate or level; avoidance of the depletion of natural resources in order to maintain an ecological balance.” In the Engineering and Architectural Design Guidelines (The VHB/HNTB Team – a Joint Venture 2017), resilience is defined as “a system’s ability to recover from an acute extreme weather event (i.e., storm surge or flooding event) or to anticipate and respond to future climate condition scenarios (i.e., increasing temperatures, sea-level rise, or changing precipitation patterns).” Likewise, the Flood Resiliency Design Directive (MBTA 2019) defined resilience as “as the ability of a system or asset to withstand or recover from an extreme weather event.” For the purposes of this document, resilience is expanded to encapsulate disruptions associated with pandemics or disease outbreaks due to the impact from the COVID-19 pandemic. In future iterations, resilience could be expanded to address other non-climate related hazards and disruptions such as earthquakes, terrorism, cyberthreats, population shifts, and other manmade conditions. Section 2.4.4.2, Resilience Disruptors, further defines disruptors (such as extreme weather) and disruptions (such as power loss) that will be considered during design. Section 2.4.4.5, Resilience Adaptation Strategies, discusses physical adaptation and operational strategies.

Sustainability and resilience take holistic and systematic approaches to design, which lead to synergies and tradeoffs in process (see Figure 2.4-1). For example, energy through the sustainability lens would focus on efficiency and renewable energy for the sake of reducing the impact on the natural environment, improving air quality, and reducing costs. Energy through the resilience lens would consider increasing redundancy and diversity in power supply and/or using onsite renewable energy with battery backup to reduce reliance on the electric grid. Both sustainability and resilience practices may prefer the use of renewable energy to reduce greenhouse gas emissions for air quality and climate change mitigation purposes. Some resilience measures may promote outcomes that may not be the most efficient, such as using additional raw materials to build redundancy. The overall goal is to maximize synergies and reduce tradeoffs wherever possible.

The following guidelines assume that the site selection has occurred, and that sustainability and resilience were considered in the process.

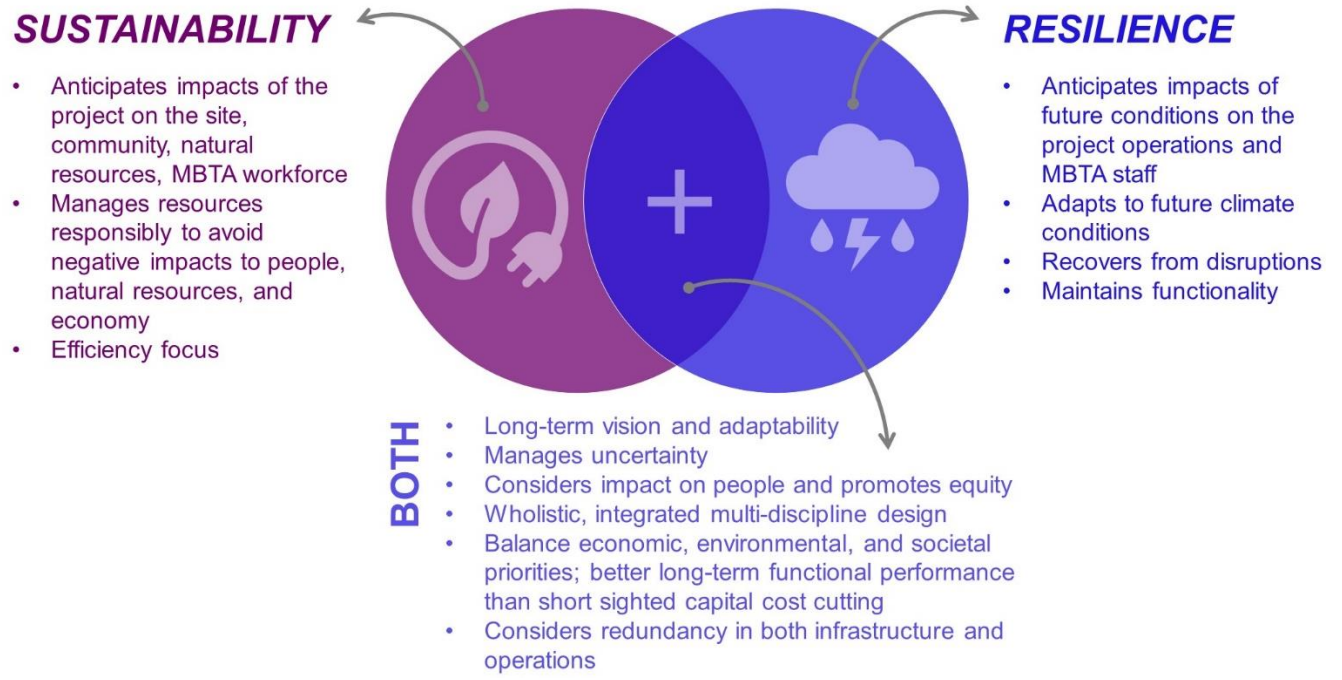


Figure 2.4-1. Sustainability and Resilience Overlap

2.4.1 Sustainability and Resilience Leadership and Project Management

Project teams are better able to serve the MBTA and project communities when led and managed by people and organizations that have a strong commitment to the principles of sustainability and resilience and are able to effectively incorporate these principles into projects. Design teams shall be assembled with the requisite expertise in these areas to provide the required data, evaluate potential impacts over time, and design a facility that incorporates sustainable and resilient features and construction principles.

2.4.1.1 Leadership Roles and Requirements

Design teams shall 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 leads can be subconsultants. These sustainability and resilience leads will interface with each other, the design and construction Project Managers (PMs), and the MBTA PM throughout the project timeline to ensure compliance with the requirements herein, accountability, and continuity. The MBTA PM will facilitate coordination of the design team with the MBTA Environmental and Energy Department at the onset of the project to develop project-specific goals and expectations.

- 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.

The sustainability and resilience information throughout this document holistically addresses new construction project types. If any project scope necessitates a major renovation, compliance paths may vary from guidance provided herein and will need to be reviewed on a per-project basis. The S+R Admin and Coordinator are responsible for identifying any applicable variances and coordinating with the project team to accomplish all requirements.

Refer to Appendix A for additional required qualifications for the S+R Admin and Coordinator.

2.4.1.2 Sustainability and Resilience Management Plan

In conjunction with the project team, the S+R Admin shall 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 SRMP shall detail how sustainability and resilience will be integrated into the project's design, track compliance and progress throughout the design process, and include placeholders for required components related to the construction phase that will be populated as the project progresses. The SRMP also requires specific forms for documenting critical assets, confirming critical functionality and resilience performance thresholds, and describing how resilience was integrated into each discipline. The following main aspects combine to represent the SRMP content:

- Specific project design and performance tracking for MBTA use
- Documentation of design intent and criteria
- Energy, water, and materials performance requirements
- Construction activities required for certification
- Resilience assessments and considerations

See Appendix A for required SRMP details, including submission milestones, component descriptions, and primary responsible parties.

2.4.1.3 Pursuit of Third-party Certifications: Envision and LEED

During the design process, MBTA will indicate whether formal third-party certification(s) will be pursued for a specific project. The SRMP described in Section 2.4.1.2, Sustainability and Resilience Management Plan, is a necessary tool for proving performance, tracking progress, and fostering accountability to obtain third-party certification(s). If the project does not pursue formal certification, the criteria from the rating systems and other reputable sources still allows the MBTA, design, and construction teams to have reliable benchmarks for measuring and recording project performance.

Regardless of certification pursuit, project teams shall use relevant criteria from Envision and LEED certification programs to guide project design, construction, and documentation and achieve a highly sustainable and resilient project encompassing location, community, site, and building. Throughout this document, the design team is provided with applicable Envision and/or LEED design considerations for easy reference. Most content is provided within the individual reference guides provided by these rating systems; any additional content has direct references provided for the user.

Refer to Appendix A for descriptions of Envision and LEED, resources, and framework overlap.

2.4.1.4 Integrative Process

The integrative process actively seeks to design and construct projects that are cost-effective over both the short and long terms, by engaging all project team members in an intentional process of discovering mutually beneficial interrelationships and synergies between systems and components, in a way that unifies technical and living systems so that high levels of building performance, human performance, and environmental benefits are achieved. The process unites project stakeholders in their efforts to plan, program, design, construct, commission, and transition to operation new building projects.

The entire project team shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

See Appendix A for further instruction on integrative process requirements.

2.4.1.5 Sustainability and Resilience Educational Material

To take advantage of the educational value of the sustainable and resilient features of a project, design teams shall actively incorporate instructional design components appropriate for each project to communicate the sustainability and resilience value to MBTA stakeholders, occupants, visitors, and the general public, particularly for the community in which the project will reside.

The S+R Admin shall work with the project team and MBTA PM to determine the desired format and content for presenting sustainability and resilience educational material specific to the project to the project's end users and visitors. The S+R Admin may use the SRMP as the organizing tool since it will contain all major sustainability and resilience measures specific to each project in a uniform format that will exist for each project. Additional measures outlined throughout this Design Guideline or new concepts brought forth by the project team will be considered for inclusion in the content to present a holistic summary of each project's sustainability and resilience contributions. The entire project team shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to Appendix A for details on developing and documenting content for the education requirement.

2.4.1.6 Construction Activities Requirements

The design team is responsible for providing directives for the construction team in the form of construction drawings and specifications. The SRMP shall also describe construction documentation needed for third-party certification submittal and provide templates for the construction team to complete. The SRMP is not contractually binding by itself, therefore the specifications shall include explicit requirements for the contractor performance and documentation for the contractor to fairly price and staff these actions in the bid. The requirements outlined in this subsection educate the project team and the S+R Admin on aspects that shall 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
- Waste management and indoor air quality during construction
- Post-design commissioning activities

Refer to Appendix A for additional details of the construction phase requirements.

2.4.2 Local and Regional Sustainability and Resilience Initiatives

Though MBTA is not required to adhere to location-specific project criteria (in accordance with Massachusetts General Law (M.G.L.) Chapter 161A Section 3(i), the MBTA), project teams shall be aware of their project's relationship with its location, as well as the relationship between the host city and the MBTA. In many ways, the MBTA has intentionally aligned their own policies and procedures with these greater efforts; as such, the designer shall review the local requirements for comparison to MBTA standards. Appendix A includes a list of regionally specific initiatives and parallel commitments from the MBTA.

2.4.2.1 MBTA Sustainability and Resilience Plans and Policies

Environmental stewardship and resilience are key priorities for the MBTA, as outlined in its 2018 Strategic Plan Update (MBTA 2018). Designers shall coordinate with the Energy and Environment Department for updates on current policies and plans related to sustainability and resilience. Appendix A includes a preliminary list and description of key participations for both sustainability and resilience.

2.4.3 General Sustainability Requirements

The following subsections outline key, multidisciplinary areas where numerous project team members—rather than single disciplines, technologies, or products—contribute to overall performance of the facility via integration into the overall design.

2.4.3.1 Site-related Requirements

Requirements related to the project context, location, and site are individually addressed primarily in Section 2.5, Environmental Protection and Enhancement, and Section 3.1, Civil and Landscaping, and include, but are not limited to, the following:

- Outdoor air quality
- Stormwater management
- Equity and environmental justice
- Noise and vibration
- Community connections and enhancement
- Open space and natural preservation/restoration
- Reduction of heat island effects
- Electric vehicle charging
- Project carbon reduction
- Light pollution mitigation

Associated Envision and LEED credit references are located in context with the above topics.

2.4.3.2 Towards Net-Zero Carbon

The design team shall develop a Carbon Reduction Plan that moves the project towards net-zero carbon, considering both operational and embodied carbon. Operational carbon is defined as carbon associated with the energy required to operate the building over time. Embodied carbon is defined as the carbon associated with the materials used to build the project throughout material's life-cycle, including the construction process itself. Achieving net-zero carbon may not be feasible for all bus maintenance facility projects, but the designer shall seek opportunities and implement designs that reduce operational and embodied carbon to the greatest extent possible. The Carbon Reduction Plan shall include strategies to achieve or move towards the following:

- Operational Carbon: A minimum of 25 percent reduction in energy consumption from the baseline building performance (requires coordination with Section 2.4.3.3, Energy Efficiency Performance)

- Zero Combustion: Eliminating onsite combustion of any fossil fuel source for any purpose (MBTA may approve an exception for code-required emergency standby power)
- Embodied Carbon – Primary Materials: Reducing embodied carbon by 10 percent or more for Primary Materials (i.e., foundation, structure, and enclosure systems) from a baseline building
- Total Embodied Carbon: Avoid exceeding 500 kg-CO_2e/m^2 of total embodied carbon of Primary materials and all other interior materials

The project team shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to Appendix A for additional details about the Carbon Reduction Plan and moving towards net-zero carbon.

2.4.3.3 Energy Efficiency Performance

The efficient use of electrical energy is critical to both resilience and sustainability. Efficiency provides economic and environmental benefits in normal operations. During events like power outages, efficiency facilitates passive survivability through the reduced requirement for onsite generation of electricity. When attempting to power a building with onsite renewable energy, efficiency simplifies the requirements for renewable energy.

Designing a high-performance building through an integrative design approach is required as a key criterion to providing resilience and sustainability where all design, construction, and operations personnel think of the building as a system, not as individual components. Interdisciplinary solutions shall be identified that result in savings that dwarf component-based efficiencies. Well thought-out, cost-effective, simple-to-maintain strategies shall result in the downsizing of HVAC equipment, artificial lighting, and electrical systems to provide low-energy performance with a conventional budget that meets the facility operational requirements.

Design team members shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

See Appendix A for detailed requirements related to achieving overall project energy efficiency goals.

Refer to *Envision Sustainable Infrastructure Framework* (v3)*, RA2.1 Reduce Operational Energy Consumption*; LEED v4.1, *Energy and Atmosphere Credit 2 Optimize Energy Performance*; LEED v4.1, *Energy and Atmosphere Credit 4 Grid Harmonization*.

2.4.3.4 Water Performance

Efficient water use provides economic and environmental benefits during normal operations and is key to a sustainable and resilient design. During events when there is an interruption in water supply, water efficiency optimizes resilience and the use of scarce water resources.

It is anticipated that all projects will be served by a variety of existing municipal potable water supply sources. Consider the costs and benefits of using a non-potable water source instead of potable water where appropriate and safe. Non-potable sources include recycling of bus wash water, rainwater, and greywater harvesting. Water-efficient design is primarily concerned with first reducing the demand for potable water, and secondarily reducing the demand for non-potable water. The LEED references below provide design guidance for indoor and outdoor potable water use.

Provide a Water Performance Plan report highlighting predicted potable water demand reductions for sanitary systems, process systems, and exterior systems. Identify any sources or potential for non-potable water use. Design team members shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

If the project includes a new intake from surface or groundwater resources, then the related analyses in the referenced Envision credits are applicable.

Refer to Envision Sustainable Infrastructure Framework (v3), *RA3.1 Preserve Water Resources; NW2.4 Protect Surface & Groundwater Quality; NW3.2 Enhance Wetland & Surface Water Functions; and CR2.2 Assess Climate Change Vulnerability;* Refer to LEED BD+C v4/4.1 Credits*: WE Prerequisite and WE Credit: Outdoor Water Use Reduction; WE Prerequisite and WE Credit: Indoor Water Use Reduction*; *WE Prerequisite: Building-Level Water Metering*, *WE Cr 4 Water Metering; WE Cr 3 Cooling Tower Water Use*.

Indoor Water Quality

Requirements contributing to water quality (water that is intended for human consumption) are individually addressed in Section 3.6, Plumbing, with full details provided in Appendix A (including associated Envision and LEED credit references), and include, but are not limited to, the following:

- Filtering and treatment systems
- Contaminant reduction
- Testing procedures

2.4.3.5 Commissioning Activities (Design Phase)

The commissioning process is critical to ensuring high-performance. Early involvement of a commissioning authority helps prevent long-term maintenance issues and wasted energy by verifying that the design meets the owner's project requirements and functions as intended. Commissioning is a connecting activity linking the decisions made in the early design energy simulations to ongoing efficiency in operations by balancing and tuning energy systems, and providing the feedback means with metering and monitoring for sustainable and resilient performance.

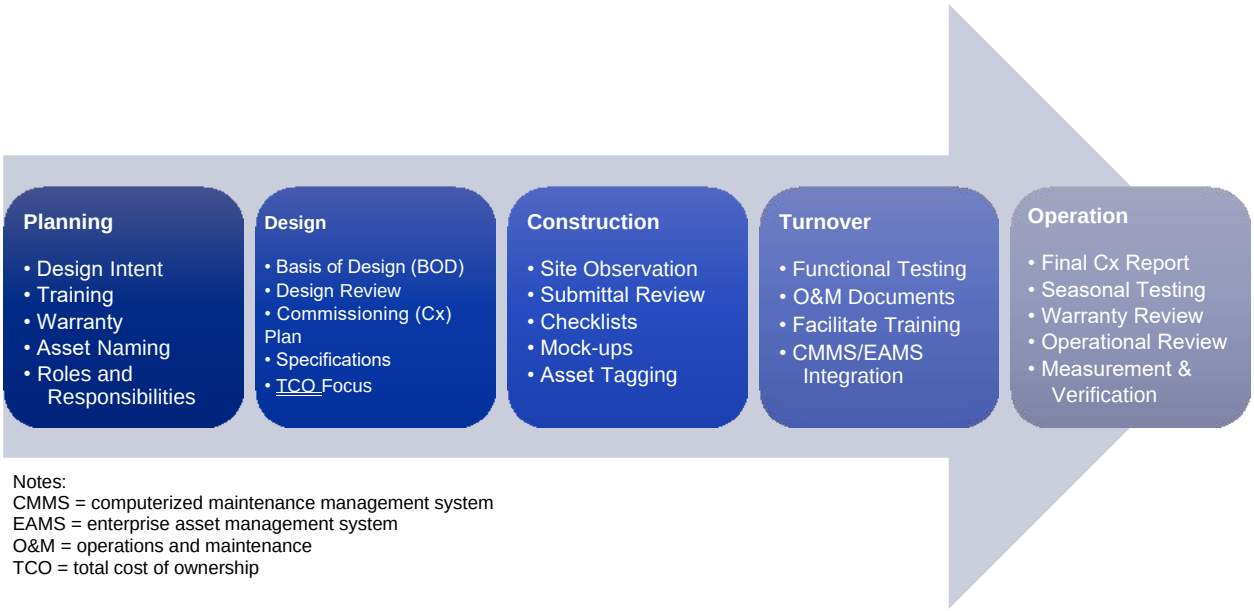


Figure 2.4-2. Commissioning Activity Workflow

Assurances can be provided by integrating a *total building commissioning program* into each new construction and renovation project. The program extends from planning through activation and occupancy. The operations and maintenance plan shall also include anticipation of disruptions, and guidance on restoring the systems to effective and efficient functioning. This section describes key

elements of the program. The level of detail for each component is adjustable to match the size and complexity of the project.

Refer to Appendix A for additional explanation of the commissioning authority's roles and responsibilities associated with the design phase.

Refer to Envision Sustainable Infrastructure Framework (v3), RA2.4 Commission and Monitor Energy Systems; LEED BD+C v4/4.1: EA Prerequisite: Fundamental Commissioning and Verification and EA Credit: Enhanced Commissioning.

2.4.3.6 Health and Safety Procedures

Project Safety Plan

Because project teams may encounter enhanced design, product, or construction specifications that may not be present in standard criteria, project teams shall conduct a life-cycle safety and health analysis and develop a Project Safety Plan to address risks associated with using new materials, technologies, and/or methodologies. The purpose of the Project Safety Plan is to support high-performance, cost- effective employee safety and health outcomes across the building life-cycle through early attention to safety and health hazards. The components of these requirements address safety procedures for onsite workers, personnel training and development, and site and information security. These themes not only protect the individuals working on the site, they help to maintain safe and secure operations of the asset and provide a foundation for proper operations and maintenance of the facility. The project design team shall initiate the Project Safety Plan and transfer the document to the construction team to inform construction phase implementation of these project features.

Refer to Appendix A for additional details on Project Safety Plan requirements, which shall be coordinated and in alignment with the safety certification process outlined in Section 1.3.

Pandemic-related Considerations

The project team will incorporate appropriate design features in response to COVID-19 and other similar potential occurrences. Decisions shall be made by following the most current guidelines and requirements from appropriate authorities, including the Massachusetts Governor's office and the Centers for Design Control, and coordinated with the MBTA. The following sources (and any future editions) shall be consulted for discipline-specific considerations as appropriate:

- AIA. 2020. COVID-19 Resources for Architects.
- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). 2020. Coronavirus (COVID-19) Response Resources from ASHRAE and Others.

2.4.3.7 Materials and Resources Performance

All projects shall develop a Material and Product Plan to identify and determine qualifying components for inclusion in final full design specifications and project drawings. The Material and Product Plan shall be initiated by the S+R Admin and finalized in collaboration with the full design team. It shall then be communicated to the S+R Coordinator and construction team, the party responsible for final implementation via informed procurement. Designers shall communicate these requirements as well as requirements to track material and product data to project contractors via contract documents.

The Material and Product Plan shall contain at a minimum a list of all materials in the project, organized by Construction Specifications Institute division format, and identifying performance values and compliance with each sustainability target. Refer to the Living Building Challenge Materials Tracking

Table available at http://living-future.org for an example (International Living Future Institute 2020). These targets include, but are not limited to, the following:

- Recycled Materials – reduce demand for virgin materials through the use of recycled, renewable and reused materials
- Salvaged Materials – One material per 5,000 GSF of project area
- Material Content, Transparency, Sourcing and Reuse Potential – 50 percent by cost which meet requirements of one or more of the listed categories
- Red List Compliant – Materials compliant with the Living Building Challenge Red List of chemical components, for 70 percent or more of all materials by cost
- Low Emitting Materials
- Embodied Carbon – Cross referenced embodied carbon materials and Carbon Reduction Plan

Refer to Appendix A for additional details of the Material and Product Plan requirements.

2.4.3.8 Indoor Environmental Quality Performance

Indoor Air Quality Performance

Requirements contributing to indoor air quality are addressed primarily in Sections 3.2, Architectural, and 3.4, Mechanical, (with associated Envision and LEED credit references) and include responsible material and product selection, minimum and enhanced indoor air quality strategies, increased filtration, and microbe and mold control. Refer to Appendix A for detailed requirements of indoor air quality monitoring and devices.

Flexible Design of Buildings

Adaptability to future building use conditions is described in the MBTA Focus40 plan as the Scenario Planning Framework. Flexible design is a priority in operational facilities, as priorities can shift and require different functionalities. Having flexible major building elements increases project space flexibility, ease of adaptive functional building use, and recycling of building materials while considering differential durability and premature obsolescence over building design life and individual component service lives.

All projects shall produce a project-specific Flexible Building Study in early design phases, prior to the completion of concept development. The Flexible Building Study shall explore design strategies that could be used to ensure longevity of the building past initial intended use and occupancy type.

Contents of the Flexible Building Study will vary based on main areas included in the facility design. Some projects may have fewer opportunities; such circumstances shall be included in the Flexible Building Study to explain why a particular project may have had project-specific constraints and could not adequately address flexibility and adaptation.

The design team shall ensure, via coordination between the S+R Admin and that of the construction team, that performance is tracked through construction to confirm that the reuse and flexibility requirements specified in the project documents are implemented in their entirety. Design team members shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

The following compiled documentation shall be provided to the S+R Admin for inclusion in the SRMP and MBTA PM in accordance with the above requirements:

- A narrative indicating which strategies will be implemented in the project, and justification of why remaining strategies were not employed

- Site drawings, floor plans, and sections identifying flexibility strategies, as applicable
- Cutsheets and product information showing compliance with flexibility strategies, as applicable

Refer to *Envision Sustainable Infrastructure Framework* (v3)*, LD2.1 Plan for End of Life* ; LEED BD+C v4/4.1, *Innovation Catalog, Innovation – Design for Flexibility* (USGBC 2020a)*.*

Vertical Circulation Performance Requirements

Stair climbing is classified as moderate-to-vigorous physical activity and can enhance the health and fitness of building occupants. By creating aesthetically designed staircases and hallways, and encouraging stair use when available, MBTA facilities can encourage occupants to accrue bouts of health-enhancing physical activity throughout the day. To promote design that enables occupants' daily physical activity and movement through the design of the circulation in a facility, the design team shall consider strategies addressing both accessibility and aesthetics.

For All Spaces

Implement point-of-decision signage that encourages stair use at each of the following locations within the project boundary (minimum of one sign per location):

- Elevator banks or other modes of motorized vertical circulation (such as escalators)
- Base of stairs/stairwells and re-entry points at each floor
- Junctions in corridors that lead to either a stairwell open to regular building occupants or an elevator bank (or other modes of motorized vertical circulation)

Stairways

Primary staircases in multilevel buildings shall be located physically and/or visibly before any motorized vertical circulation (that is, an elevator), as measured from the main point of entry to the project or building. The primary stair shall be visible from the main corridor by either:

- Providing transparent glazing of at least 10 square feet at all stair doors or at a side light
- Providing magnetic door holds on all doors leading to the stairs
- Providing unenclosed stairs

At least one stairway or other active path between floors (such as a ramp) shall be accessible to all regular building occupants, service all floors of the building, and be aesthetically designed through the inclusion of at least two of the following per floor:

- Artwork
- Light levels of at least 215 lux (20 foot-candles [fc]) when in use
- Views of an interior atrium, courtyard or daylight via windows or skylights
- Natural design elements (for example, plants, water features, images of nature)

Provide a summary of the circulation measures implemented and submit in final electronic format to the Sustainability and Resilience Administrator for inclusion in the SRMP, and MBTA PM as part of the design closeout phase. Design team members shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to LEED BD+C v4/4.1, *Innovation Catalog, Innovation: Design for Active Occupants* (USGBC 2020b).

Quality Lighting Design

Requirements contributing to optimal electric lighting design are individually addressed primarily in Section 3.5, Electrical (with associated Envision and LEED credit references) and include occupancy, daylighting, brightness, and glare controls; color rendering quality; and controllability.

Daylight and Views

Access to appropriate levels of natural daylight and views to the outside world in indoor environments can be achieved through building design and space layout. Windows, atriums, and skylights are design features that can be used to increase daylight in a space. The interior layout of the space also has an impact on the daylight exposure received by users; for example, conference rooms can be added to the center of the floor plate so that regularly occupied spaces in the main area have daylight exposure. Lighting strategies using electric lighting can be used to achieve required light exposure. Sensors are recommended to dim artificial lighting when sufficient daylight is available.

Design teams shall also consider occupants' views to the outside world when selecting interior partition types, doors, furniture, and other potentially obstructing space components that may not affect daylighting levels in the same manner.

Design team members shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

See Appendix A for detailed daylight and views requirements.

2.4.3.9 Interior and Exterior Quality of Life

Accessible, Inclusive, and Universal Design

Universal Design recognizes and encourages assets inclusive for all users regardless of age, size, or ability to use an asset. It addresses multiple aspects of a built space, including infrastructure, signage, and technologies, and seeks to enhance the opportunity for all individuals to exist independently and comfortably in a space. Due to variations in legislation and design practices for accessibility, usability, and inclusivity, the project criterion herein does not stipulate extensive, specific design requirements, dimensions, or number of each type of feature within the asset. However, this criterion lists strategies that design teams shall consider for integration in order to constitute a reasonable level of provision and design of features for the type, size, and number of users of any particular asset.

Design team members shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to Appendix A for details of associated design requirements.

Acoustic Comfort

The project team shall produce an Acoustics Implementation Plan that is submitted in electronic format to the S+R Admin for inclusion in the SRMP and to the MBTA PM as part of design closeout. Performance criteria and documentation for indoor, occupied spaces shall be based on LEED v4.1 IEQ Credit for Acoustic Performance. Performance criteria and documentation for outdoor spaces and indoor spaces occupied for less than 1 hour per workday shall be based on Envision Sustainable Infrastructure Framework (v3), QL 1.4 Minimize Noise and Vibration.

<u>Impact Noise Mitigation</u>

Sound can transmit between rooms as structure-borne impact noise and is especially prevalent at maintenance facilities. Impact noise travels through structures (e.g., walls, floors, columns, piping) as

vibrations that are then radiated as airborne noise. Buildings constructed with resilient, composite floor-ceiling construction (e.g., thick concrete slab, suspended ceiling, floor with underlayment) generally exhibit lower degrees of impact noise radiation. Increasing acoustical separation between floors can foster better environments for focus and productivity and help maintain consistent, comfortable background noise levels in rooms.

To address this concern in the non-maintenance, regularly occupied project areas, the floor-ceiling construction in the spaces shall meet the minimum Impact Insulation Class ratings with materials tested in accordance with ASTM E492-09, ISO 717.2 or equivalent, unless other project criteria dictate specific treatment (see Table 2.4-1).

Table 2.4-1. Impact Insulation Class Requirements

Space Type	Location of Applicable Floor-Ceiling Assembly	Minimum Impact Insulation Class Rating
Quiet zones (except areas for concentration)	Above	55
Enclosed Areas for Concentration and Conferencing	Above	50
Open Areas for Concentration	Above	45

Refer to LEED Pilot Credit, *Enhanced acoustical performance - exterior noise control for additional design considerations* (USGBC 2020c).

Design team members shall contribute to the documentation; the S+R Admin is responsible for guiding the process.

2.4.4 General Resilience Requirements

The general resilience project requirements are structured as follows:

- **Section 2.4.4.1**: Resilience framework for bus maintenance facility design
- **Section 2.4.4.2**: 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 2.4.4.3**: Overall resilience performance goals to protect assets/infrastructure and minimize disruption under specific conditions or thresholds
- **Section 2.4.4.4**: Framework for designers to evaluate operational capacity to meet performance goals and establish acceptable downtime with MBTA stakeholders
- **Section 2.4.4.5**: Sample resilience adaptation strategies that designers can incorporate into both physical design and operational considerations to meet performance goals

Refer to Envision Sustainable Infrastructure Framework (v3), CR2.2 Assess Climate Change Vulnerability; CR2.3 Evaluate Risk & Resilience; CR2.4 Establish Resilience Goals and Strategies; and CR2.5 Maximize Resilience.

2.4.4.1 Resilience Framework

The resilience framework for MBTA bus maintenance facilities design focuses on strengthening and maintaining critical functionality today and in the future by utilizing 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 2.4.4.2 for descriptions of disruptors. A resilient system will maintain critical functionality, have a reduced recovery time during and after the disruption, and/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.

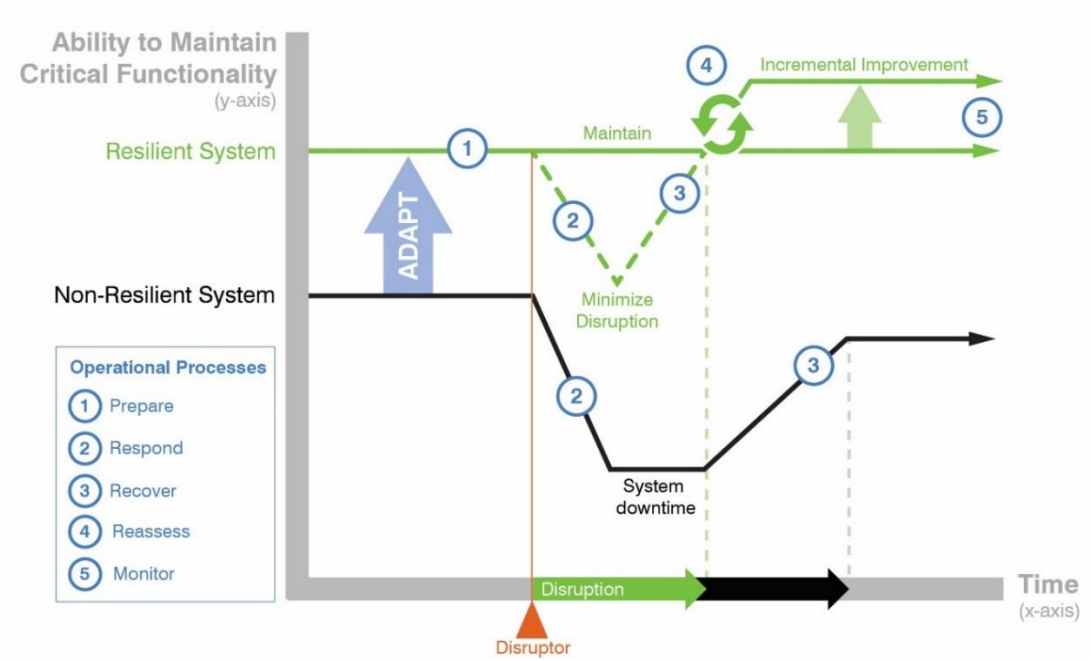


Figure 2.4-3. Resilient Framework—System Ability to Maintain Critical Functions/Minimize Disruption

As in Figure 2.4-3, 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 2.4.4.3, 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 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity, and Section 2.4.4.5, Resilience Adaptation Strategies.

Adapting to a resilient system is often accomplished during design of the asset, but designers shall 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.

"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[3] 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.

2.4.4.2 Resilience Disruptors

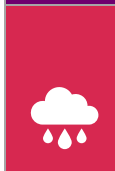
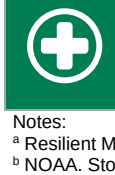
Bus maintenance facilities are vulnerable to natural hazards and other disruptors, such as manmade disasters and diseases outbreaks/pandemics. Many natural hazards are predicted to intensify and occur more frequently with climate change. As bus maintenance facilities are anticipated to function for decades, climate change considerations will be incorporated into design. Natural and climate hazards can be divided into four main categories with several types of extreme weather events falling into each. Likewise, preparation for the possible occurrence of future disease outbreaks and pandemics 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 State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) is the main source for the Historic Frequency and Increased Exposure Areas columns in Table 2.4-2 below. Although the information provided is for statewide occurrences, they are 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) (resilientma.org 2020).

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. Under each Impact Category in Table 2.4-3, there are example risks and corresponding considerations that will be addressed in the facility design.

[3] 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 percent of the statewide median ($62,072 in 2010); or 25 percent or more of the residents identify as a race other than white; or 25 percent or more of households have no one over the age of 14 who speaks English only, or very well.

Table 2.4-2. Resilience Disruptors – Historic and Future Trends

Icon	Categories and 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 1842-2016 ▪ 1 disaster declaration from severe storm every 9 years ▪ 1-2 tornadoes per year ▪ 44 high wind events per year on average from 2008-2017 ▪ 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 ▪ National Oceanic and Atmospheric Administration (NOAA) Storm Center Database[b]
	**Coastal Flooding** ▪ Sea-level rise ▪ Coastal surge	▪ 1 day of coastal flooding per year on average from 1950-2017	▪ 4.3 ft. of sea-level rise by 2070[c]	▪ Coastal areas ▪ Climate Ready Boston Map Explorer[d] – view High Tide and Coastal Flood Risk Maps	▪ Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map FIRMs ▪ MC-FRM[c]
	**Extreme Precipitation** ▪ Riverine flooding ▪ Stormwater ▪ Urban flooding	▪ State experienced a disaster declaration flood event once every three years based on events from 1954-2017 ▪ 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°F ▪ 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 two 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
	**Disease/Pandemic**[e] ▪ Zoonotic/ vector transmission ▪ Airborne transmission ▪ Direct contact transmission ▪ Contamination	▪ Undocumented at this time	▪ Confined areas ▪ High contact surfaces	▪ Center for Disease Control	

Notes:
[a] Resilient MA, Massachusetts Climate Change Clearinghouse. 2018. *Massachusetts State Hazard Mitigation & Climate Adaptation Plan.* September. http://www.resilientma.org/shmcap-portal/index.html#/full-plan.
[b] NOAA. Storm Events Database. https://www.ncdc.noaa.gov/stormevents/.
[c] Massachusetts Coast Flood Risk Model (MC-FRM)
[d] Climate Ready Boston Map Explorer. 2020. http://boston.maps.arcgis.com.
[e] Information not provided in SHMCAP.

Table 2.4-3. Resilience Disruptors – Physical and Operational Considerations

Impact	Example Risks	Example Consequences from Impacts	Disruptors
Assets and Infrastructure Threats	Equipment Damage	▪ Critical assets' condition, location, power source, and elevation ▪ Critical component replacements and storage locations	
	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.)	
	Accelerated Deterioration of Assets	▪ Equipment prone to overheating	
		▪ Possible structural damages from exceeded loads	
		▪ Corrosion of critical assets	
Operational Capacity Threats	Reduced Workforce Capacity	▪ Trained staff availability and capacity to reach site	
		▪ Preparation time and available resources (deploy flood barriers, move buses from parking lot, etc.)	
		▪ Response time and resources (bring in supplies/ batteries as needed, de-ice, snow removal, additional cleaning)	
		▪ Recovery time and resources (decontaminate, fix damages)	
	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	
		▪ Snow removal site/plan	
		▪ Supplies to charge extra batteries or more frequently charge batteries during peak demand or during periods of reduced battery life	
	Communication Breakdown	▪ Backup communications and controls	
Public Health and Safety Threats	Employee Safety	▪ Languages spoken	
		▪ Material choice (easy to clean)	
		▪ Sanitizer placement ▪ Ventilation systems with fresh air, filtration, ultraviolet disinfection, etc. ▪ Contactless options	

Table 2.4-3. Resilience Disruptors – Physical and Operational Considerations

Impact	Example Risks	Example Consequences from Impacts	Disruptors
		▪ MBTA employee data and emergency contact information	
		▪ Emergency response access ▪ Evacuation routes out of facility ▪ Storm shelter room ▪ Shelter in place preparation	
	Mobility	▪ Backup service ▪ Nearby bikeshare locations ▪ Options for people with disabilities ▪ Existing bike/ped options	
Financial Threats	Maintenance Costs	▪ Increased maintenance as a result of more frequent disruptors	
	Operating Costs	▪ Increased cleaning costs ▪ Overtime hours ▪ Utility cost spikes	
	Emergency Costs	▪ Increased Insurance costs ▪ Repair costs ▪ Reduced revenue	
Environmental Threats	Contamination	▪ Hazardous material storage locations ▪ Impacted building materials ▪ Impacted groundwater/vapor intrusion	
	Water Quality	▪ Site drainage/soil types ▪ Standing water potential	

2.4.4.3 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 shall 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 Resilient MA Action Team (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 shall refer to the most recent version of those standards and guidelines by visiting http://www.resilientma.org 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 Building Automation System 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 shall 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 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity, and shall be documented in the SRMP (see Appendix A). Critical assets and infrastructure are features of the facility necessary to function to support these performance goals, as well as any additional assets and/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 2.4.4.1, Resilience Framework. The specific conditions for each threshold are organized by disruptors as identified in Section 2.4.4.2, 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. Please refer to Appendix A for additional information related to the RMAT Statewide Climate Resilience Design Standards and Guidelines, including information related to the webtool for the preliminary climate risk screening output and standard methodologies to calculate the identified design criteria (e.g., future design flood elevations, rainfall depths) that are recommended in this section.
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 these guidelines below 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 2.4.4, 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 from 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 shall be documented in the SRMP (see Appendix A).

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 2.4.4.2, 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 shall 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 (Resilient MA 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.

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 2.4-4 by ASCE 7 Risk Category

Table 2.4-4. Snow and Ice Importance Factors (CAS-B12, 2015)

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

  - 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.

- **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 2.4.4.5, Resilience Adaptation Strategies.
  - 10 inches of snowfall within a 24-hour period
  - 30 inches of snowfall within a 72-hour period

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 2.4.4.5, Resilience Adaptation Strategies, under Category 4 Hurricane wind speeds.

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 shall 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 percent annual exceedance probability coastal flood with at least 2 ft. 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 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity, under the following conditions:
  - Current and future (2070 planning horizon) design flood elevation and duration for a 0.2 percent 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.

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 shall consider the intensity and frequency of these events today, as well as throughout their service life.

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 percent 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 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity, under the following conditions:
  - Current and future (2070 planning horizon) 24-hour rainfall depth and peak intensity for a 100-year (1 percent annual exceedance probability) design storm.

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 percent annual exceedance probability riverine flood with at least 2 ft. 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 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity, under the following conditions:
  - Current and future (2070 planning horizon) peak flood elevation and duration for a 0.2 percent 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.

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 degrees Fahrenheit (°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 shall 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 shall 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°F, 95°F, 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 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity, under the following conditions:
  - Current and future (2070 planning horizon) events that exceed the primary thresholds listed above for days over 90°F, 95°F, and 100°F and days below 32°F by up to 10 percent.
  - Current and future (2070 planning horizon) cooling degree days and heating degree days that exceed the primary thresholds listed above by up to 10 percent.

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.

Cumulative Disruptions

When one or more disruptors occur simultaneously or consecutively, the consequences may be greater and the ability to adapt, respond and recover may be more difficult. 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 five 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 four 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 2.4.4.4, Identifying Acceptable Downtime & Operational Capacity, for guidance.

2.4.4.4 Identifying Acceptable Downtime & 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 shall be referenced, such as any guidance provided by the MBTA Risk Council (pending release scheduled after the release of these guidelines). Designers shall utilize 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 (SWOP) (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 for the 2020 Hurricane Season (FEMA 2020) 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 shall 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 & 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 2.4.4.3, 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?

3. **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 2.4-3 for example consequences. Designers will identify the maximum acceptable downtime based on these consequences and associated disruptors.

4. **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 2.4.4.5, Resilience Adaptation Strategies, that meet the primary and secondary threshold performance requirements.

2.4.4.5 Resilience Adaptation Strategies

Both operational and physical design strategies shall be considered to meet the performance goals identified in Section 2.4.4.3, Resilience Performance Requirements and Goals. The resilience adaptation strategies presented in this section are categorized into operational and physical as follows:

Operational Strategies	Physical Strategies
Prepare	Protect
Respond	Accommodate
Recover	Retreat
Reassess	
Monitor	

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 shall be considered together in design and communicated in the SRMP and commissioning 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 shall 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 2.4.4.2, Resilience Disruptors, and illustrated in Figure 2.4-4 below.

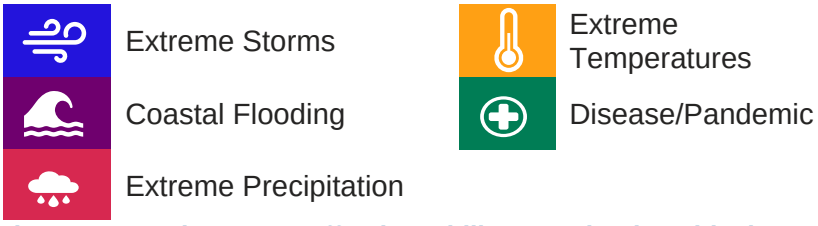


Figure 2.4-4. Disruptors Affecting Ability to Maintain Critical Functionality

Strategies can and shall 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.

Physical Resilience Strategies

When considering design strategies, refer to the resilience performance requirements and goals in Section 2.4.4.3, 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, 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. See the *Resilience Co-Benefits* section for more information on representative co-benefits.

Table 2.4-5. Physical Resilience Strategies

Design	Design Component	Strategy	Disruptors				
Retreat	General	Relocate assets out of flood zones and vulnerable locations if possible.	■	■	■		
		Elevate critical assets above design flood elevations.	■	■	■		
Protect	General	Secure elements that could erode or become debris and damage other assets or impact operations due to a storm event.	■	■	■		
		Seal and insulate elements that are common conduits for air and water entry.	■	■	■	■	■
		Install adequate shading structures and shelter for site occupants.				■	
	Site/Civil	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 site plan for incorporation of increased sanitary stations and space for social distancing.					■
	Architectural	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).	■		■		
		Include redundancy in design to prevent further compromising critical functionality of mechanical, electrical, and communication systems.	■				
		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.		■			
		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.					■
	Structural	Provide permanent site perimeter protection from floodwater.		■	■		
		Reinforce exposed structural elements to resist direct flood action and hydrostatic pressures.		■			

Table 2.4-5. Physical Resilience Strategies

Design	Design Component	Strategy	Disruptors				
		Design and construct deep foundations in flood zone.		■			
		Dry floodproof and reinforced walls.			■		
		Install permanent flood barriers around site to block flooding.			■		
	Mechanical	Provide redundancy in mechanical systems through standby units as needed.	■	■	■		
		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.		■			
		Wet floodproof critical systems with waterproof membranes or sealants.			■		
		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.				■	
		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.					■
	Electrical	Provide redundancy in backup battery supply for buses in storage and extra charging capacity.	■	■			
		Install heat exchangers in enclosed systems to dissipate heat.				■	
		Install electrical distribution equipment in well ventilated areas.				■	
		Provide cast coil transformers with fans for the distribution system.				■	
Accommodate	General	Consider corrosive resistant materials.		■			
		Consider reflective materials and solar facades.				■	
		Select easy to clean materials and surfaces.					■
	Site/Civil	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).	■		■		
		Provide pavement sections that will adequately withstand adverse weather impacts.	■		■		
		Design green infrastructure with salt-tolerant vegetated species that are resistant to extreme temperatures.		■	■	■	
		Consider destratification fans-internal circulation to eliminate thermal stratification.				■	
	Architectural	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.				■	
		Resilient roofing design with heating pads to de-ice and remove snow.	■				
	Structural	Design breakaway walls in coastal flood areas for storm surge.	■	■			
		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.			■	■	

Table 2.4-5. Physical Resilience Strategies

Design	Design Component	Strategy	Disruptors
		Install hydrostatic relief valves in the floor slabs and sub-floor trenches.	
		Dry-flood proof entrances that lead to mechanical rooms.	
	Mechanical	Install floor guard connections to floor drains and under slab drains in mechanical room to prevent backflow and flooding; consider backflow preventers.	
		Install an exterior duplex pump system to remove water in sub-floor trenches.	
		Consider emergency alternatives and shut-off pathways for air flow.	
		Consider sanitation and cleaning requirements in mechanical system design.	
		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.	
	Electrical	Provide extra battery supply for buses in storage and extra charging capacity.	
		Provide feeders and raceways resilient to flooding.	
		Consider alternate fuel sources for standby power.	
		Consider using submersible exterior transformers and substations.	
		Consider submersible sump pumps with water level sensors.	
		Provide enclosures rated for the extreme environments with heating and ventilation.	
		Consider thermic barriers and zones to reduce building energy demand and during extended temperature extremes.	
		Provide touchless (motion sensor) lighting.	

Operational Resilience Strategies

Operational strategies shall support the physical design of the bus maintenance facility assets and infrastructure. The strategies are structured for different stages of planning for a disruptor.

Table 2.4-6. Operational Strategies

Design	Design Component	Strategy	Disruptors				
							
Prepare	Plans	Plan for sharing facilities and/or buses with public and private partners					
		Plan for snow removal to designated storage sites					
		Plan for multiple evacuation routes in the event of flooding, obstacles, or blockages					
		Plan for site infrastructure inspection and maintenance, such as stormwater management systems to maintain proper working conditions					
		Storm shelter in place plans and supplies for critical staff to stay at the building during an extreme event					
		Develop an emergency communication plan and update contacts annually					
	Equipment	Where possible, relocate potentially vulnerable portable assets to protected locations in advance of a storm / temperature extreme					
		Test emergency equipment regularly. Confirm that equipment has not been damaged in storage and that parts have not been lost					
		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					
		Have available emergency alternatives to typical equipment, assets, and infrastructure					
	Workforce	Provide regular training for staff who would provide emergency support and develop protocol for preparation, response, and recovery					
		Designate area and supply storage for sheltering in place					
		Assemble staff and supplies for response and recovery					
Respond	Equipment	Adjust building automation system (BAS) equipment to save energy and continue operations during power outages					
		Deploy emergency response equipment					
		Provide and resupply hand sanitizer stations, PPE					
	Communication	Alert external media/communication contacts and internal employee emergency contacts					
		Share emergency messages in all languages spoken					
	Workforce	Provide adequate time, staff, and materials for response					

Table 2.4-6. Operational Strategies

Design	Design Component	Strategy	Disruptors
Recover	Equipment	Clean facilities and equipment after an extreme event and clear debris	
		Identify and address damage to facilities and equipment	
		Move buses and any temporarily relocated equipment back to facility	
	Communication	Alert external media/communication contacts and internal employee emergency contacts	
		Share emergency messages in all languages spoken	
	Workforce	Provide adequate time, staff, and materials for recovery	
Reassess	Plans	Update operations and maintenance plan for emergency equipment	
	Workforce	Consider additional staffing, training, equipment, or communications needs	
Monitor	Plans	Continue to review existing plans and changes to the natural environment that may affect them	
	Equipment	Continue to maintain equipment and review changes to the natural environment that may affect equipment performance	
	Workforce	Continue to evaluate staffing and training needs and changes that may affect workforce availability	
	Communication	Continue to evaluate communications needs and changes that may affect existing systems	

Resilience Co-Benefits

In addition to meeting the performance goals, the strategies identified in the sections above 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. A summary of representative examples of co-benefits is included below.

Table 2.4-7. 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, CSO 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 venerable portable assets to protected locations in advance of a storm / temperature extreme	Economic co-benefit of reducing maintenance costs

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 shall embrace strategies that adapt over time and respond to changing conditions. Designers shall 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 shall 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.

2.5 Environmental Protection and Enhancement

The environmental design requirements outlined in this section focus on preserving, protecting, enhancing and promoting environmental resources and environmental policies of MBTA and the Commonwealth. The specific regulatory and policy requirements may vary depending on the type of environmental review (federal, state, local) and the level of environmental review (CE, EA/ENF, Environmental Impact Report/EIS). Determining the Class of Action for projects involving federal funds is a first step, and FTA shall be engaged for this decision early. MBTA bus facilities will typically require review by the Massachusetts Environmental Policy Act Office with the specific level of review (Environmental Notification Form or Environmental Impact Report) to be determined.

The design team and Environmental Manager shall follow the MBTA Office of the Chief Engineer's Environmental Regulations Design Directive, dated June 2, 2020, for documentation and incorporation of environmental review into the design process. This Directive specifies the project will complete and provide up-to-date submission of the *Environmental Regulation Matrix* at each Phase/Submittal of the design process. The requirements within the Directive identify applicable state environmental regulations, energy efficiency standards, and other agreements/obligations that may be relevant to projects.

The bus maintenance facility size and location within developed communities and environmental resource areas determine the National Environmental Policy Act (NEPA) and Massachusetts Environmental Policy Act (MEPA) review processes in terms of review documents, timeframes, and project critical path. Key early questions involved in establishing the scope and timeframes for environmental review and permitting efforts are as follows:

- Is the project to be federally funded?
  - Is the project described in FTA categorical exclusions as defined in 23 CFR Part 771.117(c)/(d)?
  - Does the project solely consist of either a lawfully existing structure, facility, or activity; routine maintenance; a replacement project; or been previously reviewed under MEPA?

The Environmental Manager shall use the *Environmental Review and Permitting Checklist (ERPC) (MBTA, 2019)* to identify and track NEPA and MEPA environmental review requirements during early planning and throughout the design process.

In addition to following federal, state and local environmental regulations and policies, MBTA bus facilities (rehabilitated and new) shall incorporate state of the practice, smart technology-enabled, sustainable and context-sensitive solutions to minimize impacts to the environment. Designing facilities that preserve and protect environmental resources requires an iterative approach as the design advances and specific facility needs are established.

2.5.1 Local, Regional and MBTA Sustainability & Resilience Initiatives, Plans and Policies

The project team shall review local and regional sustainability and resilience initiatives, as well as, MBTA sustainability and resilience plans and policies to ensure commitments made to address potential environmental, climate and resilience impacts and concerns are incorporated into the project as appropriate. Below are some initiatives the project team shall review for environmental issues. Refer to Appendix A for the full list of regionally specific example initiatives and their parallel commitments from the MBTA.

Table 2.5-1. Local and Regional Sustainability and Resilience Initiatives

Topic	Document	Description
Air Quality	MA Global Warming Solutions Act (2008)[a]	This Act required the Massachusetts Department of Environmental Protection (MassDEP) to establish mandatory greenhouse gas (GHG) 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.
Floodplain, Stormwater	Boston Planning and Development Agency's Coastal Flood Resilience Design Guidelines (2019)	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 project outside of Boston located in coastal areas. Provides in depth technical considerations for buildings.
Environmental Justice, Stormwater	Medford Climate Vulnerability Assessment (2019)	Designers may look at the plan to preliminary view areas that are modelled 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 shall be considered.
Environmental Justice, Floodplain, Natural Resources	Statewide Hazard Mitigation and Climate Adaptation Plan (SHMCAP) (2018)	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.
Floodplain, Stormwater	BPWD Climate Resilient Design Guidelines for Public Rights of Way (2018)	Guidelines for designing flood protection within the City of Boston and for impacts to the public right-of-way
Floodplain, Stormwater	Boston Planning & Development Agency Climate Change Checklist (2017)	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.
Environmental Justice, Stormwater	Climate Ready Boston (ongoing)[b]	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. Neighbourhood plans provide short, mid, and long-term actions that may be application.
Environmental Justice	Climate Change Vulnerability Assessment - Part 1 (2015)	Part 1: Focuses on the vulnerability of assets to increased precipitation, heat, and the social and economic impacts of climate change.
Air Quality	Cambridge 2020 Climate Action Plan[c]	The goal of this action plan is to reduce GHG 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.
MBTA Plans & Policies	▪ MBTA 2017 Sustainability Report & Program (MBTA 2017) ▪ Storm Water Pollution Prevention Plan (SWPPP) (MBTA 2015a) ▪ 2019 Flood Resiliency Design Directive (MBTA 2019c) ▪ APTA Sustainability Commitment & Guidelines (APTA 2016)	

Notes:
[a] Mass.gov. 2020. *Global Warming Solutions Act Background.* https://www.mass.gov/service-details/global-warming-solutions-act-background
[b] Greenovate Boston. 2020. *Prepared City.* https://www.greenovateboston.org/prepared_city/
[c] Cambridgema.gov. 2020. *Climate Change Planning.* https://www.cambridgema.gov/CDD/climateandenergy/climatechangeplanning

2.5.2 Air Quality

An air quality analysis shall be performed, and an Air Quality Report prepared for the project based on the requirements of NEPA and/or MEPA and Massachusetts environmental requirements. If the project is found to produce any of the criteria pollutant emissions, the project team shall develop strategies to minimize or eliminate the emissions and/or include ongoing monitoring and management of direct air pollutant emissions.

The 1970 Federal Clean Air Act (CAA) (42 U.S.C. § 7401) requires a Transportation Conformity determination and Mobile Source Air Toxics analysis for the National Ambient Air Quality Standards as part of the NEPA documentation.

At the state level, the Code of Massachusetts Regulations Title 310 (310 CMR) 6.00: Ambient Air Quality Standards are ambient Air Quality Standards set by the Massachusetts Department of Environmental Protection (MassDEP). MassDEP has amended six regulations in response to a court ruling and Executive Order 569, directing the agency to establish specific declining greenhouse gas emission limits on many types of sources across the state to meet the requirements of Section 3(d) Global Warming Solutions Act of Chapter 21N General Laws. One of the six regulations, 310 CMR 60.05 (Global Warming Solutions Act Requirements for Transportation) was issued, requiring MassDOT to meet limits on carbon dioxide (CO_2) emissions from equipment owned by MassDOT and MBTA.

Refer to *Reduce Emissions (ANSI/ASHRAE/IES Standard 90.1–2010);* and *Envision Sustainable Infrastructure Framework* (v3), *CR1.2 Reduce Greenhouse Gas Emissions* and *CR1.3 Reduce Air Pollutant Emissions*.

2.5.3 Ecologically Sensitive Areas and Endangered Species

Refer to Section 7 Consultation of the Endangered Species Act of 1973 [16 U.S.C. 1531-1544] and the Massachusetts Endangered Species Act M.G.L. enacted in December 1990 (c. 131A) and revised as of January 2020 (321 CMR 10.00) administered by the Natural Heritage and Endangered Species Program.

A review of the project area, including a site visit, and coordination with the U.S. Fish and Wildlife Service and National Marine Fisheries Services, and the Massachusetts Natural Heritage and Endangered Species Program shall be performed to identify sensitive habitats and threatened or endangered species within and adjacent to the project area. When reviewing areas for sensitive habitats, the project team shall also consider ecosystem functions that support a diversity of species and habitats.

If sensitive habitats and/or threatened and endangered species are identified within or adjacent to the project area, the project team shall identify mitigation measures (i.e., avoidance, minimization, restoration, or offsetting) to address potential adverse impacts. A mitigation plan shall be developed by a qualified professional with expertise in ecological, natural resources and environmental habitats, and meet regulatory approval through federal and/or state agencies.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *NW1.1 Preserve Sites of High Ecological Value and NW3.1 Enhance Functional Habitats*.

2.5.4 Hazardous Materials

An environmental baseline survey of existing facilities or development parcels to be acquired shall be conducted in accordance with ASTM E1527-13 Standard for Environmental Site Assessments: Phase I ESA Process and, if applicable, ASTM E1903-19 Standard Practice for Environmental Site Assessments: Phase II ESA Process. Under the MassDEP Waste Site Cleanup Program, projects shall

ensure compliance with M.G.L. Chapter 21E and the Massachusetts Contingency Plan (MCP) (310 CMR 40.0000).

If contaminants of concern are identified in the project area, and has not been previously remediated or contained, the project team shall coordinate with regulatory agencies to determine the appropriate mitigation and/or remediation strategy for the site.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *NW2.1 Reclaim Brownfields*; LEED v4/4.1 SS Credit: *High Priority Site.*

2.5.5 Historic and Archeological Resources

The project team shall identify historic and cultural resources in and around the project site through coordination with community stakeholders and required regulatory and resource agencies. The project team shall also consider protecting cultural resources that are not necessarily protected in state or national registries. These cultural resources could include places, events, natural features, oral traditions, or local skills that are important to the community culture.

Any projects that require funding, licenses, or permits from federal agencies shall be reviewed in compliance with Section 106 of the National Historic Preservation Act (54 U.S.C. 306108). The specific process described at 36 CFR 800 requires federal agencies to consider the effects of their actions on historic properties and archeological resources.

Section 4(f) of the U.S. Department of Transportation Act of 1966 (49 U.S.C. §303 and 23 U.S.C. §138) protects public open space, parks, refuges and recreation areas, and historic properties. In addition, the State Register review (M.G.L. Ch. 9, sections 26-27c, as amended) and Ch. 254 of the Acts of 1988 (950 CMR 71) are similar to the Section 106 process and may be coordinated.

If historic or cultural resources are identified within and/or around the project site, measures shall be taken to protect, enhance or mitigate impacts to the resources. These measures shall be done in collaboration with community stakeholders and required regulatory and resource agencies.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL3.2 Preserve Historic and Cultural Resources.*

2.5.6 Stormwater

Refer to Section 3.1.7, Stormwater Drainage.

2.5.7 Land Use Compatibility

Although the MBTA is not subject to local zoning requirements, it seeks to develop its facilities consistent with local land use plans and zoning. In addition, the project team shall identify potential siting hazards that can expose the proposed project infrastructure asset to increased risk. Whenever possible, the project shall avoid developing or encouraging development in areas prone to hazards, such as frequent flood zones or areas of steep slopes.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR2.1 Avoid Unsuitable Development.*

2.5.8 Parks and Open Space

The project shall identify and assess potential impacts to existing public spaces and/or amenities in and around the project site through coordination with community stakeholders and resource agencies. At the very least, the project shall not contribute to a loss of public amenities, and ideally would add or restore public resources to the community.

The following regulations shall be followed as applicable:

- Section 4(f) of the U.S. Department of Transportation Act of 1966 (49 U.S.C. §303 and 23 U.S.C. §138) protects public open space, parks, refuges and recreation areas, and historic properties.
- Section 6(f) of the Land and Water Conservation Fund Act (16 U.S.C. 460 l-4) protects land purchased or improved using Land and Water Conservation Fund funding.
- Article 97 of the Articles of Amendments to the Massachusetts Constitution protects land and easements used for the enjoyment of natural, scenic, historic, and aesthetic aspects of the environment.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL3.4 Enhance Public Space and Amenities.*

2.5.9 Title VI Equity Analysis and Environmental Justice and Community Impact Assessment

A Title VI Equity Analysis shall be prepared in accordance with FTA and MBTA guidelines. The analysis shall evaluate the potential for siting locations to have disparate impacts to minority populations and disproportionate burden on low-income populations.

The Environmental Justice and Community Impacts Assessment included in the Title VI Equity Analysis shall evaluate the potential community and socioeconomic impacts of siting the project at the selected location, in accordance with the federal regulations for implementing the NEPA.

The Federal Highway Administration (FHWA) *Community Impact Assessment: A Quick Reference for Transportation* guide describes the iterative process to evaluate the effects of a transportation action on a community and its quality of life. The assessment process is an integral part of transportation planning and project development that shapes the outcome of transportation decisions. The Community Impacts Assessment is part of the NEPA process where all applicable environmental laws, executive orders, and regulations are considered, often referred to as working under the “NEPA umbrella”.

If the project team identifies negative social impacts that specifically include equity and social justice, the project team shall use the Title VI Equity Analysis, Environmental Justice, and Community Impacts Assessment to understand potential social impacts to stakeholders and ensure the impacted communities are represented and included in the stakeholder engagement process.

The following guidance shall be used in evaluating Title VI Equity and Environmental Justice:

- On December 16, 2011, FHWA issued a memo titled Guidance on Environmental Justice and NEPA describing the process to address Environmental Justice during the NEPA review.
- The FTA published Environmental Justice Policy Guidance for Federal Transit Administration Recipients Circular 4703.1 on August 15, 2012 for public transit agencies.
- The FTA also published Title VI Requirements and Guidelines for Federal Transit Administration Recipients Circular 4702.1B on October 1, 2012 for public transit agencies.
- Principles of Environmental Justice and Title VI will be reflected in existing policies, programs, procedures, processes, and accompanying documentation.
- In Massachusetts, the Executive Office of Energy and Environmental Affairs’ (EOEEA) *Environmental Justice Policy of Executive Office of Energy and Environmental Affairs* sets forth a policy for promoting equal protection and involvement.

Refer to *Envision Sustainable Infrastructure Framework (v3)*, *QL1.1 Improve Community Quality of Life and QL3.1 Advance Equity and Social Justice*.

2.5.10 Acquisitions and Relocations

All right-of-way acquisitions and relocations shall be planned to adhere to the Uniform Relocation Assistance and Real Property Acquisition Policies Act (Uniform Act), 42 U.S.C. 4601, et. seq., and the implementing regulations, 49 CFR Part 24.

2.5.11 Noise and Vibration

The Federal Transit Administration "Transit Noise and Vibration Impact Assessment Manual" (FTA 2018a) requires noise impact assessments for different types of land uses and their sensitivity to noise. Analysis of noise impacts may be required in Environmental Impact Report documents. MassDEP defines noise as "sound of sufficient intensity and/or duration as to cause a condition of air pollution" and is considered a form of regulated air pollution. The project shall review MassDEP regulations (310 CMR 7.10 U) for noise level criteria.

If after performing a baseline noise assessment where applicable and there is potential for construction and/or operational noise or vibration impacts, strategies shall be implemented to mitigate noise. Strategies considered by the project team shall include avoidance/source eliminations, minimization, abatement/receiver reduction and offsetting. The project shall also evaluate if there are local noise standards in place or if target project noise levels shall be adopted for the project.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL1.4 Minimize Noise and Vibration*.

2.5.12 Transportation

A Traffic Impact Assessment (TIA) (MEPA/MassDOT) may be required if a MEPA transportation threshold is triggered by the proposed project or if MassDOT State Highway Access Regulations are triggered. If no TIA is required, the designer shall describe the existing multi-modal transportation conditions, proposed new trips and impacts, the ability of the existing roadways to accommodate project-generated trips, and proposed mitigation if warranted. Also see Section 3.1.9, Traffic Impact Analysis.

The project team shall assess the mobility and accessibility of the project site with regards to site access configuration and modes in which the site could be accessed. Sustainable transportation options shall be evaluated for inclusion into the project, such as walkability to pedestrian-accessible transportation and public transit facilities, bike paths and trails.

Refer to *Envision Sustainable Infrastructure Framework* (v3), Q*L2.1 Improve Community Mobility Access* and *QL2.2 Encourage Sustainable Transportation*.

2.5.13 Safety and Security

The project team shall ensure the project meets all health and/or safety regulations and laws for operation and describe the measures that would need to be taken to provide for safe and secure operation of the facility after construction, such as fencing, public address systems, and lighting.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL1.2 Enhance Public Health and Safety*.

2.5.14 Water Resources

2.5.14.1 Wetlands and Waterways

The project team shall delineate wetlands and waterways on the proposed project site to determine if there are any potential temporary and/or permanent impacts to the Waters of the United States and/or Massachusetts jurisdictional wetland resource areas by the project. The project shall coordinate with the appropriate agencies U.S. Army Corps of Engineers (Section 401 and 404 of the Clean Water Act (33 U.S.C. §1251)) and/or MassDEP (Wetlands Protection Act (301 CMR 10.00)) for jurisdictional determinations and mitigation strategies, if and where applicable.

Because wetlands and waterways provide important ecological processes, such as mitigating flooding, improving water quality, and providing wildlife habitat, the project shall employ mitigation strategies to avoid and/or protect these resources, when possible. Protection could include implementing buffers areas and/or engineered controls around the resources.

Refer to *Envision Sustainable Infrastructure Framework* (v3)*, NW1.2 Provide Wetland and Surface Water Buffers* and *NW3.2 Enhance Wetland and Surface Water Functions*.

2.5.14.2 Floodplains

The project team shall identify if the project is within a floodplain (100-year or design frequency floodplain). In addition, project teams shall factor how climate change will impact the flood levels in their designs. Executive Order 149 provides for Massachusetts participation in the Federal Emergency Management Agency National Flood Insurance Program and requires state agencies to avoid projects in floodplains to the extent possible (44 CFR § 60.3 (d)(3)).

Refer to *Envision Sustainable Infrastructure Framework* (v3), *NW3.3 Maintain Floodplain Functions*.

2.5.14.3 Water Quality

The project team shall incorporate measures to prevent pollutants from contaminating surface and groundwater and monitor impacts during construction and operations. The project shall adhere to the U.S. Environmental Protection Agency National Pollutant Discharge Elimination System and MassDEP standards (Clean Water Act 33 U.S.C. 1341 and M.G.L. Chapter 21, Section 25-53) for construction and operation activities. In addition, the Safe Drinking Water Act (42 USC § 300f et seq.) protects public drinking water and establishes Wellhead Protection Areas.

Refer to *Envision Sustainable Infrastructure Framework (v3), NW2.4 Protect Surface and Groundwater Quality*.

2.5.14.4 Wastewater

Generation of wastewater from bus washing, sanitary wastewater, and water use shall be minimized. Activities contributing to the generation of wastewater shall be evaluated for both quantity reduction and pollutant reduction. To the extent the designer can incorporate wastewater recycling into the design, or that water uses are evaluated to determine if there are dry alternatives or if there are alternatives that result in less pollutant loading into the wastewater, they shall be incorporated.

Refer to *Envision Sustainable Infrastructure Framework (v3), NWRA3.2 Reduce Operational Water Consumption*.

2.5.15 Public & Stakeholder Engagement Plan

The MBTA recognizes the process required to engage residents, businesses, stakeholders, and public officials to join the MBTA as partners. Initiating proactive stakeholder involvement and public engagement as early as possible is critical to understanding the full range of a community's needs, goals and issues. Early and consistent involvement provides community leaders and stakeholders the opportunity to learn about any tradeoffs involved with the proposed project and facilitates consideration of a diverse range of community views in the development of options or solutions.

In collaboration with MBTA, the project team shall prepare a Public Engagement Plan for the project. In addition, throughout each phase of the project (planning, design, construction, and operation), the Project Manager and S+R Admin shall document the relevant community needs, goals and issues and if/how these were incorporated into the planning and design process.

Refer to *Envision Sustainable Infrastructure Framework (v3), QL1.1 Improve Community Quality of Life* and *LD1.3 Provide for Stakeholder Involvement*.

3 SITE AND BUILDING REQUIREMENTS

3.1 Civil and Landscaping

Civil and landscaping elements shall be designed to meet the requirements outlined in the following subsections.

3.1.1 Sustainability Coordination

This section summarizes site design guidelines for meeting project sustainability and resilience goals and requirements; additional sustainability requirements are integrated in other site design subsections, as applicable. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach.

3.1.1.1 Local, Regional and MBTA Sustainability & Resilience Initiatives, Plans and Policies

The project team shall review local and regional sustainability and resilience initiatives, as well as, MBTA sustainability and resilience plans and policies to ensure commitments made to address potential environmental, climate and resilience impacts and concerns are incorporated into the project. The project team shall document applicable sustainability related criteria decisions in the project Basis of Design (BOD) and document project-specific metrics in the SRMP. Below are some initiatives the project team will review for civil and landscaping design. Refer to Appendix A for the full list of regionally specific example initiatives and their parallel commitments from the MBTA.

Table 3.1-1. Local and Regional Sustainability and Resilience Initiatives

Document	Description
Statewide Climate Resilience Design Standards and Guidelines for the Resilient Massachusetts Action Team[a]	Recommended design standards and guidelines on how to use them to incorporate climate resilience into projects with physical assets. MBTA is part of the Resilient Massachusetts Action Team (RMAT) and a key stakeholder in this resource.
Medford Climate Change Vulnerability Assessment (2019)[b]	Designers may look at the plan to preliminary view areas that are modelled 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 will be considered.
Boston Public Works Department *Climate Resilient Design Standards & Guidelines for Public Rights-of-Way*[c]	Guidelines for designing flood protection within the City of Boston and for impacts to the public right-of-way.
Climate Ready Boston (ongoing)[d]	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 application.
Climate Change Vulnerability Assessment Part 1[e]	Part 1: Focuses on the vulnerability of assets to increased precipitation, heat, and the social and economic impacts of climate change.
Resilient Boston Harbor Plan[f]	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 harborwalks.
MBTA Plans & Policies	▪ MBTA 2017 Sustainability Report & Program[g] ▪ Storm Water Pollution Prevention Plans (SWPPP)[h] ▪ 2015 Design of Permanent Construction Directive[i]

Table 3.1-1. Local and Regional Sustainability and Resilience Initiatives

Document	Description
	▪ 2015 Construction Specification Development Directive[j] ▪ 2018 Transit Asset Management Plan[k] ▪ 2019 General Design Directives[l] ▪ 2019 Material Selection Directive[m] ▪ 2019 Flood Resiliency Design Directive[n] ▪ APTA Sustainability Commitment & Guideline[o]

Notes:
[a] Mass.gov. 2020. *Climate Resilience Design Standards and Guidelines Project*. https://www.mass.gov/info-details/resilient-ma-action-team-rmat
[b] City of Medford. 2019. *Medford Climate Change Vulnerability Assessment.* https://drive.google.com/file/d/1DvxUiXpGnp8soxA3njZUgCSMBcWki_fm/view
[c] Boston Public Works Department. 2018. *Climate Resilient Design Standards & Guidelines for Public Rights-of-Way.* October 17.
[d] Greenovate Boston. 2020. *Prepared City*. https://www.greenovateboston.org/prepared_city/
[e] City of Cambridge, Massachusetts. 2015. *Climate Change Vulnerability Assessment Part 1.* November. http://envision.cambridgema.gov/wp-content/uploads/2016/08/Cambridge_November2015_FINAL-web.pdf
[f] Boston.gov. 2020. *Resilient Boston Harbor*. https://www.boston.gov/environment-and-energy/resilient-boston-harbor
[g] Massachusetts Bay Transportation Authority (MBTA). 2017. *MBTA Sustainability Report.* https://cdn.mbta.com/sites/default/files/Sustainability/sustainability-report-092617.pdf
[h] Massachusetts Bay Transportation Authority (MBTA). 2015a. Storm Water Pollution Prevention Plans.
[i] Massachusetts Bay Transportation Authority (MBTA). 2015b. *Design of Permanent Construction*. Design Directive. https://cdn.mbta.com/sites/default/files/engineering/003-directives/2015-01-06-design-of-permanent-construction-directive.pdf
[j] Massachusetts Bay Transportation Authority (MBTA). 2015c. *Contract Specification Development.* Design Directive. https://cdn.mbta.com/sites/default/files/engineering/003-directives/2015-08-11-construction-specification-development-directive.pdf
[k] Massachusetts Bay Transportation Authority (MBTA). 2018. *MBTA Transit Asset Management Plan.* September. https://cdn.mbta.com/sites/default/files/engineering/007-plans/2018-10-01-transit-assessment-management-plan.pdf
[l] Massachusetts Bay Transportation Authority (MBTA). 2019a. Design Directives. https://www.mbta.com/engineering/directives
[m] Massachusetts Bay Transportation Authority (MBTA). 2019b. *Material Selection.* Design Directive. https://cdn.mbta.com/sites/default/files/engineering/003-directives/2019-04-17-material-selection-directive-accessible.pdf
[n] Massachusetts Bay Transportation Authority (MBTA). 2019c. *MBTA Flood Resiliency Design Directive.* Design Directive. https://cdn.mbta.com/sites/default/files/2019-12/2019-11-18-flood-resiliency-directive-accessible.pdf
[o] American Public Transportation Association. 2020. *APTA Sustainability Commitment.* https://www.apta.com/research-technical-resources/sustainability/apta-sustainability-commitment/

3.1.1.2 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 these goals.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA3.2 Reduce Operational Water Consumption,* and LEED WE Prerequisite and Credit *Outdoor Water Use Reduction.*

3.1.1.3 Reducing Embodied Carbon

The civil engineer and landscape architect shall 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 percent from the baseline building shall be achieved; concrete and steel are the primary materials of greatest impact while vegetation provides ideal opportunities for sequestration. The civil engineer shall 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 Section 2.4, Sustainability and Resilience, for additional information on the coordination of carbon reduction strategies.

Refer to Envision Sustainable Infrastructure Framework (v3), CR1.1 Reduce Net Embodied Carbon; and LEED MR Credit Building Life-Cycle Impact Reduction.

3.1.1.4 Reducing Operational Carbon

All project facilities have a goal to move towards net-zero carbon. The site team shall coordinate with the architect to address this goal in a holistic manner. In addition to other design aspects, site-focused required considerations include orientation and massing (full descriptions are detailed in Section 2.4, Sustainability and Resilience).

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR1.2 Reduce Greenhouse Gas Emissions* and *CR1.3 Reduce Air Pollutant Emissions*; and LEED EA Prerequisite *Minimum Energy Performance* and Credit *Optimize Energy Performance*.

3.1.1.5 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 *Envision Sustainable Infrastructure Framework* (v3), *RA1.2 Use Recycled Materials* and *RA1.1, Support Sustainable Procurement Practiced;* and LEED MR Credits *Building Product Disclosure Information* (three separate credits) and EQ Credit *Low Emitting Materials.*

3.1.2 Resilience Coordination

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 shall meet the resilience performance goals included in Section 2.4, Sustainability and Resilience, under the conditions for the disruptors outlined in Section 2.4.4.3, 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 subsections below by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR2.2 Assess Climate Change Vulnerability, CR2.3 Evaluate Risk and Resilience, CR2.4 Establish Resilience Goals and Strategies,* and *CR2.5: Maximize Resilience.*

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 above ground 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:

- 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 above ground 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 shall meet the resilience performance goals under the coastal flooding conditions outlined in Section 2.4.4.3, Resilience Performance Requirements and Goals. 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:

- 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:

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

3.1.2.5 Disease/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 Site Design

Overall site design is governed by several factors including the amount of available land, the size of the assigned bus fleet and bus type, and the specific maintenance operations at the facility. The fully enclosed building area will be determined by the overall needs of the maintenance facility and the size

of the bus fleet being stored (see Section 3.2, Architectural, for building design criteria). The size of the bus storage and queue areas, apron, employee parking area, and space for internal site circulation can be estimated using the Facility Program Matrix in Appendix B. Bus storage and queue areas shall 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.

3.1.3.1 Open Space and Habitat Preservation

Adequate vegetated, open space will be incorporated into the site to foster recreation and interaction. The LEED credit requires that at least 30 percent of the total site area be dedicated to open space, and a minimum of 25 percent of that space shall be vegetated. Wetlands and stormwater management ponds may serve as open space as long as they are vegetated and banks are not steeper than 4H:1V (on average). The open space shall be physically accessible to people and include aspects that support outdoor social activities, physical activity, visual interest, or garden space. The vegetated space shall use only hardy, native and adapted plantings, and require no permanent irrigation after initial establishment periods. Trees shall be carefully selected and their locations specifically designed to allow for adequate root development, avoidance of soil compaction, and adequate soil depth to reach and maintain maturity. The civil engineer and landscape architect will coordinate their deign efforts to best address these goals.

Refer to LEED SS Credit *Site Development—Protect or Restore Habitat;* and SS Credit *Open Space.*

3.1.3.2 Heat Island Reduction

The reduction of heat islands will be achieved through proper treatments to roofs, parking lots, and other hardscape surfaces, as well as the prioritization of vegetated site. Review Resilience Coordination for heat mitigation design strategies that assist in mitigating extreme temperature scenarios. Meet the following design shading performance 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 shall coordinate their design efforts to best address this goal.

Refer to LEED SS Credit *Heat Island Reduction.*

3.1.3.3 Site Circulation

Internal site circulation plays a large role in the development or redevelopment of new or existing MBTA facilities. The designer shall accommodate 360-degree coverage of internal vehicle circulation around the site. While pedestrian circulation is equally important, there may be areas where it is deemed unsafe to allow access to pedestrians.

Below are principles the designer shall incorporate into the design:

- Any internal driveway traversing the site shall be a minimum of 30-feet wide if used as a path of travel by buses, maintenance vehicles or loading. All other internal circulation drives can be a minimum of 24 feet.
- Bus vehicle movements shall be one-way, forward movements in a counterclockwise direction (required for 60-foot buses, preferred for 40-foot buses).

- Facility site circulation modes for pedestrian, vehicular, and bus movements shall be separately delineated to maximize safety. Locations where circulation modes cross or interface shall be well identified, and sight lines maximized.
- Provide the most direct roadway access possible between the entrance to the site and the parking areas.
- Provide convenient loop turnarounds for dropoff/pickup vehicles.
- The minimum turning radius of internal driveways shall be 25 feet.

The project will enhance community livability by supporting public access, such as by providing a walking and biking connection through a site. At the very least, the project will not contribute to a loss of public amenities, and ideally would add or restore public resources to the community. It is the civil engineer's responsibility to incorporate these requirements into the BOD.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL2.3: Enhance Public Space and Amenities*.

3.1.3.4 Design Vehicles

The designer shall 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 shall be verified utilizing AutoTurn software. At a minimum, the following design vehicles shall be accommodated in the site design process:

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

3.1.4 Survey and Mapping

Surveys shall be made as necessary for the preparation and completion of preliminary and final designs, contract plans and layout plans for the project, including an investigation and survey of property boundaries and property owners' names as obtained from records filed at the Registry of Deeds. The most current existing property survey information on file shall be field checked and verified; any differences shall be provided in writing to the MBTA or designee.

Survey and design consultants performing work on projects funded, managed, or constructed by MassDOT agencies shall be pre-qualified in MassDOT Architectural and Engineering board's "S2-Total Station AutoCAD Base Plan Services" category.

The survey base shall be in conformance with all MassDOT survey requirements and shall be sealed by a Professional Land Surveyor registered in the Commonwealth of Massachusetts. Before commencing fieldwork, the Survey Consultant shall obtain the latest MassDOT Standard Point Description Key Codes. Field control points shall be based the North American Datum of 1983 (NAD83), and on the North American Vertical Datum of 1988 (NAVD88).

All survey data shall be collected electronically for the preparation of base plans including soil, topography, utility and base maps for the site. The surveyor shall lay the grid and indicate soil boring locations on the survey drawings as directed by a Geotechnical Engineer. Additionally, the surveyor shall pick up flags for wetland delineations as directed by the Wetland Specialist. These surveys shall also locate and identify sources of power, water, communications and other utilities such as existing storm water, wastewater and natural gas lines.

The survey shall also 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 shall include a point file and break-line file in addition to the digital elevation model or contour lines. Areas of tie in such as curb ramps, storm sewer connection inverts, sewer system connection inverts, roadway entrance and exit connections shall provide spot elevations and detail sufficient to allow for design and construction without grade bust or revisiting the site.

More information is available in the General Survey Guidelines (Mass.gov 2020).

3.1.4.1 Codes, Standards, and Manuals

- Massachusetts 250 Code of Massachusetts Regulations (CMR) 6.00 Procedural and Technical Standards for the Practice of Land Surveying
- Minimum Standard Detail Requirements for American Land Title Association/American Congress on Surveying and Mapping American Congress on Surveying and Mapping Land Title Surveys
- United States National Map Accuracy Standards
- MassDOT Surveys Manual
- MassDOT General Survey Guidelines

3.1.5 Utilities

The design shall 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 availability, type, current capacity and capabilities of public utility services shall be determined with new services provided where required. Consideration of the relocation, protection and maintenance of existing utilities is advised. The MBTA shall make initial contact to the various utility companies whose facilities or services may be affected by the proposed project including the design team for coordination. Potential development constraints and limitations resulting from past land use activities shall also be identified during this design phase.

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

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

The designer shall identify if there are any existing utility easements within the site. These will need to be maintained and may require relocation as part of the site redevelopment. The relocation of these utilities and associated easements will need to be coordinated with the individual utility companies and/or the local municipality. Utility work shall be coordinated with the survey team, local municipality or utility company to provide updated mapping and to verify any available utility as-builts.

3.1.5.1 Codes, Standards, and Manuals

- MassHighway Project Development and Design Guide

- MassDOT Highway Division Load and Resistance Factor Design Bridge Manual Design Guidelines
- MassDOT Highway Division Right-of-Way Manual
- MassDOT Standard Specifications for Highways and Bridges
- MassDOT Highway Division Supplemental Specifications to the Standard Specifications for Highways and Bridges
- MassDOT Highway Division Standard Special Provisions
- MassDOT Construction and Traffic Standard Details
- MassDOT Highway Division Engineering Directives
- MassDOT Highway Division Policy Directives
- Design criteria for municipality-owned and privately owned utilities

3.1.6 Roadways and Intersections

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

Roadway design shall 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 shall be designed to current standards set forth by the Massachusetts Department of Public Works and as required by local codes.

The design shall 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.

3.1.6.1 Codes, Standards, and Manuals

- MassHighway Project Development and Design Guide
- MassDOT Construction and Traffic Standard Details
- MassDOT Standard Specifications for Highways and Bridges
- MassDOT Standard Traffic Management Plans
- MassDOT Standard Drawings for Traffic Signals and Highway Lighting
- Federal Highway Administration, Manual on Uniform Traffic Control Devices (with all revisions and Massachusetts amendments)
- MassDOT Highway Division Engineering Directives
- MassDOT Highway Division Policy Directives
- FHWA
- American Association of State Highway and Transportation Officials (AASHTO)
- Transportation Research Board
- United States Access Board
- Massachusetts Architectural Access Board

- American Society for Testing and Materials
- Municipal standards

3.1.6.2 Standard Roadway Dimensions and Gradients

Table 3.1-2. Standard Roadway Dimensions and Gradients

Standard	Dimension or Gradient
Roadway Lane Widths	12 feet preferred 10 feet minimum 11 feet for bus lanes 16 feet for one-way
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%

3.1.6.3 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, drop off/pick up volume, site topography, traffic volumes on adjacent streets, and adjacent land uses. Driveway standards and dimensions are outlined in Table 3.1-3. Access for bus operations will be separate from employee or visitor access. Site access shall be coordinated with safety and security requirements in Section 3.8, Communications and Security Systems.

Table 3.1-3. Driveway Standards and Dimensions

Standard	Dimension
Number of Driveways	Minimum - 2 Maximum - 4
Driveway Width	Minimum – 30 feet Maximum – 60 feet
Driveway Length	Minimum – 50 feet (unless requested otherwise by MBTA)

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 shall 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 shall be considered to separate left- and right-hand turns. The width of auxiliary lanes shall align with Table 3.1-2 (see Figure 3.1-1 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 allow facility vehicles to not interfere with other vehicles circulating the site, maintenance, employee or otherwise. For further information on the design of intersections, auxiliary lanes and deceleration lanes, see A Policy on the Geometric Design of Highways and Streets, published by AASHTO.

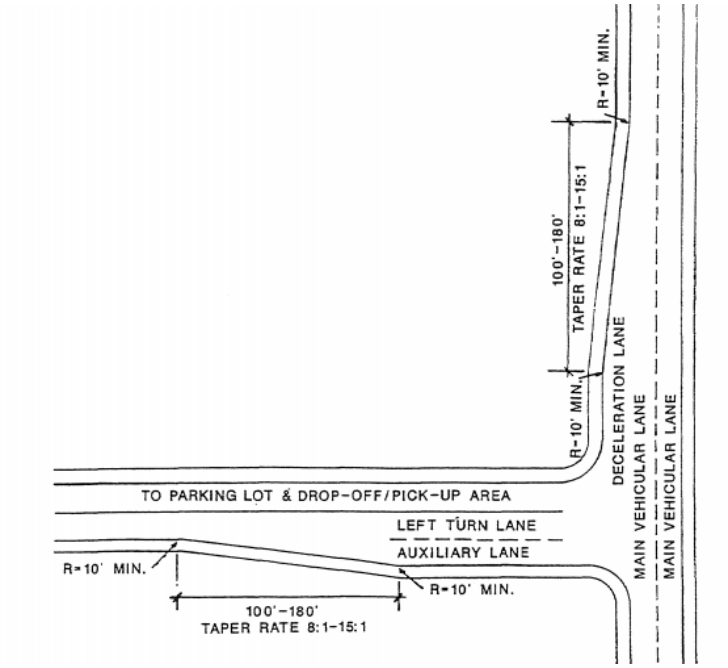


Figure 3.1-1. Layout of Auxiliary and Deceleration Lanes

3.1.6.4 Pavement Design

The pavement for drive aisles, employee parking, and other general-purpose roadways shall at a minimum meet the pavement design requirements in the MBTA Busway Design Directive 2020.

Areas used by buses for parking, queuing, and building approach and departure shall require heavy-duty concrete with minimum epoxy coated reinforcing. Refer to current AASHTO guidance, which discusses flexible, rigid, and composite pavements. The pavement structure below provides a minimum standard design to consider.

Surface: 10” Cement Concrete Pavement (5000 PSI)

Subbase: 4” Dense Graded Crushed Stone; 8” Gravel Borrow

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 shall 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.

3.1.6.5 Maintenance of Traffic

The designer shall 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. Traffic maintenance within the public right-of-way shall be coordinated with and approved by state or local authorities. The designer shall follow all Manual on Uniform Traffic Control Devices Guidelines for the development of the Maintenance of Traffic Plan.

3.1.7 Stormwater Drainage

The designer is responsible for the modelling, 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 stormwater drainage design shall accomplish the following:

- Collect stormwater run-off within the project area, as well as flows from tributary offsite areas to the project area.
- Collect building-source stormwater run-off, such as roof drainage.
- Convey the collected flows and discharge at permitted locations.
- Provide sufficient stormwater management facilities to comply with all applicable federal, state and municipal requirements and permits related to stormwater management, including measures to control water quality, flow rates and flow volumes.
- Utilize minimal maintenance systems, such as surface storage facilities, where possible.
- Prioritize nature-based solutions or low-impact development best practices that reduce the potential for inland flooding and urban heat island effects.
- The use of steel as a material for stormwater is prohibited.

3.1.7.1 Codes, Standards, and Manuals

- MassDOT Project Development and Design Guide
- MassDOT Construction Standard Details
- MassDOT Standard Specifications for Highways and Bridges
- MassDOT Storm Water Handbook for Highways and Bridges
- MassDOT Engineering and Policy Directives
- MassDEP Stormwater Policy
- MassDEP Stormwater Management Standards
- MassDEP Stormwater Handbook
- MassDEP Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- MassDEP Protocol for Stormwater Best Management Practice Demonstrations
- National Pollutant Discharge Elimination System Stormwater Management Plan for MassDOT Owned and Operated Highways
- National Pollutant Discharge Elimination System Stormwater Discharges from Municipal Sources (MS4) Guidelines
- Massachusetts State Building Code

3.1.7.2 General Stormwater Requirements

The design of surface drainage, underground drainage systems, stormwater management facilities, and erosion and sediment control shall be in conformance with the applicable requirements of the local regulatory authority and follow the MassDEP Stormwater Handbook and Stormwater Standards (MassDEP undated).

The designer shall develop a Stormwater Management Plan 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.

Temporary and permanent erosion and sediment control practices shall be provided in accordance with local regulatory requirements during both the construction and operational phases of the project.

Overland flow and natural site features shall be used where stormwater drainage will not impact site function. Drainage systems shall prevent erosion of existing soils, prevent ponding, and convey flow to a suitable outfall location.

The designer shall analyze upstream and downstream stormwater conveyance system capacities to identify riverine and coastal flooding vulnerabilities to be mitigated by onsite design such as increased detention volume or increased overland relief capacity.

Early design analysis of riverine and coastal flood risk shall be completed and documented to inform infrastructure decisions and stormwater management alternatives. MBTA project sites are potentially impacted by upstream and downstream conditions of prior human impacts to the natural systems. Consider 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.

3.1.7.3 Stormwater and Sustainability

Reduce stormwater run-off and improve water quality by using low-impact development and green infrastructure, or by managing run-off entirely onsite. Using pervious surfaces, avoiding soil compaction and loss of vegetation, and restoring or maintaining natural drainage patterns are some of the ways of achieving this guideline. The civil engineer and landscape architect will coordinate their design efforts to best address this goal.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *NW2.2 Manage Stormwater;* and LEED SS Credit *Rainwater Management.*

In the project BOD, document whether there are increased flood resiliency, ecosystem benefits, or LEED / Envision credit requirements to be met by increasing infiltration, evapotranspiration, or rainwater harvesting onsite for stormwater volume control above the minimum regulatory requirements. In particular, Massachusetts stormwater management requirements for redevelopment sites are compared to conditions of prior site development, not greenfield site hydrology. Consider increasing the restorative benefits of the stormwater management system to more closely replicate the historical undeveloped hydrology. Maintain or increase the initial abstraction and soil infiltration rates of areas intended to absorb precipitation.

In the BOD, document whether there are increased flooding resiliency or ecosystem benefits in increasing the stormwater temporary detention volume available on site in areas where the design depth of will not cause a risk to infrastructure or operations. Additional flooding resiliency and ecosystem benefits of increased stormwater storage volume may be justifiable reasons to export earthwork volume from the site instead of balancing cut and fill volumes onsite. Additional flooding resiliency in raising the building floor elevation may be a justifiable reason to increase importing structural fill into the site instead of balancing earthwork volume onsite.

In general, MBTA bus maintenance facilities are likely to be in areas where the natural receiving streams and wetlands have been impacted by uncontrolled run-off from prior development. If impacted streams, wetlands, or shorelines occur onsite, the site design is encouraged to restore these features using reinforced vegetated practices. For example, remove a segment of storm pipe and associated earth fill and restore a stream channel and overbank using nature-based design techniques in

accordance with the Natural Resources Conservation Service Stream Restoration Design or other criteria approved by authorities having jurisdiction including Massachusetts Division of Ecological Restoration and US Army Corps of Engineers.

Material Pollutants

Avoid or minimize the use of materials in the building exterior and site work that can be a source of pollutants in stormwater including:

- Copper and zinc roofs, roof gutters and downspouts, and siding
- Galvanized materials (fences, guardrails, signposts)
- Treated lumber
- Parking lot coal tar sealants
- Fertilizers
- Pesticides

Develop an integrated plan to minimize the use of deicing salt for sidewalks and site driveways and document in the Stormwater Management Plan. Permeable pavements in accordance with Massachusetts Stormwater Handbook may reduce the need for deicing salt.

Time of Concentration Design Methods

Time of concentration shall be calculated using the TR-55 method or as approved by the TR-55 Curve Number method. The Rational Method may also be used for drainage areas smaller than 200 acres. Regional intensity-duration-frequency curves are available in the MassDOT Project Development and Design Guide or from NOAA. Designs shall also adhere to the resilience requirements in Section 2.4.4.3, Resilience Performance Requirements and Goals.

Design Storm Frequency

For design of the drainage system, a minimum 10-year storm frequency, the minimum required by the local governing authority, or the minimum resilient threshold developed in line with the requirements in Section 2.4, Sustainability and Resilience, shall be used, whichever is more stringent. Storm drainage systems are to be evaluated for hydraulic grade line to prevent surcharge.

3.1.7.4 Site Grading

Site grading is critical to prevent flooding of the building during extreme precipitation events. Refer to MBTA Flood Resiliency Design Directive (MBTA 2019) for requirements for the minimum building floor elevation and for requirements for rainfall intensity to use in site overland relief drainage calculations. Site grading shall 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.

Impervious Surface Grading

Determine the appropriate requirements for site grading and accessibility. Ensure that the grading and associated stormwater run-off 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), Americans with Disabilities Act (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.

Below is a list of key criteria to follow:

- Longitudinal Grades of Roadways
- Transverse Grades of Roadways
- Concrete Pavement
- Bituminous Pavement in Parking Areas
- Permeable Pavement in Parking Areas
- Sidewalks, Longitudinal Slope
- Sidewalks, Transverse Slope

Pervious Surface Grading

The designer shall use Table 3.1-4 to determine the appropriate requirements for pervious surface grading around the project site.

Table 3.1-4. Pervious Surface Grading Requirements

Description	Requirement	Best Practice
Landscape Islands	Minimum – 1.0%	-
Landscape Areas	Minimum Slope – 2:1	Minimum Slope - 3:1
Surface Detention Ponds	Minimum Slope – 2:1	Minimum Slope - 3:1
Gravel Areas	Minimum Slope – 2:1	-
Existing Woods/Landscape Areas	-	Protect and Maintain

3.1.7.5 Surface Drainage

Surface storage systems shall 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 shall be provided.

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

- Advanced Drainage Systems https://www.ads-pipe.com/markets/detention-infiltration
- CONTECH, Engineered Solutions https://www.conteches.com/stormwater-management/detention-and-infiltration
- CULTEC, Inc. https://cultec.com/products/stormwater-products/

Any underground detention will accommodate H-20 Loading in areas of heavy vehicle traffic, including bus queue, bus storage, and loading bays.

Stormwater Structures

Storm structures for roads and site drainage shall be in accordance with MassDOT's Standards and Specifications, or the requirements of the applicable local regulatory agency that governs stormwater management, whichever is more stringent. Structures shall provide access for maintenance. Internal

dimensions shall not be less than 2 feet in any one direction. Ensure that catch basins, curb inlets, and manholes 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 (HS25) and meet any additional requirements set forth in the most recent MassDOT construction standard. Grate type shall 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.

Stormwater Piping

Straight alignments are required for piping between storm drainage structures. Deflection at structures shall 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 shall not pass under buildings and the designer shall try to maintain a parallel distance of at least 10 feet from building foundations. Care shall be taken to avoid conflicts with other utilities. The design shall 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 for more information.

3.1.7.6 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 shall 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 shall 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.

3.1.8 Snow Management

The designer shall develop a snow management plan with accommodations that consider the resilient performance thresholds developed in alignment with Section 2.4.4.3, Resilience Performance Requirements and Goals, and predicted future snowfall events.

3.1.9 Traffic Impact Analysis

A TIA shall be conducted for all new facilities. Due to the nature and frequency of use, understanding impacts to traffic is critical for facility operations and acceptance from the community. The TIA shall identify level of service impacts of the proposed development and shall be used to determine necessary improvements to support the development. The analysis shall be conducted for the morning and evening peak commute hours, as well as for other peak hours applicable to the proposed use (e.g., a Saturday peak hour for retail development). The designer shall check if the local jurisdiction has

specific requirements for Traffic Impact Analyses that supersede the MassDOT requirements. At a minimum, the impact analysis shall 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 signalization or roundabouts
- Bus operations schedules

In general, number of average daily trips are based on trip generation rates as defined by the most recent publication of the Institute of Transportation Engineers “Trip Generation.” However, as is the case with these facilities, the use and frequency of use can be better estimated by understanding the makeup of the facility. For example, office space, maintenance space and operator space, bus trips as well as the number of employees by shift can help estimate the daily trips.

3.1.10 Accessibility

The design shall provide for accessibility 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 re-developed, all features shall be updated to allow such access. Sustainability considerations for universal design standards for public access will be included. The civil engineer will communicate these requirements to best address requirements.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL2.3 Improve Access and Wayfinding;* and LEED Pilot Credit *Inclusive Design*.

3.1.10.1 Codes, Standards, and Manuals

- United States Department of Justice (U.S. DOJ), *ADA Standards for Accessible Design*
- U.S. DOJ, Guidance on the 2010 ADA Standards for Accessible Design
- United States Access Board, Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way
- Massachusetts Architectural Access Board Regulations (521 CMR)
- American with Disabilities Act and Architectural Barriers Act - Accessibility Guidelines for Outdoor Developed Areas (36 CFR Part 1195)
- Americana with Disabilities Act, Accessible Rights-of-Way, A Design Guide
- FHWA, Designing Sidewalks and Trails for Access, Part II of II: Best Practices Design Guide
- AASHTO, Guide for the Development of Bicycle Facilities, 4th Edition
- MassDOT, Shared Use Paths and Greenways
- Municipal Planning and zoning ordinances, including specifications, and Department of Public Works permits

3.1.10.2 Pedestrians

The designer shall evaluate pedestrian safety by determining pedestrian desire lines and making sure pedestrian facilities are located closest to these desire lines. There may be multiple desire lines from a

single area depending on the size of that area and possible access point to their destination. The designer shall also identify pedestrian and vehicle conflict points (especially bus vehicles) and provide adequate warning of this conflict to pedestrians and vehicles. Awareness and responsibility are shared by both the pedestrian and vehicle, so additional warning and safety features will be considered such as pavement markings, bollards, in-pavement lighting, additional overhead lighting, and clear sight lines.

While these design considerations are critical to improved pedestrian safety, an education campaign will also be considered to supplement any new standards and approaches focused on improving pedestrian safety as some operators may not be fully aware of how these improvements may impact their day to day operation.

Sidewalks shall 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 shall be provided such that site buildings may be reached safely on foot and adhere to the following principles:

- Pedestrian pathways shall meet current ADA/Architectural Access Board requirements as well as any engineering directives as provided by MassDOT or the MBTA.
- Pedestrian pathways shall be direct, well defined, and provide a clear indication of where they lead.
- Pedestrian access from the surrounding community shall be encouraged by providing a direct, paved walkway to the facility.
- An accessible route of travel, free from steps, shall link the building accessible entrance with public sidewalks, bus stops, parking, and passenger dropoff areas.
- The MBTA Guide to Access 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 shall be beveled with a maximum slope of 1:2.
- Walkway surfaces shall 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 shall be considered in the location and design of sidewalks as to not obstruct the path of travel.

3.1.11 Bicycles

To encourage sustainable transportation methods, convenient and close connections to a local bicycle network will be provided, as well as access to bicycle storage and shower rooms. Travel of pedestrians on bicycles shall be accommodated. Bicycle parking stations will be provided internal to the building for staff and employees and external to the site for visitors, preferably close to at the main entrance(s) to the building. The civil engineer and architect shall coordinate their design efforts to address these goals.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL2.1 Improve Community Mobility and Access* and *QL2.2 Encourage Sustainable Transportation*; and LEED LT Credit *Bicycle Facilities*.

3.1.12 Parking

The number of parking spaces provided shall be determined based on the assigned fleet size, office space, and maintenance space at the proposed facility and informed by the Facility Program Matrix in Appendix B. A review of parking accommodations at existing and operating MBTA facilities shall be used to properly gauge the necessary requirements for parking areas associated with the developments.

ADA requirements for the number and dimensions of handicap parking spaces shall be met. There are specific requirements for accessible parking spaces for cars and vans, including the number, size, and location of these spaces as well as vertical clearance for van spaces. Refer to 521 CMR and ADA Accessibility Guidelines for specific parking standards. Where accessible parking is more than 200 feet from a building entrance, an accessible dropoff area shall be provided. In addition, refer to the AASHTO *Guide for the Design of Park-and-Ride Facilities* (AASHTO 2004) for guidance in parking layout and recommendations for parking stall dimensions based upon the angle of parking.

The size of the dropoff/pickup area and the number of associated short-term spaces shall be determined according to projected demand. Best practice calls for right-angle parking with sufficient aisle width for January 2006 Intermodal Facilities and Rest Areas 12-3 2006 EDITION 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” shall be provided at the direction of MBTA.

Parking spaces for employee and company electric vehicle charging shall be provided as determined by the MBTA.

3.1.12.1 Employee Parking

Onsite employee parking shall be provided. The number of employee parking spaces can be determined by the number of fleet vehicles in use with consideration given to operations, maintenance and administrative staff. Employees may also travel to the site by alternative means, such as bicycles or MBTA service. A review of employee parking needs and usage at existing MBTA bus maintenance facilities shall be performed to determine a parking ratio specific to and suitable for future facilities.

3.1.12.2 Green Vehicles

The project design shall encourage the use of alternative vehicle technologies by designating a minimum number of preferred parking spaces for such vehicles. For electric vehicles, charging stations coupled with parking spaces may be either Level 1 (hourly parking/quick charging) or Level 2 (all day parking/slow charging). The civil engineer and electrical engineer will coordinate their design efforts to incorporate these requirements.

Refer to LEED LT Credit *Green Vehicles*.

3.1.13 Site Lighting

Security, visual comfort, compatibility with surrounding uses, energy efficiency, and attractiveness shall 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 shall be provided with suitable lighting. The lighting design shall 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

Reduce light pollution to minimize the negative impacts of excessive light while providing adequate lighting for safety and visibility at night. Light will be contained within the project's lighting boundary to avoid light trespass by taking into consideration lighting zones. Fixtures will comply with uplight requirements and can be selected to respond to ambient lighting, 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 best address these goals.

Refer to Envision Sustainable Infrastructure Framework (v3), *QL1.6 Minimize Light Pollution;* and LEED SS Credit *Light Pollution Reduction.*

3.1.14 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.

There are many benefits to incorporating appropriate landscaping, including its role in creating a more sustainable design. Proper use of existing landscaping, when combined with the selective use of new landscape elements, can help improve site compatibility with the surrounding area. For facilities that are located near residential areas, landscaping can help act as a buffer providing a natural screening to the facility. Grass and trees help provide lower temperatures and reduce the impacts associated with heat islands. Landscaping can help improve air quality and provide treatment of stormwater for improved water quality and reduction in run-off volumes.

Landscaping for MBTA bus facilities shall be hardy enough to survive cold winters and drought tolerant to survive hot summers yet require minimal maintenance. During the spring, summer, and fall, the landscaping adds form, color and textures and provides some of the benefits discussed above. During the winter, landscaping also provides snow storage area and therefore shall be coordinated with the snow management plan. Plants shall be tolerant to the maintenance of these snow storage areas.

3.1.14.1 Codes, Standards, and Manuals

- Commonwealth of Massachusetts Department of Public Works, Standard Specifications for Highways and Bridges
- MassHighway Project Development and Design Guide, Chapter 13: Landscape and Aesthetics
- MassDEP, Massachusetts Stormwater Handbook
- United States Department of Justice, 2010 ADA Standards for Accessible Design
- United States Department of Transportation, ADA Standards for Transportation Facilities
- Massachusetts Architectural Access Board, 521 CMR
- American Nursery and Landscape Association, American Standard for Nursery Stock ANSI Z60.1
- American Society for Testing and Materials
- Association of Official Agricultural Chemists
- United Stated Department of Agriculture, Plant Hardiness Zone Map
- M.G.L. Chapter 87: Shade Trees

3.1.14.2 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 (Massachusetts Highway Department 2006).

- Evaluate the health of trees and plantings on the project properties and create a plan to protect, prune or remove as required for safety and design purposes.
- Protect existing plantings and trees on abutting properties with canopies or drip lines extending within limits of the project.
- Provide permanent slope stabilization for all slopes greater than 3H:1V.
- Restore all disturbed areas on abutting properties to existing conditions.
- Minimum depth of topsoil shall be 6 inches in seeding or turf areas, 18 inches in areas to be planted with shrubs, and 36 inches in areas to be planted with trees unless otherwise approved by the MBTA. Amend or cover all planting media and areas with topsoil, except for planting pits which shall not be amended in order to prevent inadequate root development. Place topsoil and compact in a uniform manner to prevent uneven settlement. Coordinate topsoil nutrients with the plant material to be installed.
- Finished settled grade of topsoil in lawn areas shall be 0.5 inch below adjacent hardscape. No soil shall be stripped, placed or worked while frozen or wet. Topsoil shall not be placed on untilled or un-scarified surfaces. De-compact planting areas to achieve adequate drainage immediately prior to placing planting soil.
- Water shall not drain across walkways. Sidewalks or paving shall drain to adjacent planted areas.
- Design landscape and exterior lighting taking into consideration the principles of crime prevention through environmental design.
- 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.
- Design landscape in parking lots and around the facility to perform water quality and detention functions.
- The landscaping shall not reduce the sight distance of drivers, bus operators, and the public with respect to other vehicular traffic.
- Plant materials installed around any historic building(s) shall be used in a manner that enhances the historic setting and character of the building.
- 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 landscaping suited to the climate and resistant to vandalism.
- Use appropriate hardy, non-invasive, and native plants.
- High maintenance, residentially-scaled plant materials shall not be used.
- Apply 2 inches of fine-shredded pine bark mulch to all tree and shrub planting areas.
- The tree planting will preference planting beds. Trees that shall be planted close to hardscape shall use structural soil or a structural root support product to allow the roots to safely expand under the hardscape without damage to the hardscape.

- Plant material adjacent to paved surfaces shall 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 shall 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 shall be used as the preferred soil amendment in all maintenance and construction projects. Amendment shall include organic content, mitigation of compaction, and testing of either the soil chemical characteristics or biological function. Soil amendments shall 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 shall be used as horticultural subsoil, where appropriate for planting, based upon soil testing to be performed by the landscape installer.
- Commercial topsoil shall 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.

Landscape Tracking Plan

The designer shall develop and implement a Landscape Tracking Plan. The plan will be developed to meet the requirements and targets herein for non-hazardous landscape waste, non-hazardous soil, existing trees, tree planting and plant materials. The Landscape Tracking Plan shall be documented within the SRMP (see Section 2.4, Sustainability and Resilience). The SRMP shall also include a copy of the Leading by Example form for Landscaping.

The design team shall designate a landscape management coordinator responsible for implementing, monitoring and reporting the status of the Landscape Tracking Plan. Progress reports shall be provided during construction on at least a monthly basis that communicate cumulative and report-period updates. A final report shall be provided at the end of construction that summarizes the results for landscape waste, non-hazardous soil, existing trees, tree planting and plant materials. Original documents shall be saved for the life of the project plus three years.

The Landscape Tracking Plan shall include sections on non-hazardous landscape waste, non-hazardous soil, existing trees, tree planting, and plant materials as follows. The same units of measurement shall be used consistently throughout the Landscape Tracking Plan.

- Non-hazardous landscaping waste
  - Achieve end-of-project rate for reuse/composting of at least 90 percent by weight. Indicate anticipated types and quantities/percentages by weight of the non-hazardous landscape waste generated by the project.

  - Waste reduction plan: Indicate each type of landscape waste and whether it will be reused onsite or offsite, composted onsite or offsite or disposed including names of vendors/locations. Include points of waste generation, total quantity of each type of waste, quantity for each means disposal, and handling and transportation procedures.
  - Include legible copies of onsite logs, weight tickets and receipts. Receipts shall be from reuse, composting and/or disposal site operators who can legally accept the materials for the purpose of reuse, recycling or disposal.

- Non-hazardous soil
  - Reuse at least 50 percent of all non-hazardous soil either within the project or offsite. Indicate anticipated types and quantities/percentages by weight of the non-hazardous soil waste generated by the project. Conduct an earthwork balance estimate for the project during design. Include soil import or export within engineers' opinion of probable construction costs. Specifications shall include submittal requirements for onsite and offsite soil disposal.
  - Waste reduction plan: Indicate each type of soil waste and whether it will be reused onsite or offsite or disposed including names of vendors/locations. Include points of waste generation, total quantity of each type of waste, quantity for each means disposal, and handling and transportation procedures.
  - Include legible copies of onsite logs, weight tickets and receipts. Receipts shall be from onsite reuse, offsite reuse and/or disposal site operators who can legally accept the materials for the purpose of reuse, recycling or disposal.
- Existing Trees
  - Before beginning work at a site, engage an independent Person to prepare a record of trees that are within the Limit of Works with a caliper greater than 6 inches. The record shall include photographs, location, species, and caliper of the trees and indicate if the tree will remain or will be removed. For all removed trees with a caliper greater than 6 inches, record the date and means of removal and location to which it will be moved if applicable. If a tree with a caliper greater than 6 inches is removed, the property owner and MBTA shall receive 30 Days' notice before the tree removal.
  - Include legible copies of onsite logs, receipts and plans. Documentation to confirm the trees, the species, caliper and removal.
- Tree plantings
  - Identify sourcing locations within a 200-mile radius of the project. Track and record all trees planted as part of the project. For each tree, indicate the species, caliper, sourced location and planting location. Planting location to be recorded in plan drawings as well as written record. Track and record the distance in miles of the sourced location from the project site for all trees.
  - Include legible copies of onsite logs, receipts (shall be from tree suppliers) and plans, including documentation to confirm sourcing location and vendor of the trees, the species, caliper and planting location.

- Plant materials
  - Identify sourcing locations within a 200-mile radius of the project. Track and record all planting materials as part of the project. For each plant, indicate species, if it is non-invasive, native or adapted, and/or drought tolerant, the sourced location and planting location. Planting

location to be recorded in plan drawings as well as written record. Track and record distance in miles of the sourced location from the project site for all trees.

- Include legible copies of onsite logs, receipts and plans. Documentation to confirm sourcing location and vendor of the plant, the species, and planting location. Receipts shall be from suppliers of the plant material.

3.1.15 Security

Security for each facility shall be considered. At a minimum, the site shall be fenced with gates to prevent unauthorized access, damage and vandalism. Lighting, CCTV, and other forms of security shall be provided in accordance with requirements outlined in Sections 3.5, Electrical, and 3.8, Communications and Security Systems.

3.1.15.1 Fencing Requirements

- Install fence foundations to the minimum regional frost depth stated in the Massachusetts Building Code.
- The fencing shall be minimum 6-foot-tall fusion bonded black vinyl coated chain link unless otherwise required.
- "No Trespassing" signs and video surveillance shall be attached.
- Include personnel and vehicle gates at all driveway entrances and pathways leading to facility.
  - Personnel gates and vehicle gates shall be separate but in similar locations if possible.
  - Gates shall be a minimum 6-foot-tall with width compatible with access needs.
  - Gates shall be fusion bonded black vinyl coated galvanized steel and vertically hinged at 2-foot centers.
  - Gates shall 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 shall be lift gates or slide gates depending on site constraints.
  - Vehicular gates shall be motorized unless otherwise noted by MBTA personnel.
  - Each gate area shall 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 shall 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 shall consider the surrounding area, especially when adjacent to residential zoning, and provide appropriate mitigation for screening and security.

3.1.16 Right-of-Way

Any additional right-of-way necessary to properly fit the design shall 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 shall 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.

3.2 Architectural

Architectural elements will be designed to meet the requirements outlined in the following subsections.

3.2.1 Sustainability Coordination

This section summarizes architectural design guidelines for meeting project sustainability and resiliency goals and requirements. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach.

The architectural design principles described in the following subsections shall be included in the project design.

3.2.1.1 Reflective Roofing and Heat Island Effect

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

Refer to LEED SS Credit *Heat Island Reduction.*

3.2.1.2 Reducing Embodied Carbon

It is critical that the architect 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 percent from the baseline building shall 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 shall 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 Section 2.4, Sustainability and Resilience, for additional information on the coordination of carbon reduction strategies.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR1.1 Reduce Net Embodied Carbon;* and LEED MR Credit *Building Life-Cycle Impact Reduction.*

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

3.2.1.3 Reducing Operational Carbon

The architect shall coordinate with the civil, mechanical, and electrical engineers to address the goal to move towards new zero carbon in a holistic manner. In addition to other design aspects, architecturally focused required considerations include the following (full descriptions are detailed in Section 2.4, Sustainability and Resilience):

- Orientation and massing
- Building envelope
- Assembly U-values
- Envelope airtightness
- Windows and glazing

- Building assembly analysis
- Lighting and controls

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR1.2 Reduce Greenhouse Gas Emissions* and *CR1.3 Reduce Air Pollutant Emissions;* and LEED EA Prerequisite Minimum *Energy Performance*, and Credit *Optimize Energy Performance*.

3.2.1.4 Energy Consumption and Performance

Establish a baseline energy performance for the facility and reduce the energy requirements, prioritizing passive 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 shall work with the electrical and mechanical engineers to coordinate energy efficiency measures and maximize savings.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA2.1 Reduce Operational Energy Consumption*; and LEED EA Credit *Optimize Energy Performance.*

3.2.1.5 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 *Envision Sustainable Infrastructure Framework* (v3), *RA1.2 Use Recycled Materials* and *RA1.1 Support Sustainable Procurement Practiced*; and LEED MR Credits *Building Product Disclosure Information* (three separate credits)*,* and EQ Credit *Low Emitting Materials.*

3.2.1.6 Enhanced Indoor Air Quality Strategies

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 shall 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.*

3.2.1.7 Reflectivity of Interior Surfaces and Materials

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

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

The architect shall 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, to have a Color Rendering Index of 80 or higher.

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

3.2.1.8 Daylight and Views

For optimal daylighting, regularly occupied spaces (as defined by LEED) shall meet a spatial daylight autonomy of a minimum of 55 percent, and the annual sunlight exposure $ASE_{1000,250}$ of no more than 10 percent 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 percent 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 above requirements for up to 30 percent of the floor area. The architecture team is responsible for achievement of these priorities.

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

Control Solar Glare

All exterior envelope glazing shall have shading. Atria or lobbies may be excluded. The shading shall 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 percent of all regularly occupied space.

3.2.1.9 Acoustical Performance and Comfort

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.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL 1.4 Minimize Noise and Vibration;* and LEED EQ Credit *Acoustic Performance.*

3.2.1.10 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; refer to Section 2.4, Sustainability and Resilience, for the full requirements. The architect shall work with the civil and electrical engineers to comply with these requirements.

Refer to LEED Pilot Credit *Inclusive Design* (USGBC 2020d).

3.2.1.11 Interiors Life-Cycle Impact Reduction

Design the space for flexibility and reuse for different purposes in the future to extend a project's lifetime. For additional information, refer to the Life-Cycle Cost Analysis section for project requirements around life-cycle cost analysis. The architect shall coordinate with other disciplines as noted and appropriate for concept overlap (see Section 2.4, Sustainability and Resilience, for further information).

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA1.2 Use Recycled Materials; and* LEED Interior Design and Construction (ID+C) MR Credit *Building Life-Cycle Impact Reduction, Option 3 Building and Material Reuse* (USGBC 2020e).

3.2.1.12 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 building envelope shall 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 shall 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.

3.2.2 Resilience Coordination

Architectural design shall meet the resilience performance goals included in Section 2.4, Sustainability and Resilience, under the conditions for the disruptors outlined in Section 2.4.3.3, Energy Efficiency Performance (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 subsections below by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

3.2.2.1 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 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:

- 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)
- 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)
- 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

3.2.2.2 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 shall meet the resilience performance goals under the coastal flooding conditions outlined in Section 2.4.3.3, Energy Efficiency Performance. Possible architectural design strategies include:

- 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

3.2.2.3 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 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:

- 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)

3.2.2.4 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:

- 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

3.2.2.5 Disease/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:

- 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

3.2.3 Dimensions and Clearances

The design of the fully enclosed maintenance facility shall 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 shall be utilized during the design process.

Table 3.2-1. Minimum Dimensions and Clearances

Overhead Unobstructed Clearances	
Office areas	8 feet, 0 inches
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
Fluid distribution, waste storage, and compressor room	12 feet, 0 inches
Shops with no overhead hoist	12 feet, 0 inches
Shops with overhead hoist	18 feet, 0 inches
Bus exterior wash bay and fueling	16 feet, 0 inches

Table 3.2-1. Minimum Dimensions and Clearances

Maintenance bay with lifts	21 feet, 0 inches
Maintenance bay with roof access and monorail or crane	24 feet, 0 inches
Inspection bay	16 feet, 0 inches
Bus chassis wash bay with platform lift	20 feet, 0 inches; 25 feet, 0 inches preferred
Bus storage (required for BEB fleet)	20 feet, 0 inches minimum below primary roof framing members
Door Openings (width by height)	
Shipping and receiving area	12 feet, 0 inches by 12 feet, 0 inches
Fueling bays	14 feet, 0 inches by 14 feet, 0 inches
Bus exterior wash bay	14 feet, 0 inches by 14 feet, 0 inches
Work Area Dimensions and Clearances	
Front of vehicle work area clearance	7 feet, 0 inches minimum clearance between vehicle and any obstruction
Back of vehicle work area clearance	10 feet, 0 inches minimum clearance between vehicle and any obstruction
Bus maintenance bay 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, 0 inches, 60 feet recommended
Maintenance bay length for 60-foot vehicle	77 feet, 0 inches, 80 feet recommended
Circulation	
Pedestrian corridors Pedestrian walkway (in open work and storage areas)	Refer to building codes, Occupancy and egress - 3 feet, 8 inches 5 feet, 0 inches minimum
Bay access aisle (not vehicle drive aisle)	8 feet, 0 inches minimum, 10 feet, 0 inches recommended
Corridor for forklift traffic	10 feet, 0 inches minimum, 12 feet, 0 inches + recommended (check forklift turning radius)
Street or Yard Tightest Turning Radius 90° Turn (Verify with Autoturn)	
40-foot bus	45 feet, 6 inches minimum, 51 feet preferred
60-foot bus	43 feet, 6 inches minimum, 49 feet preferred
Door or Bay Access Turning Radius 90° Turn (Bus needs to be straight to clear entrance opening)	
40-foot bus	70 feet, 0 inches minimum, 80 feet preferred (field test bus at minimum dimensions)
60-foot bus	68 feet, 0 inches minimum, 78 feet preferred (field test bus at minimum dimensions)

3.2.4 Exterior Finishes

Exterior envelope systems shall be designed to mitigate life-cycle costs and prioritize durability and reduced maintenance requirements.

Rainscreen systems are preferred for enhanced thermal and moisture management. Wet sealant joints shall be limited to the greatest extent possible. Acceptable rainscreen cladding materials are described in Appendix C to allow the designer to adapt to specific site requirements, design goals, and budgets.

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

The preferred roofing material is ethylene propylene diene monomer. Options are described in Appendix C and shall be reviewed against other specific project conditions.

Exterior thermal, envelope, and other characteristics shall comply with the requirements in the following subsections and shall be coordinated with the sustainable design criteria set out in Section 2.4, Sustainability and Resilience, Section 3.2.1, Sustainability Coordination, and with Envelope Building E Technology and Environmental Council.

3.2.5 Doors and Windows

Exterior glazing shall be double pane, insulated low E coated glass set in aluminum with thermally broken window frames or curtain wall system.

Interior glazing shall be tempered and safety laminated with no portion of glass lower than 30 inches above the finish floor. Interior glazing systems shall meet acoustical criteria to reduce noise transmission between program spaces and work areas.

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

Exterior personnel doors shall be painted steel clad, thermally insulated, and thermally gasketed fitted with industrial-grade hardware and closers, including kick plates.

Exterior overhead doors shall 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 shall be high-speed and fire rated as required.

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

3.2.6 Floors

All floors shall 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 shall 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)

3.2.7 Vibration and Acoustics

Vibration and noise-generating equipment, including air compressors and pumps, shall 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 shall be rated to further reduce noise transmission to other parts of the facility.

3.2.8 Bollards

Protective bollards shall be provided at the exterior of all overhead doors and around interior or exterior equipment vehicle circulation paths. Bollards or guardrail shall 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 as referenced in 3.2.10.

3.2.9 Housekeeping Pads

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

3.2.10 Safety Issues

A comprehensive plan for safety markings, signage and warnings shall be established for the specific layouts of the project. 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 shall 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 shall 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 shall be included in the manufacturer equipment manuals.

3.2.11 Signage and Graphics

Specific signage and graphics requirements, including safety, directional, guidance, informational, traffic signs, and pavement markings, shall 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.

3.2.12 Refuse/Recycling Collection

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

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

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

3.3 Structural

The structure shall be designed to meet the requirements outlined in the following subsections. The structure shall 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 shall be demonstrated through the construction of a mathematical model and the evaluation of this model for the applied force effects. Individual members shall be provided with adequate strength at all sections to resist the shears, axial forces and moments determined in accordance with these provisions and connections shall develop the strength of the connected members for the forces indicated above. The deformation of the structure shall not exceed prescribed limits. A continuous load path or paths, with adequate strength and stiffness shall be provided for all forces from the point of application to the final point of resistance.

3.3.1 Codes, Standards, and Manuals

- Massachusetts State Building Code (789 CMR)
- International Building Code
- ASCE 7, Minimum Design Loads 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

3.3.2 Sustainability Coordination

This section summarizes structural design guidelines for meeting project sustainability and resiliency goals and requirements. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach.

3.3.2.1 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 percent from the baseline building shall 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 Section 2.4, Sustainability and Resilience, for additional information on the coordination of carbon reduction strategies.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR1.1 Reduce Net Embodied Carbon;* and *LEED MR Credit: Building Life-Cycle Impact Reduction.*

3.3.2.2 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 Envision Sustainable Infrastructure Framework (v3), *RA1.2 Use Recycled Materials and RA1.1 Support Sustainable Procurement Practiced*; and LEED MR Credits *Building Product Disclosure Information* (three separate credits) and EQ Credit *Low Emitting Materials.*

3.3.2.3 General Design 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.

3.3.3 Resilience Coordination

Structural design shall meet the resilience performance goals included in Section 2.4, Sustainability and Resilience, under the conditions for the disruptors outlined in Section 2.4.4.3, 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 subsections below by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR 2.3 Evaluate Risk and Resilience* and *CR2.4 Establish Resilience Goals and Strategies*.

3.3.3.1 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:

- 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

3.3.3.2 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 shall meet the resilience performance goals under the coastal flooding conditions outlined in Section 2.4.4.3, Resilience Performance Requirements and Goals. Possible structural design strategies include:

- 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

3.3.3.3 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:

- 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

3.3.3.4 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:

- 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

3.3.4 Building Component Requirements

3.3.4.1 Material Specifications

The structural design shall adhere to the following material specifications:

Table 3.3-1. Material Specifications

Material	Design Parameter
Concrete	F'c = 4,000 pounds per square inch (psi) (min)
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

3.3.4.2 Combination of Load Effects

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

3.3.4.3 Standard Design Loads

For the purposes of analysis and design, the following weights of construction materials shall be used. The Live Loads, Snow Loads, Wind Loads, and Seismic Loads shall 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

3.3.4.4 Serviceability Requirements

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

3.3.4.5 Foundations and Geotechnical

Each site shall 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 shall be designed based using actual loads from the BOD manufacturer(s) with appropriate factors to account for “or equal” equipment alternatives.

3.3.4.6 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 shall align with resilience performance thresholds as referenced in Section 3.3.3, Resilience Coordination, that include guidelines for specific design parameters.

Ground floor slabs shall extend to the exterior of the building along all vehicular circulation paths including areas adjacent to all overhead doors, queueing areas and loading docks. Ground floor slabs adjacent to overhead doors shall 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 shall 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 shall be installed on 6-inch high housekeeping pads.

Floor depressions and sloped slabs shall 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 shall allow for a minimum overlay material thickness of 4-inches.

3.3.4.7 Structural Frame

The basic vertical and lateral seismic-force-resisting system shall conform to the procedure outlined in ASCE 7 section 12.2. The appropriate values of the Response Modification Factor R, Overstrength Factor Ω_0, and Deflection Amplification Factor C_d indicated in ASCE 7 table 12.2-1 shall be used in determining the base shear, element design forces, and design story drift.

3.3.4.8 Roof Structure

In addition to the standard International Building Code load requirements, the roof of the facility shall 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.

3.4 Mechanical

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

3.4.1 Code, Standards, and Manuals

- Massachusetts State Building Code
- International Mechanical Code, edition referenced in the Massachusetts State Building Code
- International Energy Conservation Code, 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
- ASHRAE Handbook: HVAC Systems and Equipment
- ASHRAE Handbook: Fundamentals
- ASHRAE Handbook: HVAC Applications
- American Conference of Governmental Industrial Hygienists, *Industrial Ventilation Handbook*
- SMACNA-Sheetmetal and Air Conditioning Contractors National Association

3.4.2 Sustainability Coordination

This section summarizes mechanical design guidelines for meeting project sustainability and resiliency goals and requirements. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach.

Unless otherwise noted, the mechanical engineer is primarily responsible for compliance with the requirements outlined below. In accordance with the project's sustainability goals the following strategies shall be considered:

3.4.2.1 Energy Performance

Efficiency of the building systems and equipment included in the design and installation shall conform with ASHRAE Standard 90.1 (which is a state code requirement in Massachusetts) and with the Stretch Energy Code (which is required by the City of Boston and in most Boston-area municipalities).

The mechanical engineer shall 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 shall be provided with some form of heat recovery.
- All air handling equipment that provides mechanical cooling shall have an airside economizer.
- All boilers shall be condensing type.
- All-electric motors shall be premium efficiency type.

- Energy metering for HVAC systems shall be reported to the Enterprise Energy Management System and Building Automation System 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 shall be used where feasible or at the request of MBTA.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA2.1 Reduce Operational Energy Consumption;* and LEED EA Prerequisite *Minimum Energy Performance*, and *Credit Optimize Energy Performance*.

3.4.2.2 Reducing Operational Carbon

The mechanical engineer shall coordinate with the civil, structural and electrical engineers, and architecture team to address the goal to move towards 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 Section 2.4, Sustainability and Resilience):

- Envelope airtightness - Account for air barrier performance in system sizing
- 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 *Envision Sustainable Infrastructure Framework* (v3), *CR1.2 Reduce Greenhouse Gas Emissions* and *CR1.3 Reduce Air Pollutant Emissions*; and LEED EA Prerequisite *Minimum Energy Performance*, and Credit *Optimize Energy Performance*.

3.4.2.3 Refrigerant Management

The HVAC and refrigerant equipment shall 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*.

3.4.2.4 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 MERV13 (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.*

Location-specific Particle Filtration

It is critical for projects to be aware if their building is located in an area with elevated outdoor air pollution, as these projects often need to install a pre-filtration stage in addition to the primary filtration to maintain high-quality indoor air. Proper air filtration and the execution of a maintenance protocol over the life of a filter help to improve and maintain indoor air quality over time and play a fundamental role

in creating healthier buildings. The World Health Organization's Global Urban Ambient Air Pollution Database may be consulted to view outdoor air quality levels, available at http://www.who.int/airpollution/data/cities/en/.

Media filters shall be used in the ventilation system to filter outdoor air supplied to occupiable spaces in accordance with thresholds specified in Table 3.4-1. Filters shall be equipped with on-board pressure sensors or filter change indicators that signal when filter requires replacement.

Table 3.4-1. Outdoor Pollution Filter Needs

Annual Average Outdoor PM2.5 Threshold	Minimum Air Filtration Level
16 micrograms per cubic meter (µg/m³) or less	MERV 8 or G4
17–18 µg/m³	MERV 10 or M5
19–23 µg/m³	MERV 12 or M6
24–39 µg/m³	MERV 14 or F8
40–59 µg/m³	MERV 16 or E10
60 µg/m³ or greater	MERV 16 preceded by MERV 8, or E10 preceded by G4

Carbon Filtration

To decrease human exposure to harmful contaminants and reduce volatile organic compounds from indoor air during operations, use one of the options below:

- Activated carbon filters or a combination of particulate/carbon filters in the main air ducts to filter recirculated air.
- A standalone air-cleaning device that uses a carbon filter to treat the air (one device per area coverage as specified by the manufacturer).

Microbe and Mold Control

Prevent mold and microbe growth through a combination of condensation management plans and microbe inactivation techniques.

Ultraviolet Air Treatment

Use one of the following:

- Projects with a forced-air cooling system use ultraviolet lamps to irradiate the surfaces of the cooling coils and drain pans of the mechanical system supplies
- Projects without a forced-air cooling system use standalone ultraviolet germicidal irradiation air sanitizers in all spaces with more than 10 regular occupants.

Noted that ultraviolet treatment is required here for microbe/mold control, but it is not considered effective for COVID-19 air treatment concerns.

Condensation Management

Condensation management is addressed within the project and considers the following:

- High interior relative humidity levels, particularly in susceptible areas like laundry rooms, below-grade spaces and other high-humidity areas.
- Air leakage that could wet either exposed interior materials or interstitially hidden materials.
- Cold surfaces such as basements, slab-on-grade floors or the inside of exterior walls.
- Oversized air conditioning units.

3.4.2.5 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 shall meet this 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 percent of individual occupant spaces; provide group thermal comfort controls for all shared multioccupant spaces. The controls shall 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.*

Monitoring

Building HVAC systems shall be designed to monitor dry-bulb temperature, relative humidity, air speed and mean radiant temperature in applicable regularly occupied or common spaces within the building, satisfying the following requirements:

- Measurements are taken in occupied zones at least 3.3 ft away from exterior walls, doors, direct sunlight, air supply/exhausts, mechanical fans, heaters or other significant source of heat or cold.
- The sensor placement density is minimum one per floor or one every 3,500 ft, whichever is more stringent.
- Measurements are taken at intervals and heights specified in Table 3.4-2.

Table 3.4-2. Thermal Comfort Monitoring Requirements

Parameter	Sampling Interval	Sampling Height Above the Floor
Dry-bulb temperature	10 minutes or less	3.6–5.6 ft
Relative humidity	10 minutes or less	3.6–5.6 ft
Air speed (only if elevated air speed is used)	3 months or less	3.6–5.6 ft
Mean radiant temperature	3 months or less	3.6–5.6 ft

- Data are analyzed for regularly occupied hours (e.g., median, mean, 75th and 95th percentile)
- Dry-bulb temperature and relative humidity sensors are recalibrated or replaced annually. Air speed and mean radiant temperature sensors used for quarterly measurements are calibrated as per manufacturer's specification.

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.

3.4.2.6 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 shall 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 shall be performed by a Building Enclosure Commissioning Specialist.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA2.4 Commission and Monitor Energy Systems;* and LEED EA Prerequisite and Credit *Fundamental Commissioning and Verification*, and *Enhanced Commissioning*.

3.4.2.7 Acoustics and HVAC Equipment

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 *Acoustical Performance*.

3.4.2.8 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 *Envision Sustainable Infrastructure Framework* (v3), *RA1.2 Use Recycled Materials* and *RA1.1 Support Sustainable Procurement Practiced*; and LEED MR Credits *Building Product Disclosure Information* (three separate credits, *and* EQ Credit *Low Emitting Materials.*

3.4.3 Resilience Coordination

Mechanical design shall meet the resilience performance goals included in Section 2.4, Sustainability and Resilience, under the conditions for the disruptors outlined in Section 2.4.4.3, 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 subsections below by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR 2.3 Evaluate Risk and Resilience* and *CR2.4 Establish Resilience Goals and Strategies*.

3.4.3.1 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:

- 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

3.4.3.2 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 shall meet the resilience performance goals under the coastal flooding conditions outlined in Section 2.4.4.3, Resilience Performance Requirements and Goals. Possible mechanical design strategies include:

- 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).

3.4.3.3 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:

- 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 run-off 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.

3.4.3.4 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:

- 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

3.4.3.5 Disease/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:

- 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.

3.4.4 Design Conditions

Outdoor (ambient) conditions used for calculating the design (peak) load for HVAC systems shall 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 shall be accounted for.

Indoor design conditions that are to be maintained within the building are outlined in Table 3.4-3.

Table 3.4-3. Indoor Design Conditions

Room Type	Summer Dry Bulb (°F)	Summer Relative Humidity (%)	Winter Dry Bulb (°F)	Winter Relative Humidity (%)
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

3.4.5 Energy Source

The designer shall strive to 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. Where fossil fuel heating equipment is used, equipment shall use natural gas. The designer shall demonstrate due diligence on providing electric heating and present justification if not feasible.

3.4.6 Building Space Requirements

3.4.6.1 Office and Administration Spaces

Packaged Rooftop HVAC Unit(s) with airside economizer and variable air volume (VAV) shall be used to serve these spaces. Each of these units shall contain a heating section (if gas-fired, indirect), fan section, direct expansion cooling, and MERV 13 filtration. Units will be ducted to VAV terminal units with reheat coils. If there is a boiler plant, the reheat coils shall be hot water, with two-way modulating control valves. If there is no boiler plant, the reheat coils shall be electric, with silicon-controlled rectifier controls.

In areas that require supplemental cooling, mini-split AC / heat pump can be used. For multiple mini-split units, they can be grouped together in a variable refrigerant flow system.

Ventilation airflow rates to administrative and office spaces shall be designed to conform to the International Mechanical Code latest edition, or, if more restrictive, to ASHRAE Standard 62.1 Ventilation for Indoor Air Quality 2010. Outdoor airflow to these spaces shall be continuously monitored.

3.4.6.2 Bus Storage Space

Energy Recovery Ventilators will be used to serve the bus storage space. These units shall be provided with supply and exhaust fans, MERV 13 filtration on both the supply and exhaust sides, an energy recovery wheel and a heating section. If there is a boiler plant, the heating section shall contain either a hot-water coil with face/bypass controls. If there is no boiler plant, the heating section may be electric or indirect gas-fired (with stainless-steel heat exchanger).

Ventilation airflow rates to the bus storage space shall be designed to conform to the International Mechanical Code latest edition, for a repair garage, which is 0.75 CFM/SF. This exhaust airflow shall be provided with an equal quantity of makeup airflow, as recirculation is not allowed. Makeup airflow shall be heated as required to maintain the indoor design temperature noted above. An energy recovery unit shall be used to allow the exhaust air from this space to be used to preheat the makeup air.

3.4.6.3 Bus Maintenance Space

This space shall be served by heating, cooling, and ventilating air handling unit(s). These units shall be provided with a fan section, a heating section and a filtration section with MERV 13 filtration. The air handling unit shall also be provided with a direct expansion cooling coil with a stainless-steel coil casing and stainless-steel drain pan, with refrigerant piping to a roof-mounted air-cooled condensing unit. If there is a boiler plant, the heating section shall be provided with a hot-water coil with face/bypass controls. If there is no boiler plant, the heating section may be electric or indirect gas-fired (with stainless-steel heat exchanger).

A general exhaust system shall provide the required total exhaust flow rate of 0.75 CFM/SF from the space. This exhaust airflow shall be provided with an equal quantity of makeup airflow, as recirculation is not allowed. Makeup airflow shall be heated as required to maintain the indoor design temperature noted above.

If the facility will accommodate fossil fueled buses, spaces with maintenance bays shall be provided with a source capture system shall be provided that connects directly to the bus exhaust tailpipes. This system shall include an industrial-grade fan and a hose-reel system with a tailpipe connector.

3.4.6.4 Bus Wash Bays

This space shall be served by a heating and ventilating air handling unit. This unit shall be provided with a fan section, a heating section and a filtration section, with MERV 13 filtration. If there is a boiler plant, the heating section shall be provided with a hot-water coil with face/bypass controls. If there is no boiler plant, the heating section may be electric or indirect gas-fired (with stainless-steel heat exchanger).

3.4.6.5 Fueling Bays

This space shall be served by a heating and ventilating air handling unit. This unit shall be provided with a fan section, a heating section and a filtration section, with MERV 13 filtration. If there is a boiler plant, the heating section shall be provided with a hot-water coil with face/bypass controls. If there is no boiler plant, the heating section may be electric or indirect gas-fired (with stainless-steel heat exchanger).

In spaces where fuel is dispensed, ventilation airflow rates shall conform to the requirements for automotive motor fuel dispensing stations (1.50 CFM/SF, per International Mechanical Code [IMC] section 502). The bottom(s) of the exhaust openings in fuel dispensing areas shall be located not more than 18 inches above the floor. Exhaust airflow shall be provided with an equal quantity of makeup airflow, as recirculation is not allowed. Makeup airflow shall be heated as required to maintain the indoor design temperature noted above.

3.4.6.6 Toilet, Locker, and Shower Rooms

Roof-mounted exhaust fan(s) shall be ducted to these rooms to provide for the code-required ventilation of those spaces.

3.4.6.7 Electrical Rooms

Horizontal electric unit heater(s) shall be used.

3.4.6.8 Miscellaneous Spaces

Miscellaneous spaces include service entry rooms, parts storage rooms, mechanical rooms, and loading docks. Horizontal indirect unit heaters will be used to maintain minimum temperature setpoints

in these spaces. If there is a boiler plant, these unit heaters shall be provided with hot-water coils. If there is no boiler plant, the heating section may be electric or indirect gas-fired (with stainless-steel heat exchanger).

Ventilation of welding operations shall be in conformance with the American Conference of Governmental Industrial Hygienists *Industrial Ventilation Handbook*. The fan used to exhaust this operation shall be dedicated and shall be of spark-resistant construction.

3.4.7 HVAC Equipment Standards

3.4.7.1 Packaged Rooftop HVAC Units

These units shall be commercial-grade units with components selected for durability. Cooling coils shall be provided with stainless-steel coil casings and drain pans. If gas-fired, heat exchangers shall be stainless-steel. Fans shall be provided with variable frequency drives. These units shall be provided with airside economizers with return/exhaust fans.

3.4.7.2 Air Handling Units

These units shall be commercial-grade units with components selected for durability. Cooling coils (if included) shall be provided with stainless-steel coil casings and drain pans. If gas-fired, heat exchangers shall be stainless-steel. Where these units serve multiple zones, they shall be provided with variable frequency drives.

3.4.7.3 General Exhaust Fans

These units shall be commercial-grade centrifugal fans with spun aluminum unit covers, with integral disconnects.

3.4.7.4 Source Capture Exhaust Systems

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

3.4.7.5 Air Curtains

An air curtain with a heating component shall be provided at each overhead door. These devices shall be selected to provide for insect and wind control.

3.4.7.6 Boilers

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

3.4.7.7 Unit Heaters

Where heaters are used to serve open spaces such as storage or loading docks, they shall 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 shall 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.

3.4.8 Ductwork

Ductwork systems shall 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 VAV terminal units, SMACNA Duct Construction
- Piping systems shall be suitable for service with hot-water heating piping at 125 pounds per square inch gauge at 200°F

3.4.9 Building Automation System

The Building Automation System shall monitor and control all major HVAC equipment, including all packaged rooftop units, all air handling units and all exhaust systems/equipment. Alarms shall be provided to ensure safe operation of all equipment and alert building personnel in the event of system failure. Alarms shall include HVAC equipment status, space temperatures, as well as miscellaneous alarm points from the plumbing and electrical systems.

CO_2 sensors in densely occupied spaces of 25 people or more per 1,000 square feet (such as conference rooms) will monitor CO_2 concentrations for demand-based ventilation as an energy conservation measure. Outdoor air will be minimized to save energy when the space is not occupied or lightly occupied. Upon the sensing of oxygen concentration rises above the set point, the following shall happen:

- Increase airflow into the room by opening the VAV terminal by override the cooling demand.
- Outdoor air damper at the air handling unit may modulate to open to increase the outside air percentage in the supply air.
- When the space temperature falls, the reheat coil shall activate to maintain the temperature.

In the event of a CO_2 alarm, the following will occur:

- A local alarm will occur in the space (audio or visual).
- If the damper position of the VAV terminal supplying the space is not fully open, the damper will incrementally increase airflow until CO_2 concentrations are met after 5 minutes.
- If the damper position of the VAV terminal supply the space is fully open and the CO_2 sensor is still in alarm, the CO_2 sensor will send an audible and/or visual alarm to the building operator via the Building Automation System.

3.5 Electrical

Electrical systems shall be designed to meet the requirements outlined in the following subsections. The electrical distribution shall be designed for the maximum level of safety and convenience. Electrical design shall 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 shall be carefully considered and the level of user comfort, as determined by the availability and adequacy, seismic, and sustainability shall be addressed.

3.5.1 Codes, Standards, and Manuals

- MassDOT Design Directive - Design Lighting Levels and Fixtures
- National Fire Protection Association (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-International Energy Conservation Code
- IES - The Lighting Handbook American Public Transit Association
- 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

3.5.2 Sustainability Coordination

This section summarizes electrical design guidelines for meeting project sustainability and resiliency goals and requirements. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach. Unless otherwise noted, the electrical engineer is primarily responsible for compliance with the requirements outlined below.

3.5.2.1 Reducing Operational Carbon

The electrical engineer shall coordinate with the civil and mechanical engineers and architect to address the goal of moving towards net-zero carbon in a holistic manner. In addition to other design aspects, electrically focused required considerations include the following (full descriptions are detailed in Section 2.4, Sustainability and Resilience).

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR1.2 Reduce Greenhouse Gas Emissions* and *CR1.3 Reduce Air Pollutant Emissions;* and LEED EA Prerequisite *Minimum Energy Performance*, and *Credit Optimize Energy Performance*.

3.5.2.2 Reducing Operational Energy Consumption

The intent of the Envision metric is “conserve energy by reducing overall operational energy consumption throughout the project life”. The electrical and mechanical engineers shall coordinate with the architect in order to address this goal in a holistic manner. Per LEED Prerequisite requirements, the facility shall comply with the mandatory Massachusetts Building Energy Code and prescriptive provisions of ANSI/ASHRAE/IESNA Standard 90.1–2010; 2013 may also be used for documentation via LEED Interpretation #10481. 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.

To achieve these goals, the Lighting Power Density including task lighting in addition to other operational metrics such as heating and cooling loads shall be substantially lower than the ASHRAE baseline. As described in Section 3.5.7.4, Lighting System, 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 shall 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 (VFDs) and soft-starters overcurrent protections for larger electrical, mechanical and plumbing equipment shall be designed to reduce the overall operational energy of the building.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA2.1 Reduce Operational Energy Consumption;* and LEED EA Prerequisite and Credit *Optimize Energy Performance.*

3.5.2.3 Light Pollution Reduction

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. Meet LEED requirements for all exterior luminaires located inside the project’s site boundary based on the following:

- The photometric characteristics of each luminaire when mounted in the same orientation and tilt as specified in the project design; and
- The lighting zone of the project property (at the time construction begins). Classify the project under one lighting zone using the lighting zones definitions provided in the Illuminating Engineering Society and International Dark Sky Association (IES/IDA) Model Lighting Ordinance User Guide.

The electrical and civil engineers and architect shall coordinate their unified design approach in order to best address this goal.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *QL1.5 Minimize Light Pollution;* and LEED SS Credit *Light Pollution Reduction.*

3.5.2.4 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.

Typical electrical systems to be commissioned include service, distribution, 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 *Envision Sustainable Infrastructure Framework* (v3), *RA2.4 Commission and Monitor Energy Systems*; and LEED EA Prerequisite and Credit *Fundamental Commissioning and Verification* and *Enhanced Commissioning*.

3.5.2.5 Metering Energy Systems

The project shall 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.). Utility-owned meters capable of aggregating building-level resource use are acceptable. Additionally, advanced energy metering shall be included in the design for the following:

- All whole-building energy sources used by the building
- Any individual energy end uses that represent 10 percent or more of the total annual consumption of the building

The advanced electricity metering system shall be permanently installed, record both the consumption and demand at one-hour intervals or less and transmit data to a remote location. The meters shall be capable of reporting hourly, daily, monthly, and annual energy use. The entire building electricity meters will record the power factor, if appropriate.

The data shall be remotely accessible, and the recording system shall be capable of storing all meter data for at least 36 months.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA2.4: Commission and Monitor Energy Systems*; and LEED EA Prerequisite and Credit *Advanced Energy Metering.*

"Leading by Example Program" Compliance

The electrical engineer shall enable the project to work with the Division of Capital Asset Management and Maintenance on the Commonwealth Building Energy Intelligence program, an advanced energy metering and analytics program to reduce energy consumption and costs at state facilities. Additional energy information is gathered through utility account data collected through the Department of Energy Resources' MassEnergyInsight tool that gathers monthly energy use data for thousands of electricity and natural gas accounts. Additional information on this project can be found at https://www.mass.gov/service-details/energy-savings-optimization-program.

3.5.2.6 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 shall 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 shall be proposed.

Power produced from the photovoltaic system shall be supplied 100 percent 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 shall work directly with the MBTA to determine the preferred approach to onsite energy generation and storage. A set of bid documents shall be provided by the third-party vendor to identify potential solar contracts to design, procure, construct, and maintain the array.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA2.3 Use Renewable Energy*; and LEED EA Credit *Renewable Energy.*

3.5.2.7 Interior Lighting – Controllability

To promote end-user's comfort, productivity, and wellbeing, the project shall provide high-quality lighting including a variety of user-accessible controls. Multilevel lighting controls for all individual occupants shall enable a user to adjust the lighting (on, off, midlevel) to suit their individual tasks and needs. Midlevel is 30 percent to 70 percent of the maximum illumination level (not including daylight contributions).

In shared spaces, multizone control systems (minimum three lighting levels for on, off, and midlevel) shall enable occupants to adjust the lighting to meet group needs and preferences. Manual switches in these spaces shall be in the same space as the light fixtures and one has direct line of sight to the controlled luminaires. Also, lighting for presentation or projection wall shall be separately controlled.

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

Refer to LEED EQ Credit *Interior Lighting, Option 1: Lighting Control*.

3.5.2.8 Interior Lighting Quality

Ensure Color Rendering Quality

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

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

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 ≥ 78, IES R_g ≥ 100, -1% ≤ IES $R_{cs,h1}$ ≤ 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 shall 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 below conditions:
  - Luminaires installed at a height of 5 m [16 ft] or lower meet Unified Glare Rating of 19 or lower.
  - Luminaires installed at a height greater than 5 m [16 ft] 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 - cut-off angle)
< 20,000 cd/m² (including reflected sources)	No shielding required
20,000 cd/m² to 50,000 cd/m²	15°
50,000 cd/m² to 500,000 cd/m²	20°
> 500,000 cd/m²	30°

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.

Manage Brightness

At least four of the following requirements shall 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.

3.5.2.9 Inclusive Design

To create an inclusive design, a full range of ability, age, language, culture, gender, and other characteristics of human diversities shall be considered. For a more inclusive, adaptive design, the project shall 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* (USGBC 2020d).

3.5.2.10 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 *Envision Sustainable Infrastructure Framework* (v3), *RA1.2 Use Recycled Materials* and *RA1.1 Support Sustainable Procurement Practiced;* and LEED MR Credits *Building Product Disclosure Information* (three separate credits), and EQ Credit *Low Emitting Materials.*

3.5.2.11 Life-cycle Impact Reduction

To encourage adaptive reuse and to optimize the environmental performance of products and materials, flexible power distribution systems for at least 50 percent of the project area shall be implemented so that systems such as lighting, data, voice can be easily reconfigured and repurposed. A flexible lighting control system with plug and play components for at least 50 percent of the lighting load shall also be implemented, allowing easy reconfiguration and repurpose of luminaires and controls. In addition, if a space changes functions, the lighting will be flexible to the suit the need without rewiring or replacing luminaires.

The architect and electrical engineer will coordinate their unified design approach to best address this goal.

Refer to LEED MR Credit *Building Life-Cycle Impact Reduction, Option 3: Building and Material Reuse* (USGBC 2020e).

3.5.3 Resilience Coordination

Electrical design shall meet the resilience performance goals included in Section 2.4, Sustainability and Resilience, under the conditions for the disruptors outlined in Section 2.4.4.3, 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 subsections below by disruptor for designers to consider and to guide evaluation of possible means and methods for meeting the required performance goals.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *CR 2.3 Evaluate Risk and Resilience* and *CR2.4 Establish Resilience Goals and Strategies*.

3.5.3.1 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:

- 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)

3.5.3.2 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:

- 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

3.5.3.3 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:

- 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 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

3.5.3.4 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:

- 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

3.5.3.5 Disease/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:

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

3.5.4 Installation

All electrical devices, equipment, wire and cable within the bus maintenance facility shall be installed in accordance with the NEC with Massachusetts Amendments.

3.5.5 Supports

All electrical distribution systems of the facility shall be provided with vibration isolation. All electrical equipment, including life-safety-related equipment, shall be provided with seismic restraints as specified by the manufacturer's recommended installation instructions. The seismic-restraint system shall be designed by a licensed professional engineer, including the submission of a stamped design for review.

3.5.6 Electrical System

3.5.6.1 Incoming Electrical Service Requirement

Each facility shall have its own utility transformers, fed by available MV feeders from the utility supply lines. The entire design shall comply with seismic-restraint requirements in the International Building Code unless MBTA requires more stringent rules. The designer shall consult with the supplying utility as to the required metering configuration before design is released for construction. This direction shall be documented in writing and become part of the project/design documentation.

Two new medium-voltage (MV) feeders will be brought to the site by the local utility company. MBTA and the designer shall work with the local utility to determine where the MBTA will take ownership of the incoming service. An MV switching station will include the incoming (primary) breakers, metering and control that will be coordinated with the utility company but will be owned, operated and maintained by the MBTA. All breakers, switches and controls related to the incoming service shall be equipped with remote operable functionality and shall be installed outside the service equipment room.

Two breakers at the service create a dual service connection at the site. The MV circuit breakers will allow MBTA to disconnect from utility company for maintenance/operations purposes. The MV circuit breakers will feed opposite ends of a double-ended MV switchgear lineup (main-tie-main) in the electrical room. The primary switchgear will be set up to auto-transfer load if power is lost on one of the buses. The MV switchgear lineup shall have adequate circuit breaker projection for future BEB charging systems. Spare breakers shall be provided for future expansion.

The MV distribution from the switching facility to the bus maintenance facility shall be routed via concrete encased reinforced duct banks and manholes. Feeders shall be routed independently from each MV bus to the facility to ensure redundancy is maintained. Conduits shall be sized as required but shall not be less than 5-inch conduits for MV circuits. Manholes will be spaced at not more than 350 feet apart and shall be suitably sized per electrical codes and MBTA standards. The switching station facility shall be designed to be resilient from potential environmental incidents including earthquakes, floods, and other natural and manmade issues.

The secondary substations are equipped with a tie breaker. The tie breaker shall auto-transfer load if power is lost on one of the buses. The secondary switchgear shall be braced with ampere interrupting capacity rating of 100,000 amps minimum or as required.

Power factor correction shall be provided with auto-step/detuned units fed from each bus of the low-voltage switchgear (eight capacitor units total). Detuning shall prevent overloading of capacitors due to harmonics generated by VFDs. The design engineer shall evaluate both integrated filter to the switchboard or individual filter to each drive in each site and design for most feasible and sustainable option.

The size of the electrical room shall 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 shall be required to monitor different floors and practices (lighting, chillers, etc.) for sustainability consideration. The number of submeters shall be further discussed per each site with MBTA. The metering shall be certified to Electronic Meter National Accuracy Standards.

The power factor capacitors shall be in the room with the substation they are fed from. Transformers shall be epoxy cast coil dry type with 150 percent fan overload rating and shall be close coupled to the low-voltage switchgear. Secondary main breakers, the tie breaker, and feeder breakers shall be power circuit breakers.

Each low-voltage substation shall 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 shall avoid unplanned shutdowns. The low-voltage substations shall 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.

A separate switchgear(s) shall be provided for the electrical fleet charging systems considering plans for expansion. Exact quantity of buses that can be charged shall be based on power systems that can be provided to each site and the building. Careful consideration shall be made for building demand, diversity of electrical systems, building operations, and the project program. Additional power shall be required for charging the maximum quantity of BEBs planned and shall have to be coordinated further with system operations and available sources of power through future phases of design.

3.5.6.2 Emergency and Operational Standby Generators

The emergency generator for life-safety equipment shall be located outside 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 shall work with MBTA and the Office of the Chief Engineer 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 shall provide power during outages to enable evacuation of the facility during the temporary outage. In addition to the emergency generator, provisions shall 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 shall 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 shall send a signal to start the generator. The ATS shall then transfer the load from the normal source to the emergency source. When normal power has returned, the ATS shall make a closed transition transfer from the emergency source to the normal source. The ATS shall then send a signal to shut down the generator.

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

The loads connected to the emergency generator include:

- Egress and Emergency Lighting
- Fire Alarm Panel
- Fire Pump and Jockey Pumps
- Fire Elevators, if provided
- Automatic Sprinkler System

In addition to the emergency generator, an optional standby generator shall be provided with separate ATS and optional standby electrical distribution system to provide standby power for loads required by MBTA that are critical for facility operation. The inclusion of standby loads shall be evaluated on a per-application basis, but at a minimum shall supply the loads specified in Section 3.5.6.3, Uninterruptable Power Supply. Appendix D, Optional Standby Power Generator Equipment, provides a baseline list of equipment to consider for standby power. The design engineer shall perform additional analysis and further discussion with MBTA in each site location to determine the loads requiring optional standby power. The optional standby generator shall not include non-essential high-load functions such as welding equipment and vehicle chargers.

Per MBTA Design Directives, all generators shall be sized with a future capacity of 30 percent over the base calculated values. In addition, the generator fuel supply systems shall be sized to allow for a minimum run time of 24 hours under full load. The designer shall also consider the resilience requirements in Section 2.4.4.3, Resilience Performance Requirements and Goals.

3.5.6.3 Uninterruptable Power Supply

Rack-mounted uninterruptable power supplies (UPS) shall provide backup power for critical and other non-motor loads, such as information technology (IT) equipment and security systems, that cannot tolerate a power interruption. Separate UPS units shall 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 shall be a minimum of 30 minutes and battery monitoring shall be provided.

Each UPS shall be fed by the optional standby generator. There is no redundancy in capacity to protect against a failure of the UPS itself. UPS is anticipated to require yearly preventative maintenance, which shall be required within the system warranty period.

Each UPS shall be located in a climate-controlled room and elevated, if necessary, to meet the resilience requirements under Section 2.4.4.3, Resilience Performance Requirements and Goals.

3.5.7 Low-Voltage Distribution

The facility shall be fed by low-voltage substations through duct bank routes and shall be distributed throughout the building at a nominal 480/277V, 60 Hz., three-phase, four wire with ground. Large loads, such as the chillers, shall be fed directly from the substation and shall be run in conduit. Normal, emergency and optional standby power feeders shall be run in separate conduits.

The secondary power distribution system shall be designed to limit voltage drop to a maximum of 2 percent on feeders and 3 percent on branch circuits. Power and safety switches shall be provided and sized for mechanical equipment, plumbing equipment and fire protection equipment. Power shall 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 shall be fed from independent ATS from the separate generators through separate duct banks. Loads with backup power from emergency and optional standby generator(s) shall be fed through the respective panels. Normal and backup power feeders shall be run in separate conduits.

The design and layout of the distribution panels shall be as follows: The lighting circuits shall be fed from dedicated lighting distribution panels at 480/277v 3ph 4 wire with ground. General convenience outlets

and small appliances shall be fed from power distribution panels supplied at 208/120v 3ph 4-wire with ground. Additional power distribution panels supplied at 480/277v 3ph 4 wire with ground shall be provided for larger motor loads and equipment requiring 480V 3ph. The design of this distribution system shall be required to be sourced from different transformers and distribution panel boards.

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

3.5.7.1 480/277V Power Distribution Panels

Power distribution panels shall 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 480V shall be provided for motors (1/2 horsepower and larger), and other heavy loads greater than 5 kW. 277V shall be used for VAV fan terminal units.

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

3.5.7.2 Step-down Transformers

The standard 480V to 120/208V 3 phase transformers shall provide unclean power for general distribution on each floor. All transformers shall be of K-13 rating.

The designer shall work with the MBTA to determine each facility's requirements for isolated 480V to 120/208V 3 phase transformers to provide clean power for workstation computers, servers, security services, and audiovisual (A/V) equipment. An isolated grounding distribution system is recommended for loads such as computers, printers, and data rooms.

Step-down transformers with minimum efficiencies shall comply with National Electrical Manufacturers Association (NEMA) TP-1 Guide for determining energy efficiency for distribution transformers and shall be designed for calculated demand plus 25 percent spare capacity.

3.5.7.3 208/120V Power Distribution Panels

Receptacle outlets, special lighting, fire alarm system, security systems, communication, motors 1/3 horsepower and less, and other small appliance loads shall be wired to 208/120V, 3-phase, 4-wire panels. For dedicated receptacles and other equipment, 208V shall be provided as required.

Power Distribution Panels shall contain circuit breakers and copper bussing. The panelboards shall be sized with 25 percent spare capacity (10 percent spare breakers and 15 percent spaces for future breakers).

3.5.7.4 Lighting System

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

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

3.5.7.5 Interior Lighting

Interior lighting shall 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 shall be approved by the Office of the Chief Engineer before installation.

The bus storage, maintenance, and service area shall be luminated by LED high bay fixtures. Lighting systems in different spaces of the administration area shall be carefully selected as each space shall be designed to respond to the needs of the user, the tasks to be performed, and the architectural qualities of the space. Care shall be taken to select fixtures that achieve the recommended task illuminance levels while maintaining a power density less than the limits outlined by the Energy Code. Section 4, Area Modules, provides details on the design levels of illumination and type of fixture for each facility area, however, the MBTA's Lighting Guide and Design Directive will guide the ultimate design, fixture selection and lamp temperature.

Where suitable LED type fixtures are not available, T5 or T5 HO fixtures shall be used subject to approval by the Office of the Chief Engineer. Lamps shall be improved color, triphosphorous type with a color temperature of 4000 Kelvin, with a minimum power factor of 0.95. The voltage level shall be 277V.

In general, interior lighting fixtures shall be locally switched utilizing local 277V switches. Fixtures used in hazardous areas shall be rated for the respective area environments. The fixtures shall be installed per the applicable electrical code.

Lighting controls shall meet the control requirements as defined in Section 3.5.2.6, Renewable Energy, and shall be designed per International Energy Conservation Code recommendations. Life-safety lighting fixtures shall be controlled from panelboard circuit breakers only. Occupancy sensors shall be used throughout all areas of infrequent usage, except mechanical/electrical rooms. Open area lighting shall be switched based on probable use. The Building Management System shall be used to turn off lighting fixtures in the bus storage on a set schedule. Override switches shall be provided in these areas.

3.5.7.6 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 shall 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.

Building perimeter, stairs, ramps, dropoff/pickup areas, building entrances and exits, vehicular entrances and exits, signage, all pedestrian pathways, bicycle facilities, parking areas and roadways shall 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. The fixtures shall be vandal-resistant, and the fixture location shall be easily accessible for maintenance purposes.

The exterior lighting fixtures shall be LED. A 3000K color temperature shall be used, with a 70+ Color Rendering Index for all exterior lighting. Exterior lighting shall be IP66 rated, and Underwriters Laboratories (UL) listed for wet locations. LEDs shall have a minimum life rating of 50,000 hours with 70 percent lumen maintenance at 25 degrees Celsius.

Lighting shall conform to the MBTA Lighting Standard and Design Directive with automated dimming capabilities where needed in areas with the potential for high "spill" light. The lighting level and "spill" light shall be reviewed with each local municipality to ensure proper levels for the building location. Fixtures illuminating the building façade shall be shielded from view beyond the property line. Other fixtures with intensities shall be shielded or rated as full cut-off per the Illuminating Engineering Society

of North America (IESNA). The site lighting design shall avoid any direct illumination onto adjacent properties to limit spill light per IESNA and code cut-off requirements.

Higher levels of lighting shall be provided for loading areas and crosswalks. Additional lighting shall be provided during daytime hours at the garage entrance to transition from bright sunlight to relatively dark interior.

Lighting poles for exterior lighting shall be heavy-duty coated aluminum, or epoxy coated steel poles to maximize service life. Pole concrete bases shall extend a minimum of 12 inches above-grade. Path and walkway lighting poles shall be pedestrian scale with a maximum of 15 feet high and a minimum of 10 feet high.

Area lighting pole height shall be a minimum of 20 feet tall to optimize light distribution and coverage and prevent glare.

The lighting controls shall meet the mandatory control requirements as defined in Energy Code and Standards. Lighting controls for site areas shall turn on exterior luminaires when ambient illuminance levels drop below the design illuminance target at the ground plane. Each luminaire shall have integral occupancy and photo sensor controls. Lights shall turn off when daylight is sufficient and have an integral occupancy sensor to dim lighting when unoccupied. Lighting control shall use a programmable astronomical time clock override scheduling system. A minimum level light shall always be provided for the 24-hour parking regardless of occupancy.

The site wiring shall be underground for safety, reliability, lower long-term operating cost and aesthetics. All underground wiring and duct banks shall be installed in fiberglass reinforced epoxy sized in accordance with the Massachusetts Electrical Code.

Exposed wiring shall be enclosed in galvanized rigid metal conduit and the conduit shall follow architectural and structural members, moldings, or ornamental details in as unobtrusive a manner as possible. Conduit shall also match the color of the background on which it is mounted. Exposed exterior conduits shall be installed with vandal-resistance supporting means spaced according to the requirements of the current NEC.

3.5.7.7 Emergency Egress and Night Lighting System

Emergency lighting shall be powered from the emergency generator. Emergency lighting and exit signs shall provide minimum footcandle along egress routes, corridors, and staircases as defined by the MBTA Lighting Standard and Design Directive.

Emergency lighting fixtures shall also be used for night lighting and shall not be switched.

Cables for emergency lighting shall be run separately from other cables in a dedicated raceway.

Exterior building perimeter and exit lighting shall be wall-mounted bulkhead and floodlights with LED lamps rated for the environment and 277V.

3.5.7.8 Motor Starters

Motor starters shall have an incoming motor circuit protector and motor overload protection.

Motor control centers may be used where a cost advantage can be obtained by grouping motor starters into one factory assembled structure.

3.5.7.9 Variable Frequency Drives

VFDs shall be used to optimize energy consumption and performance.

VFDs shall have incoming fusible disconnect, 5 percent incoming line reactors and motor overload protection.

Shielded cable with 1600V insulation shall be used between the VFD and the motor. Cable shall be rated for the application.

VFDs shall be capable of being controlled by the programmable logic controller (PLC) or Building Management System through an Ethernet interface or Wi-Fi system. The design engineer shall finalize the number and type of VFD controls for each motor with approval from MBTA.

VFDs shall be installed close to their respective motors allowing reduction in electrical room size and maintaining a short motor feeder cable to reduce voltage spike stress on the motor windings and cable. Preferred discrete control voltage level and control philosophy will need to be determined and approved by MBTA.

3.5.7.10 Disconnect Switches

An enclosed circuit breaker or heavy-duty disconnect switch rated for the available short circuit shall be used at each motor. Auxiliary normally close contacts shall be provided and wired to the upstream motor starter or VFD, which open prior to the opening of the power contacts in the breaker. The number of auxiliary contacts to be determined with MBTA for each application in each site.

An enclosed 600V, 3-pole circuit breaker shall be used at each skid and control panel for the main power disconnect. Where a normal power or emergency power source is available, a separate circuit breaker shall be provided for each. The size and rating of circuit breakers shall be determined separately for each switching application.

3.5.7.11 Induction Motors

Motors rated 0.5 horsepower and above shall be 480V, 3-phase. Due to availability, motors rated below 0.5 horsepower shall be 120V, 1-phase or 480V, 3-phase based on the application (480V primarily in service and maintenance applications).

Low-voltage motors shall be totally enclosed, fan cooled premium efficiency type, designed for use with different starter types.

Motors fed from VFDs for variable speed, variable torque applications shall have 1600V insulation and a shaft bearing grounding ring or brush.

3.5.7.12 Raceways

All wiring shall be installed within rigid galvanized conduit schedule 80 with threaded, matching galvanized fittings within the facility. EMT, IMC, and Aluminum IMC shall not be allowed.

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

Aboveground conduit shall be ¾” trade size minimum. Underground conduit shall be 1-inch trade size minimum.

3.5.7.13 Wire and Cable

Low-voltage cables shall be cross-linked polyethylene high heat-resistant water-resistant (XHHW-2), multi-conductor, 600V insulated, stranded copper type tray cable with green equipment ground conductor. The minimum size for lighting and lighting system installations (480/277 V and 208/120 V)

shall be 12 AWG. “Networking” and/or “common neutral circuits” are not allowed. The minimum size for communication systems, Building Management Systems, computer networks, and other low-voltage installations under 50V shall be 24 AWG twisted pair.

All building wire (single conductor) shall be installed in conduit. Building wire shall be XHHW-2, 600V insulated, stranded copper type. See Section 3.5.7.9, Variable Frequency Drives, for cable to be used between VFD and the motor. The cable containment shall be clearly separated, and it shall be possible to identify the particular system category.

3.5.7.14 Wiring Devices

Receptacles shall be selected to suit the areas in which they are located. All general-purpose receptacles shall be 20-amp, 120V duplex unless otherwise designed for specific application.

The general convenience receptacles shall be designed 50 feet on center and within 25 feet of corridor ends. Break room areas shall have dedicated service receptacles for loads such as refrigerators. Counter receptacles in break room areas shall be ground-fault circuit interrupter (GFCI) type listed for personnel protection.

Per MBTA Directive, all junction and electrical boxes installed in wash down areas or areas subjected to water, liquids or moisture with field made penetrations created to enter an electrical junction box shall be made on the bottom of all junction boxes to limit the possibility of the entrance of moisture. When bottom entry is not possible and with written approval from the Office of the Chief Engineer, threaded weatherproof hubs shall be installed for conduit systems and threaded weatherproof compression style hubs for cable entrances will be allowed.

For specific power and wiring requirements for each facility area, see Section 4, Area Modules.

3.5.8 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 shall be provided around the building. The ground loop shall 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 shall 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 shall 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 shall 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 shall be fitted with copper ground bars, for general connection of grounding systems. Each of the copper ground bars shall allow for the connection of all of the local building ground provisions, with spare connections and shall incorporate a proprietary link facility to enable disconnection for test purposes, without the loss of the system ground connection. These ground bars shall 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.

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

Transient Voltage Surge Protection shall be supplied for all panel boards. Transient Voltage Surge Protection shall 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

An external grounding conductor shall be used for MV cables. The grounding conductor shall be included in the cable for multi-conductor low-voltage cables.

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

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

The ground system shall 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 shall be approved by MBTA and Office of the Chief Engineer. The installing contractor shall perform ground system testing per the Institute of Electrical and Electronics Engineers standards. The ground system test report shall be recorded and submitted to the MBTA's Office of the Chief Engineer for review and written approval.

3.5.9 Lightning Protection

A full coverage lightning protection system shall 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 shall comply with NFPA-780 and UL Standards UL 96 and UL 96A, and Standard for Installation of Lightning Protection Systems.

3.5.10 Hazardous Area Classification

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

Enclosures for electrical equipment shall entail the following:

- Electrical non-classified, non-washdown areas – 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

3.5.11 Fire Alarm Systems

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

The new addressable fire alarm system shall include initiation devices, notification system, monitor, and control modules. Fire alarm systems shall 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 shall be capable of identifying precise areas of fire/alarm enabling rapid direct response to an incident. The design of the fire alarm system shall comprise the division of the building into zones for ease of identification. The size of each zone shall be in compliance with statutory standards and requirements.

Refer to Section 3.7, Fire Protection, for fire protection system design requirements.

3.6 Plumbing

The following piping systems shall be incorporated into the design of MBTA bus maintenance facilities and meet the requirements outlined in the subsections that follow:

- Tempered water for emergency shower/eyewash (TW)
- Industrial wastewater (IW)
- Compressed air (CA)
- Diesel fuel (DF)
- Engine oil (EO1)
- Automatic transmission fluid (ATF)
- Engine coolant (EC), type 1 (EC1) and type 2 (EC2)
- Gear oil (GO)
- Chassis grease (CG)
- Waste oil (WO)
- Waste coolant (WC)
- Windshield washer fluid (WWF)

3.6.1 Code, Standards, and Manuals

- 248 CMR 4.00: Massachusetts Fuel and Gas Code
- NFPA 54 - National Fuel Gas Code
- 248 CMR 10.00: Uniform State Plumbing Code

3.6.2 Sustainability and Resilience Coordination

This section summarizes plumbing design guidelines for meeting project sustainability and resiliency goals and requirements. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach.

Unless otherwise noted, the plumbing engineer is primarily responsible for compliance with the requirements outlined below.

In the SRMP, document baseline and designed annual potable water use and non-potable use of the building and site as part of the Integrative Process Documentation. Document water demand reduction strategies implemented. Documentation shall be compatible with Leading by Example tracking form as mentioned in Appendix A, Sustainability and Resilience Supplement.

In the BOD, document the water quality of the public supply water intended for human consumption. If needed for reference, benchmark water quality parameters may be found in the WELL Building Standard. Obtain water supply samples and laboratory analysis for target parameters. Document findings and recommendations such as filtering systems as needed to meet the standard. Document an example treatment system installation costs and maintenance costs along with anticipated benefits. MBTA will determine whether to implement the recommended system. Additional information is provided below.

3.6.2.1 Water Consumption Reduction

The intent of the Envision metric is to “Reduce overall water consumption while encouraging the use of greywater, recycled water, and stormwater to meet water needs.” The effectiveness of the onsite wastewater reuse system is anticipated to be the largest contributor to overall potable water consumption reduction.

Per LEED Prerequisite requirements, the facility shall choose to either comply with Path 1 Prescriptive Achievement where all newly installed toilets, urinals, private lavatory faucets, and showerheads that

are eligible for labeling shall be WaterSense labeled (or a local equivalent for projects outside the U.S.) or to comply with Path 2 Usage-Based Calculation where utilizing the U.S. Green Building Council indoor water use calculator to demonstrate the overall indoor potable water usage to be 20 percent less than code-required levels (baseline). For additional points, levels of reducing indoor potable water consumption will be increased beyond the Prerequisite levels to reduce environmental and economic harms associated with excessive freshwater use.

To achieve these goals, project teams shall select high water-efficient fixtures and fittings, as well as consider alternative water sources whereas applicable and permitted by the local jurisdiction, such as municipally supplied reclaimed water ("purple pipe"), graywater, rainwater, stormwater, treated seawater, condensate, foundation dewatering water, used process water, and reverse osmosis reject water. Project teams shall 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 shall be discussed with and have final approval from MBTA prior to implementation.

Before choosing alternative sources of water, however, project teams will always prioritize the uses of least treatment first, to minimize the energy consumption, such as using rainwater for outdoor irrigation or indoor toilet flushing requiring minimal treatment.

Facility resilience shall also be considered in fixture selection. The plumbing engineer shall consult with MBTA to confirm if there are concerns or preferences around auto-sensor-operated versus manually operated fixtures. It will be noted that during extended power outages (such as in the case of natural disasters), a manual flush or manual faucet operation is more desirable.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA3.2 Reduce Operational Water Consumption;* and LEED WE Prerequisite 2 and Credit 2 *Low-Flow and Low-Flush Fixtures.*

3.6.2.2 Water Quality

The following aspects of water quality are requirements are detailed in Section 2.4, Sustainability and Resilience, and Appendix A, and shall be referenced when designing the building's water systems that are intended for human use:

- Sediment & Microorganisms
- Dissolved Metals, Organic Pollutants, Disinfectants, Herbicide/Pesticide, Fertilizer & Additives
- Drinking Water Taste Properties
- Test Display Water Quality
- Drinking Water Quality

Refer to the sections abovementioned for full design requirements.

3.6.2.3 Water End-use Metering

The intent of the LEED metric is to "Support water management and identify opportunities for additional water savings by tracking water consumption."

To meet LEED Prerequisite requirements and support MBTA efforts to monitor and reduce natural resource use, the facility shall install a permanent water meter measuring whole-building total potable water consumption and commit to sharing data with U.S. Green Building Council for a 5-year period. For additional points, level of monitoring building potable water consumption will be increased beyond the Prerequisite levels to better identify additional water saving opportunities.

To achieve these goals, project teams will identify two or more water subsystems and install permanent submeters to measure 80 percent to 100 percent of flow. These water subsystems could be irrigation,

indoor plumbing fixtures, domestic hot water, process water, reclaimed water, boiler water or cooling tower, depending on the individual facility. Bus wash systems shall also be included in these considerations.

Before installing permanent submeters, project teams shall consider subsystems with the most water consumption, or the highest operation cost, or the most closely meet the goals of the building management. Additionally, the teams shall select the most appropriate subsystems based on the project scopes.

Refer to LEED WE Prerequisite and Credit *Water Metering.*

3.6.2.4 Cooling Tower Water Use

The intent of the LEED metric is to "Conserve water used for mechanical processes and cooling tower makeup while controlling microbes, corrosion, and scale in the condenser water system."

Since MBTA facilities typically do not use cooling towers for cooling purpose, project teams will strive to comply with Option 2. No Cooling Tower.

To achieve this goal, the baseline system shall be based on ASHRAE 90.1-2016 Appendix G Table 3.1.1 with cooling tower (systems 7 and 8). The design case will not include a cooling tower nor use the latent heat of the evaporative cooling of water nor receive any cooling from a District cooling system.

Refer to LEED WE Credit *Cooling Tower Water Use.*

3.6.2.5 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 *Envision Sustainable Infrastructure Framework* (v3), *RA1.2 Use Recycled Materials* and *RA1.1 Support Sustainable Procurement Practiced;* and LEED MR Credits *Building Product Disclosure Information* (three separate credits) and EQ Credit *Low Emitting Materials.*

3.6.3 Plumbing Fixtures

Hand washing stations shall be provided in shop areas. Eyewash and safety showers shall be in hazardous areas, in repair bays, and at the Service Island as required by the Occupational Safety and Health Administration. Plumbing fixtures shall be supplied in sufficient quantity to meet or exceed the requirements of the Plumbing Code requirements and shall provide ¾-inch water service hose bib every 30 feet in bus maintenance bays. Applicable fixtures shall be low-flush / low-flow to conserve water.

To slow the spread of bacteria and viruses, handwashing stations shall be designed in a way that allows the user to avoid unnecessary contact with fixtures or surfaces. Bathroom and kitchen sinks shall meet the following criteria:

- The sink column of water is at least 10 inches in length (measured along flow of water even if angled)
- The sink column of water is at least 3 inches away form an edge of the sink
- The sink basin is at least 9 inches in width and length

3.6.4 Drains

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

- There shall be no drains in the lubricant storage area. Double walled tanks shall 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) shall pass through adequately sized wastewater reuse system before discharging to sewer. These components shall be identified and coordinated during detailed design.
- Install drains in all lift pits to grouped sumps with lift stations.

3.6.5 Compressed Air System

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

3.6.6 Liquid Bulk Distribution

The list of materials shown under piping systems is the basic list of liquid consumables that may be distributed throughout the new facility from a centrally located lube room through a central lubricant system. Other consumable materials may be required dependent upon the fleet mix. Above-grade bulk storage tanks shall be source and preferred storage method. The tanks shall be double-wall construction negating the need for constructed dikes and/or collection pits. The designer shall work with MBTA to define the size of tanks.

The central lubricant system shall provide a variety of lubricants to the appropriate locations by utilizing 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

3.6.7 Wastewater Reuse System

A wastewater reuse system shall be used in the bus wash bays, steam clean bays (chassis wash), and inspection bays. Wastewater reuse system for use within Massachusetts Water Resource Authority (MWRA) shall comply with MWRA industrial discharge permit.

3.7 Fire Protection

The following types of fire protection and suppression systems shall be provided and shall 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 FM-200 for communication rooms

3.7.1 Codes, Standards, and Manuals

- International Building Code
- International Fire code
- NFPA 13 – Automatic Sprinklers
- NFPA 14 – Standpipe Systems
- NFPA 20 – Standard for the Installation of Stationary Pumps for Fire Pumps
- NFPA 25 – Water-Based Fire Protection Systems
- Local codes and ordinances
- Municipal fire and inspectional service departments
- Owner's insurance underwriter

3.7.2 Sustainability and Resilience Coordination

This section summarizes fire protection design guidelines for meeting project sustainability and resiliency goals and requirements. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach.

Fire-protection components within the design principles listed below will be considered for sustainability inclusion:

- Use of local materials
- Waste reduction
- Toxic material reduction

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA1.1 Support Sustainable Procurement Practices* and *RA1.2 Use Recycled Materials;* and LEED MR Credits *Building Product Disclosure and Optimization - Environmental Product Declarations and Material Ingredients,* and EQ Credit *Low Emitting Materials*.

3.7.3 Fire Protection Service

The water supply for the water-based fire protection systems shall be provided by a separate connection to the public water system.

3.7.3.1 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 shall 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 in order to re-confirm the water supply information. Flow test for design submission to the Authorities Having Jurisdiction shall be performed no more than one year prior to the date of submission.

Hydrant flow test data shall include the following:

- Whether the test was performed by the municipal water department or designee
- Location of test (flow hydrant, pressure hydrant)
- Date of test
- Static pressure (pounds per square inch gauge)
- Residual pressure (pounds per square inch gauge)
- Flow (gallons per minute [gpm])

3.7.3.2 Fire Protection Service

- An 8-inch fire protection service shall be provided from the service main into the building.
- The fire service shall enter through a ground floor water entrance room.
- The contractor shall test the fire services from the wet tap to the building in its entirety in accordance with NFPA 13 and 24.
- The service entrance will be provided with an 8-inch double check valve assembly inside the foundation wall.

3.7.3.3 Standpipe Distribution Piping

- A main flow switch and riser check valve shall be provided at the water entrance room. The flow switch shall be wired to an electric bell over the fire department connection.
- A 6-inch fire main standpipe distribution main shall run across the ground-floor ceiling area distributing fire protection water to each exit stair combination sprinkler standpipe riser.
- A sufficient number of alarm check valves shall be provided to serve the floor area of the building.
- Piping shall be painted red.
- All piping shall maintain a minimum pitch to the main drain. Any low points that create a trapped portion of piping shall be provided with low point drains.

3.7.3.4 Combined Sprinkler and Standpipe System

- A combined fire standpipe shall be located in all exit stairs as required by NFPA 14 and the Building Code.
- Fire line distribution piping shall be sized in accordance with NFPA 14 code to provide 500 gpm flowing at 100 pounds per square inch (psi) residual pressure at the hose connection outlet of the top of the most remote standpipe, plus 250 gpm at each additional standpipe (standpipe may be pressurized by fire department pumper if available in coordination with the Authorities Having Jurisdiction).
- 2-1/2-inch fire department hose valves with 2.5-by-1.5-inch reducer, cap and chain will be located on every floor landing within each exit stair.

- 2-inch test and drain stacks will be provided next to every drain test connection in compliance with NFPA 14.

3.7.3.5 Sprinklers

- Sprinklers shall be fed on each floor through two combined standpipe/sprinkler floor control valve assemblies located within the stair towers.
- Each stair tower combination standpipe/sprinkler shall be fed from an alarm wet-pipe valve.
- A hydraulically designed combined wet standpipe/sprinkler system shall provide 100 percent sprinkler protection throughout the building in compliance with NFPA 13.
- Sprinklers shall be fed on each floor through combined standpipe/ sprinkler floor control valve assemblies located within stair towers.
- Return bend drops shall be provided from branch piping to the sprinklers in the finish ceilings.

3.7.3.6 Fire Department Connections

- A fire department connection shall be located on the building exterior and shall connect to the standpipe distribution piping.
- The fire department connection shall be required to be within 100 feet of a fire hydrant or as directed by the fire department.

3.7.3.7 Fire Entrance Rooms

- Requires a 2-hour rated room with direct exterior access to the building exterior or a 2-hour rated passageway to the exterior.
- Includes Fire and Jockey Pumps and controllers, double check valve assembly, and five wet-pipe valves (if required to be determined by hydrant flow test).

3.7.4 Building Space Requirements

The designer shall verify spaces included on an individual building basis to determine requirements.

3.7.4.1 Administrative Areas

- Shall be protected as a Light Hazard occupancy
- System hydraulically sized to provide 0.10 gpm per square foot over the hydraulically most demanding 1,500 square feet plus 250 gpm for hose streams
- 100 gpm interior plus 150 gpm exterior
- Maximum sprinkler spacing at 225 square feet

3.7.4.2 Mechanical Rooms and Storage Areas

- Shall be protected as an Ordinary Hazard Group 1 occupancy
- System hydraulically sized to provide 0.15 gpm per square foot over the most hydraulically demanding 1,500 square feet plus 250 gpm for hose streams
- 100 gpm interior plus 150 gpm exterior

- Maximum sprinkler spacing at 130 square feet

3.7.4.3 Fuel Pump Rooms

- Shall be protected as an Ordinary Hazard Group 2 occupancy
- System hydraulically sized to provide 0.2 gpm per square foot plus 250 gpm for hose streams
- 100 gpm interior plus 150 gpm exterior
- Maximum sprinkler spacing at 100 square feet

3.7.4.4 Communications Rooms

- Shall be protected with an FM 200 fire suppression system
- System to be complete with control panels, FM 200 Cylinders, activation devices, heat and smoke detectors, distribution nozzles and all other appurtenances to provide a complete fire suppression system
- System shall connect to the building fire alarm panel to provide notification

3.8 Communications and Security Systems

The communications systems shall include all apparatus to transmit voice, data, and video within the facility and through the MBTA Wide Area and Security Wide Area Networks and shall be designed to meet the requirements outlined in the following subsections.

3.8.1 Codes, Standards, and Manuals

- 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. (ICEA) 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)
- EIA-310-D - Cabinets, Associated Equipment and Racks, Panels
- Building Industry Consulting Service International (BICSI)
  - ANSI/BICSI Telecommunications Distribution Methods Manual (TDMM)
  - 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 (APTA) 34 - Standard for SCADA System Inspection, Testing, and Maintenance
- National Electrical Manufacturers Association (NEMA) Standard 250 - Enclosures for Electrical Equipment
- International Electrotechnical Commission 60950-1 latest edition, including all relevant national deviations as listed in the IECEE Bulletin—Product Category OFF: IT 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) 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 – Standard of Installation
- American Society for Testing and Materials (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
- Underwriters Laboratories (UL)
- International Organization for Standards (ISO) ISO 9001 - Quality Management Systems - Requirements
- Massachusetts Architectural Access Board – 521 CMR
- ADA Standards for Accessible Design

3.8.2 Sustainability and Resilience Coordination

This section summarizes communications and security design guidelines for meeting project sustainability and resiliency goals and requirements. References to related credits from Envision and/or LEED are provided for additional exploration of requirements as the design progresses. Refer to Section 2.4, Sustainability and Resilience, for the overall sustainability and resilience project approach.

The following aspects shall be included as project design requirements:

- Restriction of Hazardous Substances Directive compliant equipment and cabling where possible.
- The UPS systems for communication, security systems, and for other building systems shall be optimized and combined to minimize the total number of batteries used.

Refer to *Envision Sustainable Infrastructure Framework* (v3), *RA1.1 Support Sustainable Procurement Practices*; and LEED Credits *MR Credit Building Product Disclosure and Optimization - Environmental Product Declarations, MR Credit Building Product Disclosure and Optimization - Material Ingredients, IEQ Credit Low Emitting Materials*.

3.8.3 Communications Rooms and Closets

A main communications room (Main Distribution Frame – MDF) will be provided at the facility to house the various systems' equipment listed below, and have at least 25 percent 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 shall be provided for each system (i.e. public address, local area network, security, etc.). Each cabinet shall be sized to meet proposed equipment requirements. Each cabinet shall have perforated doors, vertical power distribution units, document drawer, slide out shelf, cable management, and top mount fans. Cabinets shall have a minimum three feet of access to the front and rear doors. Cable tray shall be provided in the room(s)/closet(s) to route data cables. Power cables shall be routed separately in dedicated conduits from the room/closet power panel. The power panels shall derive power from the backup power system (generator or UPS).

Communications rooms and closets shall 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 shall be provided and HVAC systems capacity shall be determined to maintain equipment within manufacturer recommended operating temperatures.

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

Power receptacles shall 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 shall be provided in each communications room and closet. All equipment, cabinets, conduit, and cable tray shall be bonded.

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

3.8.4 Telecommunications and Data Communications

3.8.4.1 Wide Area Network

The Wide Area Network 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 Wide Area Network, 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 shall be provided that are suitable for the bandwidth requirements of the facility.

3.8.4.2 Telephone / Data Wiring

At a minimum, Category 6 data cable will be installed to each data jack and IP device. Shielded Category 6 cable shall 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 shall be provided for all connections. Shielded Category 6 patch cables shall 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 shall 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 shall support installation of wall-mounted telephones.

3.8.4.3 Local Area Network

A Local Area Network (LAN) that supports the MBTA corporate network shall 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 shall be connected in a ring topology with either copper or fiber optic cable as the installation dictates. The LAN minimum bandwidth shall be 10GB.

3.8.4.4 Wireless Access Points (WAP)

Wireless access points shall be provided on the corporate network to provide wireless connectivity for operations and maintenance systems. Locations and quantities shall be proposed to provide coverage throughout and along the perimeter of the facility.

Additional wireless access points shall be provided in the storage and maintenance areas to support systems such as the automated fare collection system and the Trapeze TransitMaster (Wired Equivalent Privacy encryption) system. (Note that the MBTA is in the process of updating the TransitMaster system and as such requirements may change.)

3.8.4.5 Telephone System

A VoIP gateway shall be provided for the facility that will be an extension of the existing MBTA Avaya system. This gateway shall, at a minimum, include all of the features of the VoIP system. Voicemail boxes shall be provided for facility personnel as required by the MBTA.

Digital desk telephones shall be provided for each office, and analog wall telephones will be provided for each support room.

3.8.4.6 Miscellaneous Data Connections

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

- Printers/Copy Machines
- Hand scanners
- Trapeze enterprise asset management system
- Defibrillators
- Fuel Management System
- HVAC/BIM system
- Video display monitors
- Fire Alarm System
- Bus Charging System
- FleetWatch System

3.8.5 Public Address

The facility shall have a Public Address (PA) system to allow communications with employees throughout the facility and at select exterior locations. PA equipment shall he designed to comply with ADA accessibility guidelines. The system shall be able to initiate announcements from the VoIP telephone system and local microphones.

Voice intelligibility shall meet or exceed the minimum standards set forth in NFPA 72. Sound trespass to areas adjacent to the facility shall be minimized to meet local ordinances or adjustable to levels approved by the authority having jurisdiction. At least 95 percent of the facility shall 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 PA system Speech Transmission Index shall be minimum of 0.6 measured at 95 percent of the facility. Minimum levels shall be obtained when buses are not operating and when the ambient noise level is minimal.

The 70.7V PA power amplifier and loudspeaker distribution equipment shall be redundant such that the failure of any one PA channel/amplifier shall not result in the total loss of PA coverage in any facility

area. Additionally, to provide redundancy, every other loudspeaker in a zone shall be wired to a different audio channel. Include end of line monitoring for each loudspeaker array. The PA system shall also be divided into zones throughout the facility to facilitate customized audio settings and messaging for each area.

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

3.8.6 Security System

3.8.6.1 Security Wide Area Network

The Security Wide Area Network (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 shall 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 shall be provided for the facility in the main communications room. Aggregation security network switches shall 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 shall 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.

3.8.6.2 Security Local Area Network

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

Wireless access points, connected to the Security LAN, shall 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 shall be sufficient to provide adequate bandwidth to simultaneously off load video from buses when in the facility.

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

3.8.6.3 Video Surveillance

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

Cameras, with secure digital (SD) cards, shall 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 shall be installed from each camera to the security network switch. Surge suppressors shall 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 shall 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 shall be provided at the facility.

3.8.6.4 Electronic Access Control System

An electronic access control system shall 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 shall be located in communications rooms, closets, and security terminal cabinets. Doors shall 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.

3.8.6.5 Intercom System

Provide an ADA-compliant IP intercom, compatible with the MBTA's existing Security Department VoIP server, at all motorized gates and personnel gates.

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 VoIP server and provide licenses as required to account for new devices.

3.8.6.6 Physical Security Information Management System

The PSIM located at the MBTA Operations Control Center shall 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 shall be programmed per MBTA requirements.

A PSIM client workstation shall be provided for the facility, located in an area defined by MBTA. The workstation shall 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.

3.8.7 Supervisory Control and Data Acquisition

3.8.7.1 Power Supervisory Control and Data Acquisition

For proposed unit and traction power substations, SCADA Remote Terminal Units shall be provided for monitoring of these locations that are compatible with the existing Power Department SCADA system.

Power dispatcher graphical user interfaces shall be updated to display the new substations, functionality, and alarms.

3.8.7.2 HMCS/Vent Fan SCADA

A PLC compatible with the existing HMCS/Vent Fan SCADA system shall be provided at the facility to monitor indications for elevators, generators, and pumps. The graphical user interfaces for this system shall be updated to include controls, indications, and alarms as required by the MBTA.

3.8.8 Two-Way Radio System

3.8.8.1 Bi-Directional Amplifier

Provide a bi-directional 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 Authorities Having Jurisdiction, 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 Authorities Having Jurisdiction, 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 percent additional antennae. Tower height shall 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.

3.8.8.2 Distributed Antenna System

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

3.8.8.3 Systemwide Radio Units

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

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

3.8.9 Audiovisual Systems

A/V Systems shall 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 shall be provided in each class and training room. Large format flat panel monitors shall be provided in conference rooms and offices.

Large format flat panel monitors shall 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.

A/V jack panels and wireless presentation systems shall be provided in each room equipped with a large format monitor.

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

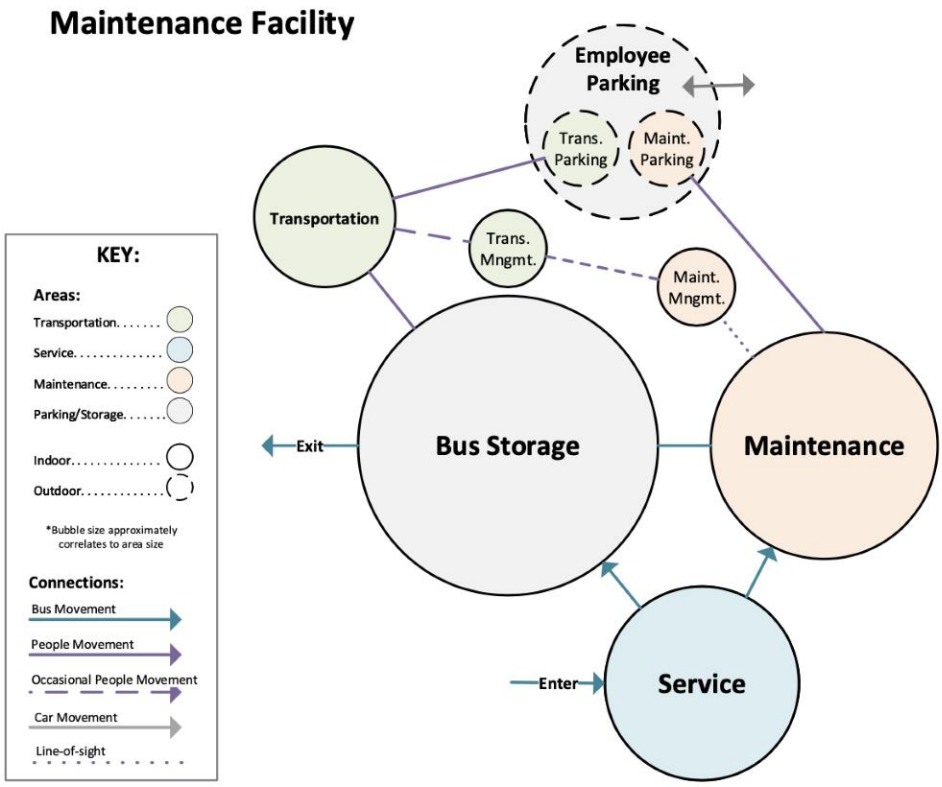
4 AREA MODULES

The area modules for the maintenance, transportation, and servicing areas of the facility in this section each contain room cards that outline baseline requirements for standard rooms and spaces in MBTA bus maintenance facilities related to each function. Room card diagrams are provided for illustrative purposes. Specific room or area layouts and orientations shall be determined through the design process with input from MBTA.

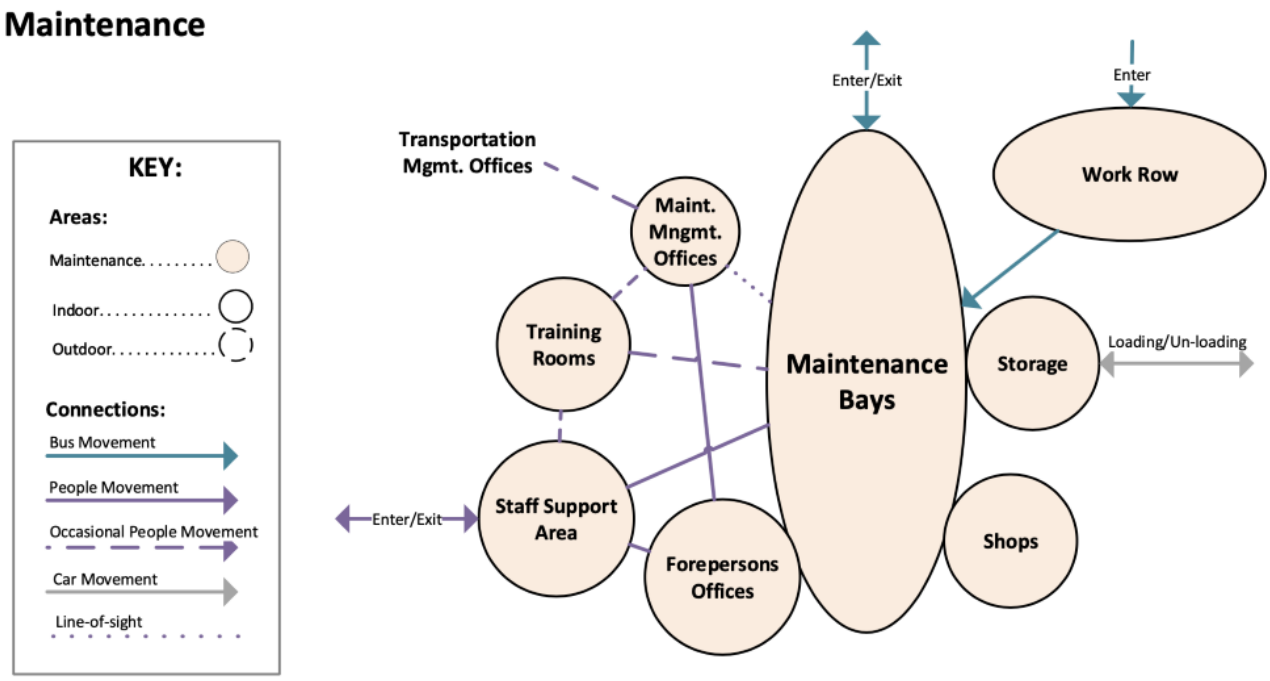
Each area module is preceded by its respective space adjacency bubble diagram, which visualize spatial connections or adjacencies, as well as people and vehicle movement between spaces that facilitate transportation, service, and maintenance operations.

The designer will use the space adjacency diagrams and the Facility Program Matrix in Appendix B 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 shall adhere to and reflect the spatial connections and relationships depicted.

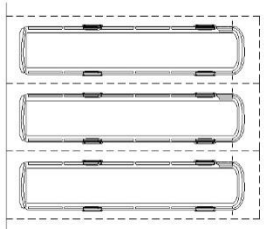
The general facility space adjacency diagram below depicts baseline requirements and relationships of standard spaces in MBTA bus maintenance facilities (excluding heavy maintenance).



4.1 Maintenance



4.1.1 Bus Maintenance Area

<table>
<tr><th colspan="2">Bus Work Row (Down line/Ready line)</th></tr>
<tr><td colspan="2">Function Characteristics</td></tr>
<tr><td>Function</td><td rowspan="2">  </td></tr>
<tr><td>• Queueing area for buses awaiting maintenance or repairs
• Parking spaces delineated by floor traffic striping
• Spaces shall be sized to accommodate a 3’-0” clear space around the parked vehicle to adjacent work row space or any physical obstructions</td></tr>
<tr><td colspan="2">Design Features</td></tr>
<tr><td>Architectural</td><td>Structural</td></tr>
<tr><td>• 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
• Layout
– Drive-through required for 60-foot buses; preferred for 40-foot buses</td><td>• Vertical clearance to the structure shall be 15’-0” minimum. Structural system at the ceiling level shall accommodate installation of mechanical, electrical, and plumbing components above the bottom of steel to maintain the 15’-0” clearance envelope.
• Columns that project into the work row shall 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.</td></tr>
<tr><td>Mechanical</td><td>Plumbing</td></tr>
<tr><td>• Space shall be ventilated in accordance with the IMC requirements for a repair garage.
• Space shall be provided with heating, to maintain the minimum temperature of 55°F.
• Space shall be provided with some form of cooling, to maintain a maximum temperature of 80°F.</td><td>• 3/4” water hose bib with standard faucet 2’-0” AFF
• Compressed air line with shut-off valve, drip valve, regulator, lubricator, and quick disconnects on air/electric drop “trapeze” at 4’-0” AFF. Provide disconnects for 1/2” and 1” impact tools at locations to be determined during detailed design
• As required by equipment</td></tr>
<tr><td>Fire Protection Sprinklers</td><td>Electrical</td></tr>
<tr><td>• Provide wet sprinklers with heads spaced a maximum of 130 square feet apart</td><td>• High bay 60,000 lumen LED luminaires
• 75 foot candle average is required throughout the area
• General convenience receptacles
• 208V and 480V receptacles
• Power provided to room equipment</td></tr>
<tr><td>Fire Alarm</td><td>System</td></tr>
<tr><td>• Manual pull stations
• Speaker and strobe devices</td><td>• Wi-fi
• Public address
• Data jacks
• Bi-directional amplifier/distributed antenna system</td></tr>
</table>

Maintenance Bay

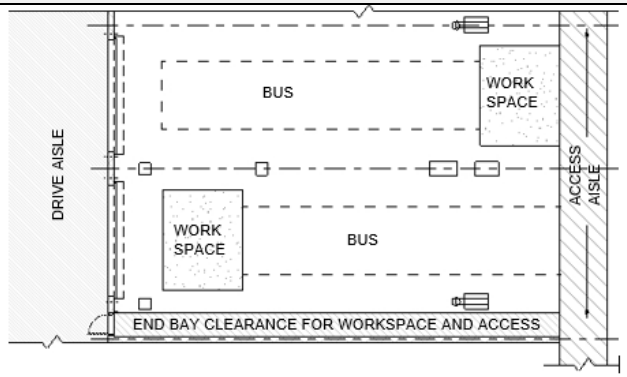
Function Characteristics

Function

- Individual bay for preventative maintenance and exchange of parts

Equipment/Furnishings (*per bay*)

- Vertical rise platform lift, axle-engaging lift, or portable lift (see Appendix E)
- Fluid reels (oil, coolant)
- 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, used oil pump, used coolant pump
- Small parts washer
- Workbench with vise



Efficient Bus Repair Bay

Design Criteria

- Bays delineated by floor traffic striping
- Spaces shall be sized to accommodate a 5’-0” clear space around the parked vehicle to adjacent bays or any physical obstructions
- All maintenance bays, including specialty bays, shall be a drive–through configuration for 60-foot buses (preferred configuration for 40-foot buses)
- Bays shall be connected with an 8 to 10' wide circulation access aisle for parts, components, and staff movement
- Toolboxes, jacks, common shop equipment, shelving, tires, and specialty equipment shall be stored at the end of the circulation aisle or behind the bay
- Bay floors shall be flat (no slope)
- Layout shall allow for easy access by an electric walk behind or riding floor cleaner for bay cleaning after a bus is removed

Design Features

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
- Doors
  - Personnel doors shall be hollow metal sized as required for use
  - Exterior overhead doors shall 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 (2 each)
- Dimensions
  - Minimum bay width: 20’
  - Add 2' to width for columns between bays; add 5' of clearance space to width to end bays (adjacent to a fixed wall) for access and full use of workspace
  - Minimum bay length: 60’ (40-foot buses); 80’ (60-foot buses)

Structural

- Control joints in-floor slab at adequate spacing, joints within service row, shall 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 (see architectural finishes for floor slab treatment)

Maintenance Bay

Mechanical	Plumbing
• 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	• Trench drain with sediment bucket and removable cover to oil water separator • Lube reel banks with ATF, EC1, EC2, EO1 at end of bay • Reel banks with CG, GO mid bay (shared, 1 each per 2 bays) • 3/4” water hose bib with standard faucet at rear of bay 2’-0” AFF (1 per 3 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’-0” AFF (between bay doors) • Provide disconnects for 1/2” and 1” 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" tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored • Utilities as required by equipment
Fire Protection Sprinklers	**Electrical**
• Provide wet sprinklers with heads spaced a maximum of 130 square feet apart	• High bay 60,000 lumen LED luminaires • 75 foot candle average is required throughout the area • General convenience receptacles • 208V and 480V receptacles • Power provided to room equipment
Fire Alarm	**System**
	• Wi-fi • Public address • Data jacks • Bi-directional amplifier/distributed antenna system

Maintenance Bay

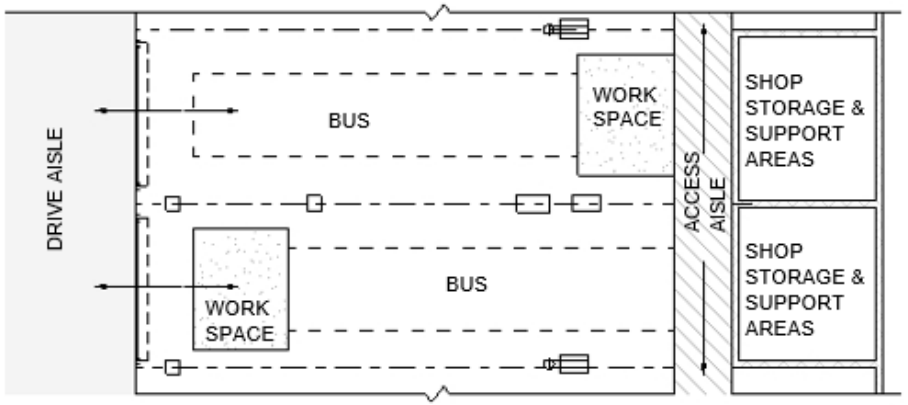
Option 1: Single Bay – Single Door

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 with Single Bay (Required for 60-foot buses, preferred option for 40-foot buses.)

Common Applications:

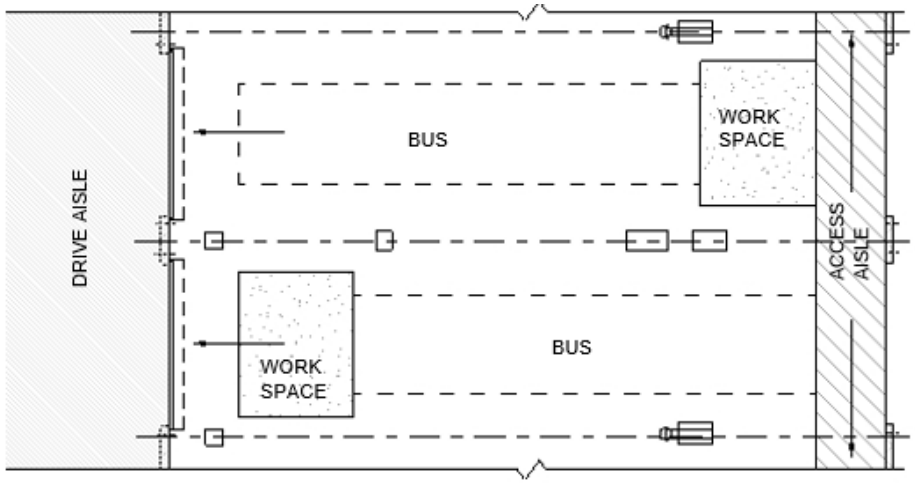
- Inspection, fuel, quick-fix (rapid emergency repair for running vehicle), and drive-through wash bays
- Wherever rapid processing of buses is operationally beneficial
- Where forward drive-through movement is needed

Limitations and Constraints:

- Building footprint increases in a lineal fashion as bay count increases
- Shops are distant from the maintenance bay rows, decreasing operational efficiency, or are between bays, reducing bay-to-bay visibility and safety
- Drive aisles on either side of the maintenance area require additional 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

Specific Design Requirements:

- Entrance visibility mirrors



Maintenance Bay

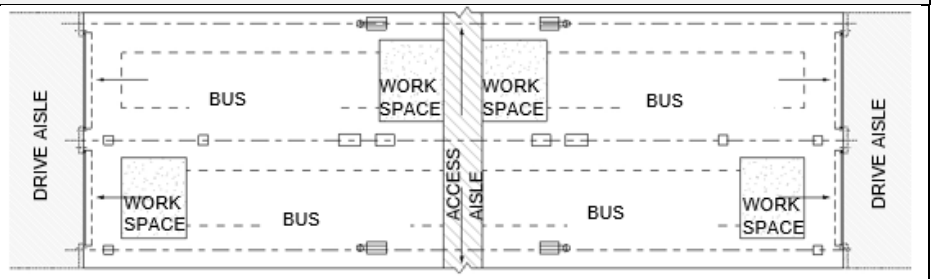
Option 3: Double Stacked Bay

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



Interior Drive Aisles

Common Applications:

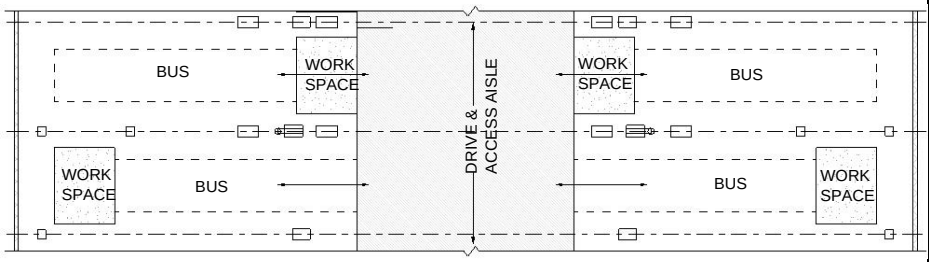
- To minimize exterior vehicle travel and reduce the number of overhead doors

Limitations and Constraints:

- Significantly higher initial capital and long-term maintenance and operational costs due to significant increase in building size

Specific Design Requirements:

- Location of drive aisle relative to the configuration of bays shall be considered
- Requires careful attention to interior building circulation



Roof Access Bay

Function Characteristics

Function

- Specialty bay designed for bus roof access by fixed or mobile platform that is at bus roof height on all four sides of the bus
- 1 roof access bay per 150 buses (if only one platform is provided in a facility, 1-2 additional bays without such a platform shall be provided with tie off safety harness trolley and monorail for temporary roof access flexibility)

Equipment/Furnishings

- Monorail trolley and hoist for removing and installing bus rooftop equipment
- Occupational Safety and Health Administration-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

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
- Dimensions
  - Minimum bay width: 24’
  - Add 2' to width for columns between bays; add 5' of clearance space to width to end bays (adjacent to a fixed wall) for access and full use of workspace
  - Minimum bay length: 50’ (40-foot buses); 75’ (60-foot buses)

Structural

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

Mechanical

- Space shall be ventilated in accordance with IMC requirements for a repair garage.
- Space shall be provided with heating to maintain the minimum temperature of 55°F.

Fire Protection Sprinklers

- Wet sprinklers

Electrical

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

Fire Alarm System

- Manual pull stations
- Speaker and strobe devices
- Public address

Inspection Bay

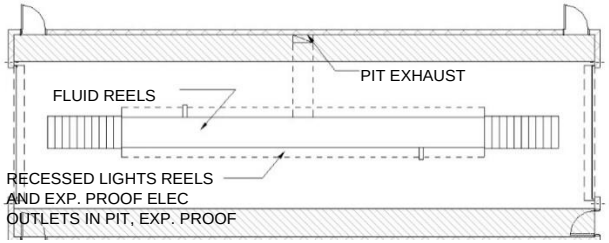
Function Characteristics

Function

- Inspection pit to allow inspection of bus undercarriage, oil changes, and transmission fluid exchanges
- 1 inspection bay per 100-120 buses

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

Architectural

- Finishes
  - Floor: Soil, grease, water, slip-resistant concrete
  - Walls: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Epoxy painted exposed structure
- Doors
  - Overhead doors on each end of space to permit pass through operation
  - Personnel doors with view panels to allow access without cycling overhead doors
- Dimensions
  - Minimum bay width: 25’
  - Minimum bay length: 60’ (40-foot buses); 80’ (60-foot buses)

Structural

- Inspection pit shall be 5’-3” deep and include recesses on both sides to allow lighting and other equipment to be stored out of the aisle.
- Floor shall 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.
- Some form of cooling, to maintain a maximum temperature of 80°F.

Plumbing

- Provide industrial waste sump pump in pit with galvanized steel cover (1 on each side)
- Lube reel banks with Chassis Grease (CG)
- 3/4” water hose bib with standard faucet at rear of bay 2’-0” AFF
- Compressed air line with shut-off valve, separator, regulator, lubricator, and quick disconnects on air/electric drop “trapeze” at 4’-0” AFF. Provide disconnects for 1/2” and 1” impact tools at locations to be determined during detailed design
- 1-½" tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored
- As required by equipment

Fire Protection Sprinklers

- Provide wet sprinklers

Electrical

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

Fire Alarm System

- Speaker and strobe devices

System

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

4.1.2 Steam Clean Bay (Chassis Wash)

Steam Clean Bay (Chassis Wash)

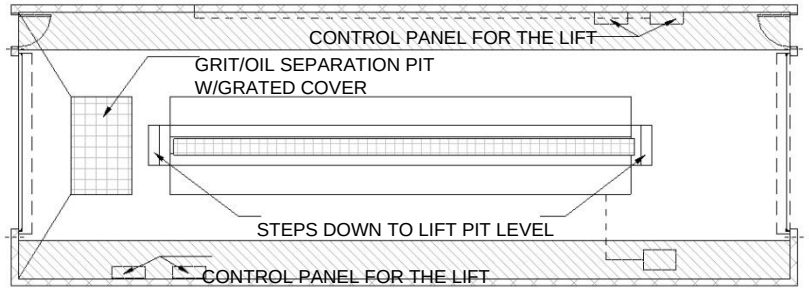
Function Characteristics

Function

- Enclosed room with weather resistant overhead or coiling doors for washing of bus undercarriages, engine compartments and other large components
- 1 bay per 150-200 buses

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 (chassis clean bay)



Design Features

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
- Doors
  - Stainless-steel personnel doors with view panels designed for wet environment
  - Assume water will drip from every surface and high-pressure spray wands can reach across the length of the bay
  - Overhead doors on each end to permit pass through operation shall include stainless-steel hardware and be installed on the exterior face of the wall to minimize exposure of door operating equipment to water spray
- Dimensions
  - Minimum bay width: 25’
  - Minimum bay length: 60’ (40-foot buses); 80’ (60-foot buses)

Structural

- Structural steel shall be galvanized and coated with marine grade coating system.

Plumbing

- Trench drain with sediment bucket and removable cover to oil water separator
- Provide domestic cold water with backflow preventer to MR-2 high pressure washer
- Provide waste oil draining pan
- Provide overhead lube reels
- 1-½" tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored.
- As required by equipment

Mechanical

- Exhausted/ventilated per IMC for a repair garage; aluminum ductwork
- Heated to maintain minimum temperature of 55°F

Electrical

- 3500 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

Fire Protection Sprinklers

- Provide wet sprinklers with heads spaced a maximum of 130 square feet apart.
- Provide high temperature sprinklers

Fire Alarm

- Manual pull stations
- Speaker and strobe devices

System

Chassis Wash Steam Equipment Room

Function Characteristics

Function

- Accommodates portable chassis wash equipment and general chassis wash storage

Equipment/Furnishings

- High Pressure Washer

Design Features

Architectural

- Finishes
  - Floor: Soil, grease, water, slip-resistant concrete
  - Walls: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Epoxy painted exposed structure
- Doors
  - 3'-0" wide hollow metal door with interior exit device
- Area
  - 80 SF

Structural

- Provide housekeeping pads for floor-mounted equipment.

Plumbing

- Provide floor drain on oil water separator system
- As required by equipment

Mechanical

- Exhausted/ventilated per IMC for a repair garage; aluminum ductwork
- Heated to maintain minimum temperature of 55°F

Electrical

- 3500 lumen LED vapor tight luminaires
- 30 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers with heads spaced a maximum of 130 square feet apart.
- Provide high temperature heads.

Fire Alarm

- Manual pull stations
- Speaker and strobe devices

System

4.1.3 Maintenance Support Shops and Spaces

<table>
<tr><th colspan="2">Common Work Area and Specialized Shops (General Machine Shop and Brake Shop)</th></tr>
<tr><td colspan="2">Function Characteristics</td></tr>
<tr><td>Function</td><td rowspan="3"></td></tr>
<tr><td>• 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
• Brake shop is where brake assemblies are disassembled, repaired and tested</td></tr>
<tr><td>Equipment/Furnishings</td></tr>
<tr><td>• 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
• Brake lathe
• Compressed air drops</td><td></td></tr>
<tr><td colspan="2">Design Features</td></tr>
<tr><td>Architectural</td><td>Structural</td></tr>
<tr><td rowspan="2">• 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
• Area
– General Machine Shop: 20’ x 30’ per 100 buses (dependent on use and bay layout; can be split up into multiple smaller areas if needed)
– Brake Shop: 400-600 SF per 100 buses</td><td>• Provide structural reinforcements as required to support specific equipment needs.</td></tr>
<tr><td>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’-0” AFF. Provide disconnects for 1/2” and 1” impact tools at locations to be determined during detailed design
• 1-½" tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored
• As required by equipment</td></tr>
<tr><td>Mechanical</td><td>Electrical</td></tr>
<tr><td>• A source of ventilation, to comply with the IMC requirements for a repair garage.
• Heating to maintain a minimum temperature of 55°F.
• Cooling to maintain a maximum temperature of 80°F.</td><td>• 3500 lumen LED vapor tight luminaires
• 40 foot candle average is required throughout the area
• Convenience GFCI receptacles
• Power provided to room equipment</td></tr>
<tr><td>Fire Protection Sprinklers</td><td>System</td></tr>
<tr><td>• Provide wet sprinklers with heads spaced a maximum of 130 square feet apart.</td><td rowspan="3">• Public address</td></tr>
<tr><td>Fire Alarm</td></tr>
<tr><td>• Manual pull stations
• Speaker and strobe devices</td></tr>
</table>

Tire Storage

Function Characteristics

Function

- MBTA utilizes outside vender servicing of all 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 tire and brake work is done and open to access aisle/maintenance bay

Equipment/Furnishings

- Tire carousel and/or tire storage rack

Design Features

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
- Doors
  - Doors for outside access that accommodate passage of a forklift
- Area
  - 600-800 SF based on capacity to store at single site (Dependent on outside service and building code)

Structural

- Provide structural reinforcements as required to support specific equipment needs.

Plumbing

- Compressed air line with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnects at 4’-0” AFF; provide disconnects for 1/2” and 1” impact tools at locations to be determined during detailed design
- As required by equipment

Electrical

- 3500 lumen LED pendant or surface luminaires
- 40 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- A source of ventilation to comply with the IMC requirements for a repair garage
- Heating to maintain a minimum temperature of 55°F

Fire Protection Sprinklers

- Provide wet sprinklers

Fire Alarm

- Smoke detector devices
- Speaker and strobe devices

System

- Public address
- Electronic Access Control on exterior doors

Battery Room and Storage

Function Characteristics

Function

- For diesel-hybrid bus fleet, this room provides storage for new batteries to be installed and used batteries to be picked up by outside vendor
- For BEB fleets, this room may require wash station, testing, and handling of large banks of batteries on specially designed racks
- Forklift accessible
- Physically separated from other areas to prevent migration of fumes
- Adjacent to parts room and repair bays

Equipment/Furnishings

- Battery wash station (for BEB)
- Pallet rack/battery rack as needed

Design Features

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
- Doors
  - Hollow metal double doors to main access aisle to maintenance bays
- Area
  - 80 SF for diesel-hybrid fleet and 300-500 SF for BEB fleet (dependent on number of BEBs)

Structural

- Provide structural reinforcements as required to support specific equipment needs.

Plumbing

- 1-½" tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored.

Electrical

- 3500 lumen LED pendant or surface luminaires
- 40 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Adequate ventilation (15 air changes per hour minimum)
- Duct work and fans to be stainless-steel

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head.

Fire Alarm

- Smoke detector devices
- Speaker and strobe devices

System

Portable Equipment Storage

Function 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
- Space may be distributed as needed based on equipment and maintenance bay layout

.

Design Features

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
- Doors
  - Double-leaf 3’-0” wide hollow metal doors
- Area
  - 80-100 SF per bay (dependent on equipment list)

Structural

- Provide structural reinforcements as required to support specific equipment needs

Plumbing

Electrical

- 3500 lumen LED pendant or surface luminaires
- 40 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Heating to maintain a minimum temperature of 55°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head.

Fire Alarm

- Smoke and heat detector devices
- Speaker and strobe devices

System

- Public address

Secured Tool Storage

Function Characteristics

Function

- Locked storage for diagnostic equipment or repair tools
- Access controlled by forepersons

Design Features

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
- Area
  - 10 SF per bay

Mechanical

- Heating to maintain the minimum temperature of 55°F.

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head.

Fire Alarm

- Smoke detector devices
- Speaker and strobe devices

Structural

Plumbing

Electrical

- 3500 lumen LED pendant or surface luminaires
- 40 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

System

- Public address

Toolbox Storage

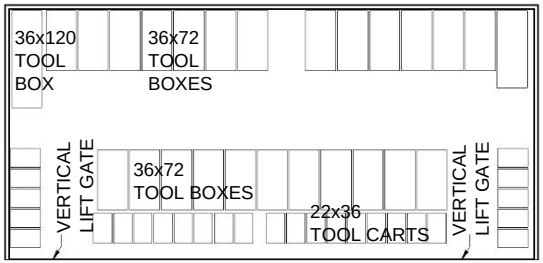
Function Characteristics

Function

- Locked area where mechanics leave their toolboxes when off duty with enclosed wire mesh partition and wide sliding gate opening for access to toolboxes (or open storage if individual toolboxes are locked)

Equipment/Furnishings

- 22” x 36” tool carts
- 36” x 72” toolboxes



Design Features

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
- Doors
- Area
  - 30 SF per mechanic

Structural

Plumbing

Electrical

- 3500 lumen LED pendant or surface luminaires
- 40 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Heating to maintain a minimum temperature of 55°F.

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head.

Fire Alarm

- Smoke detector devices
- Speaker and strobe devices

System

- Public address

Fluid Distribution and Waste Storage - Tanks and Compressor / Air Dryer

Function Characteristics

Function

- Storage in bulk double walls containers for maintenance and repair bays with 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
- Includes piping to exterior for filling bulk storage containers by outside vendors; air pumps, valves, regulator, piping to reels and leak detection alarms; compressor receiver and dryer; and emergency safety shower/eyewash

.

Design Features

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
- Doors
  - Personnel doors to meet applicable code exit requirements
  - Double 3’-0” wide hollow metal door with interior exit device
  - Forklift accessible
- Area
  - 800-1,000 SF 20X40 dimensions (May be larger if it covers waste fluids and fluids for service lanes. Dependent on delivery and waste oil pick with size of tanks).

Structural

- Provide structural reinforcements as required to support specific equipment needs.
- Raised concrete housekeeping pad under compressors and air dryers.

Plumbing

- 3/4” water hose bib with standard faucet 2’-0” AFF
- Compressed air system with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnect on wall at 4’-0” AFF for each lubricant pump
- Tank mount all lubricant pumps except Chassis Grease which will be hoist mounted, and the engine coolant diaphragm pump which will be wall mounted. Provide siphon kit for wall mounted pump
- Water tank with float valve for water to EC diaphragm pump
- Provide floor drains on building oil water separator system
- 1-½" tempered water to free standing emergency shower/eyewash will be provided where hazardous liquids or chemicals are stored
- As required by equipment

Mechanical

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

Electrical

- 3500 lumen LED hazardous location rated luminaires
- 50 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers spaced maximum 100 square feet per head.

Fire Alarm

- Smoke detector devices
- Speaker and strobe devices
- Manual pull stations

System

- Public address
- Electronic access control for exterior doors

4.1.4 Parts Storage

Loading Dock/Shipping/Receiving Area

Function Characteristics

Function

- Enclosed or open area adjacent to parts room where incoming loads of parts can be received, checked and logged into inventory and where used parts and recyclables are loaded and carried way
- Forklift accessible (large facilities need charging station for forklift)

Equipment/Furnishings

- Electric forklift and charging station
- Dock levelers
- Receiving table
- Hoist
- Hand pallet

Design Features

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
- Doors
  - Personnel doors to meet applicable code exit requirements
- Area
  - 1,600 SF (Can be combined with General Parts Storage room).

Structural

Plumbing

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

Mechanical

- Air curtains at overhead doors, to act as wind and insect barrier
- Heating to maintain minimum temperature of 55°F

Fire Protection Sprinklers

- Provide wet sprinklers spaced maximum 130 square feet per head.

Fire Alarm

- Smoke detector devices
- Speaker and strobe devices
- Manual pull station

System

- Electronic Access Control
- Intercom
- Buzzer
- CCTV cameras
- Public address
- Data jacks

Parts Management Office

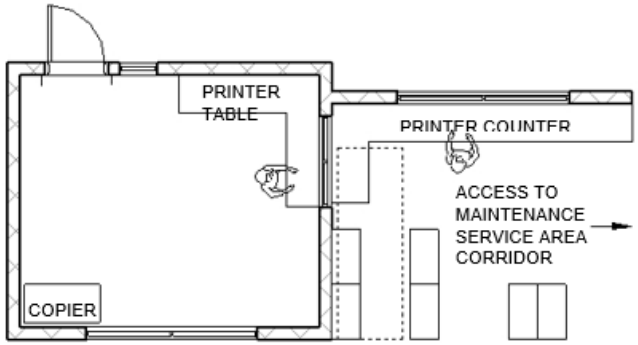
Function Characteristics

Function

- Offices where the stores department manages and distributes parts
- Includes computers to log the receipt and application of parts, order additional parts, manage disposal and recycling of used parts
- Stainless-steel service counter with sliding window
- Visual connection to maintenance and parts storage areas
- Accessed from parts room only

Equipment/Furnishings

- Computer workstations
- Printer table, copier, parts counter, chairs
- Storage cabinets and parts cart



Design Features

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
- Doors
  - Electronic door hardware with controlled access entry into room
- Area
  - 120-150 SF

Structural

Plumbing

Mechanical

- Ventilation, in compliance with IMC
- Heating to maintain minimum temperature of 68°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 Sprinklers

- Provide wet sprinklers spaced maximum 130 square feet per head.

Fire Alarm

- Speaker and strobe devices

System

- Electronic Access Control
- CCTV cameras
- Telephone
- Wi-fi
- Tel/data jacks
- Telephones/printers/copiers
- Public address
- Intercom base station

Parts Storage Room

Function Characteristics

Function

- Secured storage and distribution of vehicle parts and materials on and in pallet racks, shelving, and drawer units
- Forklift accessible

Equipment/Furnishings

- Part carts and hand pallet truck
- Optional vertical lift module or other automated storage systems for parts inventory

Design Features

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
- Doors
  - Personnel doors with view panels to meet applicable code exit requirements
  - Exterior overhead door: High-lifting sectional, steel, insulated, 10’ x 12’, with view panels, automatic operator, interior and exterior push button controls, and lockout on exterior
  - Electronic door hardware with controlled access entry into room
- Area
  - Up to 25% of maintenance area (dependent on facility specific needs)

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Heating to maintain minimum temperature of 55°F

Fire Protection Sprinklers

- Provide wet sprinklers spaced maximum 130 square feet per head.

Fire Alarm

- Smoke detector devices
- Speaker and strobe devices
- Manual pull station

System

- Data jacks
- Buzzer at Parts Window
- Electronic Access Control
- Wi-fi
- Public address

Parts Room Consumable Distribution Area (in Maintenance Area)

Function 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

Equipment/Furnishings

- Shelving units, cabinets, parts cart, bins storage

Design Features

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
- Doors
- Area
  - 80-90 SF (distributed throughout maintenance area with a minimum of 2 spaces - one at the parts room and one at the end of the maintenance bay area)

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Heating to maintain minimum temperature of 55°F

Fire Protection Sprinklers

- Provide wet sprinklers spaced maximum 130 square feet per head.

Fire Alarm

- Speaker and strobe devices
- Manual pull station

System

- Wi-fi
- Public Address

4.1.5 Bus Maintenance Support Area

Maintenance Management Suite

Maintenance Operations Superintendent's Office

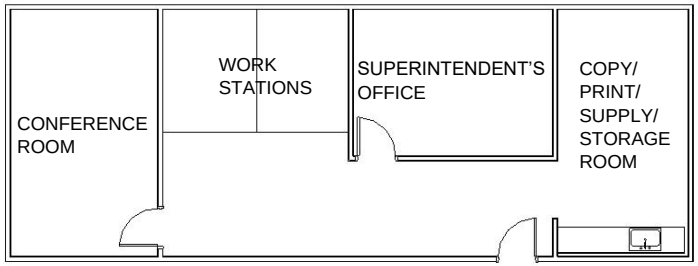
Function Characteristics

Function

- Private office for superintendent with accommodations for guests as needed

Equipment/Furnishings

- Printer, radio console and other equipment to be identified by MBTA (e.g., desk with return, chairs, lateral files, A/V including wall-mounted TV monitors)



Design Features

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
  - Secured entry by single 3'-0" door
- Area
  - 200 SF accommodates 1 superintendent and up to 4 guests (dependent on facility specific needs)

Structural

Plumbing

- Provide domestic cold water, point of use electric water heater, sanitary and vent to print room sink

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

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers spaced maximum 225 square feet per head.

Fire Alarm

- Speaker and strobe devices

System

- Public address
- Tel/data jacks
- Telephone
- Wi-fi

Maintenance Management Suite

Administrative Workstation(s)

Function Characteristics

Function	
• Freestanding workstation for administrative staff (as needed)	
Equipment/Furnishings	
• Workstation desk with return, lateral files, chair	

Design Features

Architectural	Structural
• Finishes – Floor: VCT / Resilient wall base – Walls: Acrylic latex-painted with accent wall color(s) – Ceiling: Suspended acoustical ceiling grid and tile system • Doors – Secured entry by single 3’-0” door • Area – 80 SF accommodates (1) one administrative staff	**Plumbing**
Mechanical	**Electrical**
• Ventilated per IMC • Heated to maintain minimum temperature of 70°F • Cooled to maintain maximum temperature of 75°F	• 3500 lumen LED pendant luminaires • 50 foot candle average is required throughout the area • General convenience receptacles • Power provided to room equipment
Fire Protection Sprinklers	**System**
• Provide wet sprinklers maximum spacing 130 square feet per head.	• Public address • Tel/data jacks • Telephone • Wi-fi
Fire Alarm	
• Speaker and strobe devices • Manual pull station	

Maintenance Management Suite

Conference Room

Function Characteristics

Function

- Conference room for maintenance management, including forepersons, and guests
- Visual connection to management suite

Equipment/Furnishings

- Conference table, credenza, and chairs
- A/V including wall-mounted TV monitor(s)

Design Features

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
- Doors
  - Painted hollow metal door and frame with soundproofing seals
- Area
  - 350 SF accommodates 15 forepersons, other management or guests

Structural

Plumbing

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment
- A/V and power connections for presentation equipment

Fire Protection Sprinklers

Fire Alarm

- Speaker and strobe devices
- Manual pull station

System

- Public address
- Tel/data jacks
- Conference Telephone
- Wi-fi
- Wall-mounted large format monitor
- A/V panel
- Wireless video sharing system

Maintenance Management Suite

Copy/Print/Supplies/Storage Room

Function Characteristics

Function

- Dedicated area room or alcove for copier, fax machine, printer, and storage of a small amount of office supplies

Equipment/Furnishings

- Copier
- Fax machine
- Computer printer
- Work surface and shelving

Design Features

Architectural

- Finishes
  - Floor: VCT / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Area
  - 80 SF

Structural

Plumbing

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Electrical

- 3500 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 Sprinklers

Fire Alarm

- Speaker and strobe devices
- Manual pull station

System

- Public address
- Tel/data jacks
- Wi-fi
- Copier/Printer

Mechanics and Forepersons Support Area

Mechanics Toilets, Lockers, and Showers

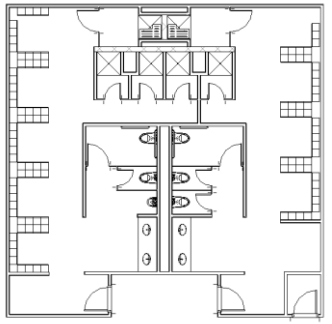
Function Characteristics

Function

- Dedicated for mechanics use
- Toilet fixture count per anticipated occupant load
- Provide (1) one full height locker per mechanic
- Includes adjacent custodial closet with utility sink to service this space
- Positioned near main maintenance staff entrance and adjacent to maintenance management

Equipment/Furnishings

- Toilets, urinals, wash sinks, showers, lockers
- Stainless-steel toilet partitions and accessories



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Design Features

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
- Doors
  - Electronic door hardware / Controlled Access entry into room
- Area
  - 20 - 30 SF per mechanic

Structural

Plumbing

- Provide domestic hot/cold water, sanitary and vent to water closets, urinals, lavatories and showers
- Provide floor drains with trap primers
- Provide hose bibbs underneath lavatories

Mechanical

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

Electrical

- 3800 lumen Recessed LED luminaires
- 50 foot candle average is required throughout the area
- Convenience GFCI receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Strobe devices

System

- Public address

Mechanics and Forepersons Support Area

Uniform Pickup/Dropoff

Function Characteristics

Function

- Room for mechanics to pick up clean hangered uniform and deposit soiled uniforms
- Usually in or adjacent to locker rooms
- Includes a closet with large rolling bin for soiled uniforms

Design Features

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
- Area
  - 4 SF per mechanic

Structural

Plumbing

Mechanical

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices

System

- Public Address

Mechanics and Forepersons Support Area

Mechanics Break Room

Function Characteristics

Function

- Used as a break area for mechanics and forepersons

Equipment/Furnishings

- Counter space and upper Cabinets
- Sink with disposal
- Microwave, coffee maker, refrigerators
- Vending machines
- Tables, chairs, and soft seating areas
- A/V including wall-mounted TV monitors

Design Features

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
- Area
  - 50 SF per mechanic during peak shift

Structural

Plumbing

- Provide domestic hot/cold water, sanitary and vent to break room sinks

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices

System

- Public address
- Tel/data jacks
- Telephone
- Wi-fi
- Large format monitor
- A/V panel
- Wireless content sharing

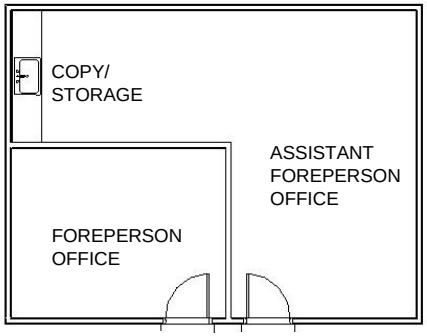
Mechanics and Forepersons Support Area

Foreperson's Office and Assistant Foreperson's Work Area

Function Characteristics

Function

- Office suite with separate office for foreperson and shared office space for assistant forepersons
- Centrally located, adjacent and visible to maintenance bay and mechanics kiosk



Equipment/Furnishings

- Desks and chairs for each staff member with additional work surfaces and guest chairs as needed
- Sink
- Lateral or under surface vertical files
- Casework storage cabinets and counter to accommodate printer/copier/radio consoles and other equipment to be identified by MBTA
- A/V including wall-mounted TV monitor

Design Features

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
- Doors
  - Electronic door hardware/Controlled Access entry into room
- Area
  - 600-800 SF accommodates 1 foreperson and 3 assistant forepersons

Structural

Plumbing

- Provide domestic cold water, point of use electric water heater, sanitary and vent to copy room sink

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Speaker and strobe devices

System

- Public address
- Tel/data jacks
- Telephone
- Wi-fi
- Intercom base station
- 2-way radio desktop unit

Mechanics and Forepersons Support Area

Copy/Scanner, File, and Library

Function Characteristics

Function

- Dedicated area, room, or alcove for copier, fax machine, printer, and storage of a small amount of office supplies

Equipment/Furnishings

- Copier
- Fax machine
- Computer printer
- Work surface and shelving

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Area
  - 120 SF

Structural

Plumbing

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices
- Manual pull station

System

- Public address
- Tel/data jacks
- Wi-fi

Mechanics and Forepersons Support Area

Mechanics Kiosk Niche

Function Characteristics

Function

- Kiosks / computer stations for data entry by mechanics (1 per bay)

Design Features

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
- Area
  - 15 SF

Structural

Plumbing

Mechanical

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- A/V and power provided to each kiosk
- Ethernet data jack points

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices
- Manual pull station

System

- Data jacks for each kiosk

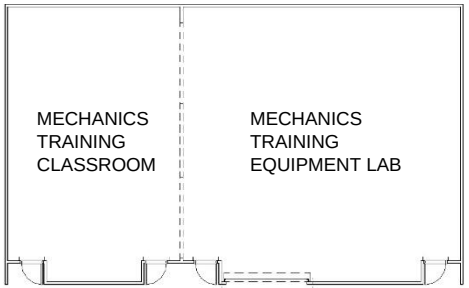
Mechanics and Forepersons Support Area

Mechanics Training Room

Function Characteristics

Function

- Training room with chairs and desk for flexible arrangement for different forms of training with large and small vehicle components
- Access for forklift and moving large components in and out of the space
- Easy access to staff support areas



Design Features

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
- Area
  - 600-1200 SF

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment
- A/V and power connections for presentation equipment

Mechanical

- Ventilated per IMC with CO_2 sensors for demand-controlled ventilation
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices

System

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Large format touch screen monitors
- A/V panels
- Wireless content sharing systems

Mechanics and Forepersons Support Area

Mechanics Trainers Office

Function Characteristics

Function	
• Office for resident trainer, bus driver, and smaller conference room size training session • Accommodates up to (1) one Trainer • Borrowed lite/ glazing for visual connection to Training Classroom (with privacy shade)	
Equipment/Furnishings	
• Desk with return, Chair, Lateral Files, Guest Chairs, Work Surfaces, Corner Work Surface, Under Surface Vertical File, Printer and other equipment to be identified by MBTA	

Design Features

Architectural	Structural
• Finishes – Floor: Carpet / Resilient wall base – Walls: Acrylic latex-painted with accent wall color(s) – Ceiling: Suspended acoustical ceiling grid and tile system • Doors – Secured entry; single 3’-0” door • Area – 120 SF.	
	Plumbing
Mechanical	**Electrical**
• Ventilated per IMC • Heated to maintain minimum temperature of 70°F • Cooled to maintain maximum temperature of 75°F	• 3500 lumen LED pendant luminaires • 50 foot candle average is required throughout the area • General convenience receptacles • Power provided to room equipment • A/V and power connections for presentation equipment
Fire Protection Sprinklers	**System**
	• Public address • Tel/data jacks • Telephones • Wi-fi
Fire Alarm	
• Speaker and strobe devices	

Mechanics and Forepersons Support Area

Mechanics Training Room Storage

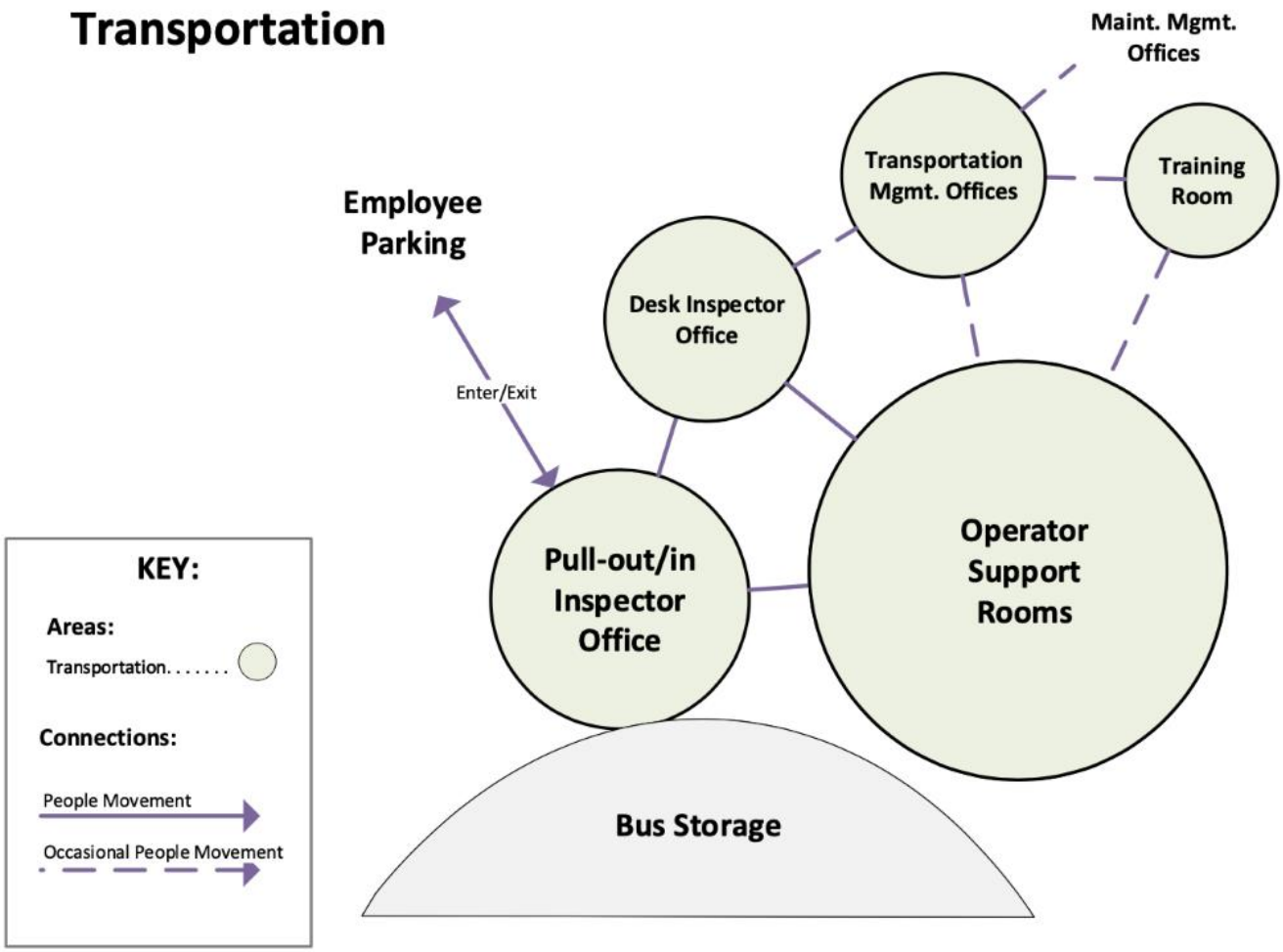
Function Characteristics

Function	
• Training material storage for small local training in conference room	

Design Features

Architectural	Structural
• Finishes – Floor: VCT – 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 • Area – 150 SF	**Plumbing**
Mechanical	**Electrical**
	• 500 lumen LED pendant luminaires • 50 foot candle average is required throughout the area • General convenience receptacles • Power provided to room equipment • A/V and power connections for presentation equipment
Fire Protection Sprinklers	**System**
	• Public address • Tel/data jack
Fire Alarm	
• Speaker and strobe devices	

4.2 Transportation



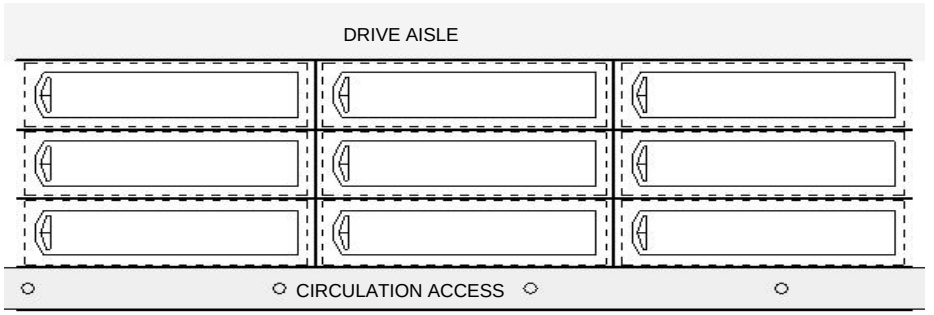
4.2.1 Transportation Operations Area

Interior Bus Storage

Function Characteristics

Function

- Secured interior storage area for parking buses when not in service and charging BEB
- Drive aisles to be minimum 75’ width for turning into/out of parking spaces with 90-degree orientation
- One-way counterclockwise circulation
- Drive lanes and pedestrian walkways delineated by floor traffic striping
- Overhead fast action insulated fabric doors at vehicle exterior entry and exit (separate entrance and exit)



Design Features

Architectural

- Finishes
  - Floor: Soil, grease, water, slip-resistant concrete
  - Wall: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Epoxy painted exposed structure
- Doors
  - Personnel doors with view panels to meet applicable code exit requirements
  - Exterior overhead door: High-lifting insulated fabric doors
  - Bollards on exterior side of jambs of overhead door (2 each)
- Area
  - Per 40-ft bus: 12’ x 45’; per 60 ft bus: 12’ x 65’
  - Drive aisles: 75' minimum width for turning 90° into row; 18’ width between rows

Structural

- Control joints in-floor slab at adequate spacing
- Concrete paving shall be used for drive lanes floor slabs shall be designed to accommodate bus and tow vehicle.

Plumbing

- Floor drains on oil water separator system
- 3/4” water hose bib with standard faucet at rear of bay 2’-0” AFF at four locations around exterior walls, on outside of fuel area, and light transit vehicle washer area
- Compressed air connections

Electrical

- High bay 60,000 lumen LED luminaires
- General convenience receptacles

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

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Heat/smoke detector; speaker and strobe devices; manual pull station

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Bi-directional amplifier/distributed antenna system
- Access control
- CCTV

Desk Inspector's Office

Function Characteristics

Function

- Area with a service counter where one or more inspectors work with operators on staffing items
- Located conveniently to operators as they report for work and where they pull in buses
- Visual connection to operators' room

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
- A/V including wall-mounted TV monitor

Design Features

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
- Area
  - 200 SF

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

Fire Protection Sprinklers

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Two-way radio desktop unit
- Bi-directional amplifier/distributed antenna system

Pull Out Inspector's Office

Function Characteristics

Function

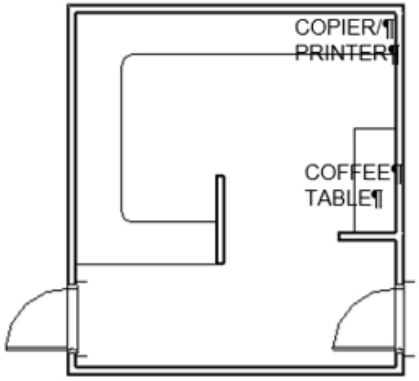
- Enclosed weather protected area where operators report for duty, are assigned buses, and report vehicle defects
- Room includes service window and visual connection to bus storage and bus yard
- Service window and work counters or workstations, chairs

Relationship to Other Areas

- Access to nearby restroom – may share with operator support area if they are adjacent.

Equipment/Furnishings

- Computer and counter workstations and chairs
- Printer, fax, copier, shredder, lateral files
- Radio consoles
- Break/coffee table
- A/V including wall-mounted TV monitor



Design Features

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
- Doors
  - Electronic door hardware/ controlled access entry into room
- Area
  - 150 SF accommodates (4) four pull-out inspectors

Structural

Plumbing

- Provide cold water connection with backflow preventer to coffee machine

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilation per IMC
- Heating to maintain minimum temperature of 70°F
- Cooling to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices
- Manual pull stations

Systems

- Public address
- Tel/data jacks
- Telephone
- Wi-fi
- Access control
- Large format monitor
- Portable radio desktop charger

Inspectors' Toilets, Lockers, and Showers

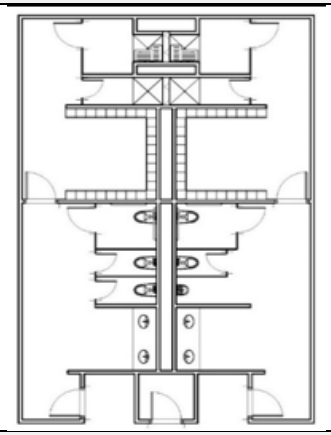
Function Characteristics

Function

- Dedicated for use by inspectors and transportation management with direct access to transportation management area
- Toilet fixture count per anticipated occupant load
- One full height locker per inspector and transportation management staff
- Adjacent custodial closet with utility sink to service this space

Equipment/Furnishings

- Toilets, urinals, wash sinks, showers, lockers, toilet partitions



Design Features

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
- Doors
  - Electronic door hardware / controlled access entry into room
- Area
  - 20 - 30 SF per inspector

Structural

Plumbing

- Provide domestic hot/cold water, sanitary and vent to water closets, urinals, lavatories and showers
- Provide floor drains with trap primers
- Provide hose bibbs underneath lavatories

Electrical

- 3800 lumen Recessed LED luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Exhausted/ventilated per IMC (no recirculation)
- Heating to maintain minimum temperature of 70°F
- Cooling to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Strobe devices

Systems

- Public address

Operators' Picking Room

Function Characteristics

Function

- Room where inspectors facilitate assignment selection by operators
- Room requirements may change when picking becomes electronic
- Visual connection to Operators' Day Room

Equipment/Furnishings

- Worktable, Chairs, A/V including wall-mounted TV monitor(s), Visual Display Boards – white boards/tack boards

Design Features

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
- Area
  - 200 SF accommodates (2) two inspectors

Structural

Plumbing

- N/A

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide Wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Large format monitors
- A/V panels

Time-Keeping Kiosk

Function Characteristics

Function

- Computer kiosk adjacent to deck inspector's office or in alcove at transportation staff entrance
- Easy access to pull-out inspector's office and operators' day room

.

Design Features

Architectural

- Finishes
  - Floor: VCT / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Area
  - 12 SF

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- 50 foot candle average is required throughout the area
- General convenience receptacles
- Power provided to room equipment

Mechanical

Fire Protection Sprinklers

Fire Alarm

- Speaker and strobe devices
- Manual pull station

Systems

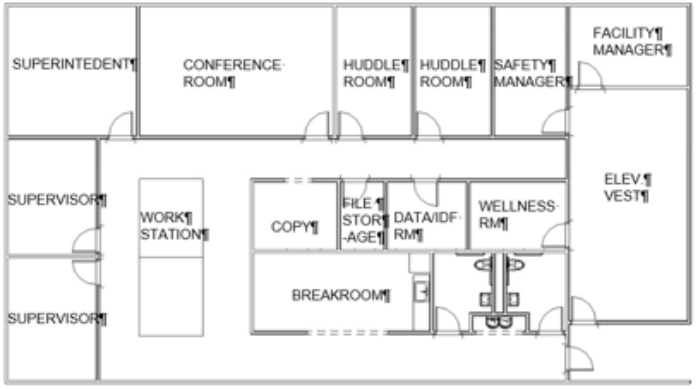
- Data facks

Transportation Management Suite

Function Characteristics

Function

- Main transportation management area with the following dedicated spaces and general reception area for facility visitor and vendors:
  - Superintendent's Office
  - Supervisor's Office(s)
  - Administrative Workstation(s)
  - Facility Manager's Office
  - Safety Manager's Office
  - Guest and Privacy Room
  - Conference Room
  - Copy/Print/File Room
  - Management Break Area



Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
- Area

Structural

Plumbing

- Provide domestic hot/cold water, sanitary and vent to water closets, lavatories, wellness sink and breakroom sink
- Provide domestic cold water to electric water cooler

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

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.

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Large format monitors
- A/V panels
- Wireless content sharing systems
- PSIM Workstation
- Electronic Access Control
- CCTV Cameras
- Printer/Copy Machine(s)

Superintendent's Office

Function Characteristics

Function

- Private office for superintendent
- Visual connection to management suite with privacy shade

Equipment/Furnishings

- Desk with return, chair, and guest chairs
- Lateral files
- Printer/radio console
- A/V including wall-mounted TV monitor(s)

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
  - Secured door with key
- Area
  - 250 SF accommodates (1) one superintendent with up to (4) four guests

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi

Supervisor Offices(s)

Function Characteristics

Function

- Private office for supervisor

Equipment/Furnishings

- Desk with return, chair, and guest chairs
- Lateral files
- Printer/radio console
- A/V including wall-mounted TV monitor(s)

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
  - Secured entry with key
- Area
  - 175 SF accommodates one (1) supervisor with up to two (2) guests

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Speaker and strobe devices

System

- Public address
- Tel/data jacks
- Telephones
- Wi-fi

Administrative Workstation(s)

Function Characteristics

Function

- Freestanding workstations for administrative staff

Equipment/Furnishings

- Workstation desk with return and chair
- Lateral files

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
  - Secured entry; single 3’-0” door
- Area
  - 80 SF per 2-4 staff

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi

Facility Manager's Office

Function Characteristics

Function

- Enclosed private office for facility manager
- Visual connection to management suite or corridor with privacy shade

Equipment/Furnishings

- Desk with return, chair, and guest chairs
- Lateral and under surface vertical file

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
  - Secured entry; single 3'-0" door
- Area
  - 275 SF accommodates one (1) facility manager with up to two (2) guests

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Large format monitors
- Security system PSIM workstation
- BIM system workstation

Safety Manager's Office

Function Characteristics

Function

- Enclosed private office for safety manager
- Visual connection to management suite or corridor with privacy shade

Equipment/Furnishings

- Desk with return, chair, and guest chairs
- Lateral and under surface vertical file

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
  - Secured entry; single 3'-0" door
- Area
  - 150 SF accommodates one (1) manager with up to two (2) guests

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Speaker and strobe devices

System

- Public address
- Tel/data jacks
- Telephones
- Wi-fi

Guest and Privacy Room

Function Characteristics

Function

- Office set up with extra guest chairs

.

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
- Area
  - 120 SF

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Strobe devices

Systems

- Public address
- Tel/data jacks
- Telephone
- Wi-fi
- Large format monitors
- A/V panels
- Wireless content sharing system

Conference Room

Function Characteristics

Function

- Conference room for transportation management
- Visual connection to management suite

Equipment/Furnishings

- Conference table, credenza, and chairs
- A/V including wall-mounted TV monitor(s)

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
- Area
  - 375 SF accommodates 18 staff

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Floor boxes, number per NEC
- Power provided to room equipment
- A/V and power connections for presentation equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephone
- Wi-fi
- Large format monitors
- A/V panels
- Wireless content sharing system

Copy/Print/File Storage

Function Characteristics

Function

- Dedicated room or alcove for copier, fax machine, printer, and storage of a small amount of office supplies

Equipment/Furnishings

- Copier
- Fax machine
- Computer printer
- Work surface and shelving

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
- Area
  - 100 SF

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephone
- Wi-fi
- Printer/copy machine(s)

Management Break Area

Function Characteristics

Function

- Small break area with coffee bar for management suite

.

Design Features

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
- Area
  - 250 SF

Structural

Plumbing

- Provide domestic hot/cold water, sanitary and vent to breakroom sink
- Provide domestic cold water with backflow preventer to coffee machine

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

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.

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Speaker and strobe devices
- Heat detector

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Large format monitors
- A/V panels

4.2.2 Transportation Operations Support Area

Operators' Day Room	
Function Characteristics	
Function	
• General break area dedicated to operator use	
Equipment/Furnishings	
• Casework with sink / faucet • Appliances (refrigerators, microwave, coffee maker) • Vending machines • Tables and chairs with soft seating areas • Computer alcove • A/V including wall-mounted TV monitors	
Design Features	
Architectural	**Structural**
• Finishes – Floor: VCT / Resilient wall base – Walls: Acrylic latex-painted with accent wall color(s) – Ceiling: Suspended acoustical ceiling grid and tile system • Doors • Area – 110 SF per operator	**Plumbing** • Provide domestic hot/cold water, sanitary and vent to operation sinks **Electrical** • 3500 lumen LED pendant luminaires • General convenience receptacles • Power provided to room equipment
Mechanical	**Systems**
• Ventilated per IMC • Heated to maintain minimum temperature of 70°F • Cooled to maintain maximum temperature of 75°F **Fire Protection Sprinklers** • Provide wet sprinklers maximum spacing 225 square feet per head **Fire Alarm** • Speaker and strobe devices	• Public address • Tel/data jack • Telephones • Wi-fi • Large format monitor • A/V panels

Operators' Toilets, Lockers, and Showers

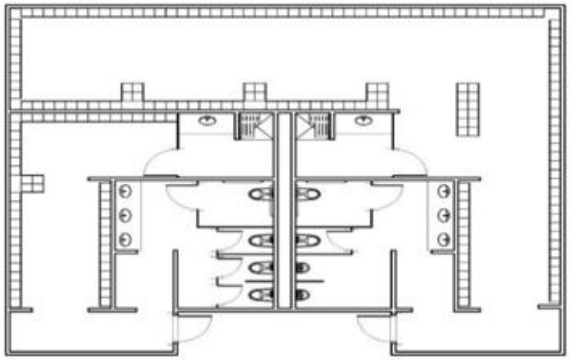
Function Characteristics

Function

- Dedicated for operator use
- Toilet fixture count per anticipated occupant load
- One full height locker per operator
- Adjacent custodial closet with utility sink to service this space

Equipment/Furnishings

- Toilets, urinals, wash sinks, showers, lockers



Design Features

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
- Doors
  - Electronic door hardware / Controlled Access entry into room
- Area
  - Full locker: 15 SF per operator
  - Half locker: 10 SF per operator

Structural

Plumbing

- Provide domestic hot/cold water, sanitary and vent to water closets, urinals, lavatories and showers
- Provide floor drains with trap primers
- Provide hose bibbs underneath lavatories

Electrical

- 3800 lumen Recessed LED luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

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

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Strobe devices

Systems

- Public address

Wellness Room

Function Characteristics

Function

- Secured, private, quiet room for personal use (e.g., nursing mothers)

Equipment/Furnishings

- Counter with sink
- Couch or chairs
- Mini refrigerator

Design Features

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
  - Secured entry; single 3’-0” door
- Area
  - 200 SF (large facilities may need more than 1)

Structural

Plumbing

- Provide domestic hot/cold water, sanitary and vent to wellness sink

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones

Operators' Training Room and Storage

Function Characteristics

Function

- Training room with chairs and desk for flexible arrangement for different forms of training
- Easy access to instructors' office and other operator support rooms
- Adjacent material and equipment storage space

Equipment/Furnishings

- Tables, desks, and chairs
- A/V including wall-mounted monitors

Design Features

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
- Area
  - Training Room: 1200-1800 SF (dependent on assigned operator shift numbers)
  - Storage: 300-400 SF

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment
- A/V and power connections for presentation equipment

Mechanical

- Ventilated per IMC, with CO_2 sensor for demand-controlled ventilation airflow
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head.

Fire Alarm

- Speaker and strobe devices
- Heat/smoke detector

System

- Public address
- Tel/data jacks
- Telephone
- Wi-fi
- Large format monitor
- A/V panel
- Wireless content sharing system

Instructors' Office

Function Characteristics

Function

- Office for resident bus operator instructor
- Visual connection to operators' training room with privacy shade

Equipment/Furnishings

- Desk/work surface with return and chair (plus guest chairs)
- Lateral and under surface vertical files
- Printer and other equipment as needed

Design Features

Architectural

- Finishes
  - Floor: Carpet / Resilient wall base
  - Walls: Acrylic latex-painted with accent wall color(s)
  - Ceiling: Suspended acoustical ceiling grid and tile system
- Doors
  - Secured entry; single 3'-0" door
- Area
  - 120 SF accommodates (1) one instructor

Structural

Plumbing

Electrical

- 3500 lumen LED pendant luminaires
- General convenience receptacles
- Power provided to room equipment
- A/V and power connections for presentation equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F
- Cooled to maintain maximum temperature of 75°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

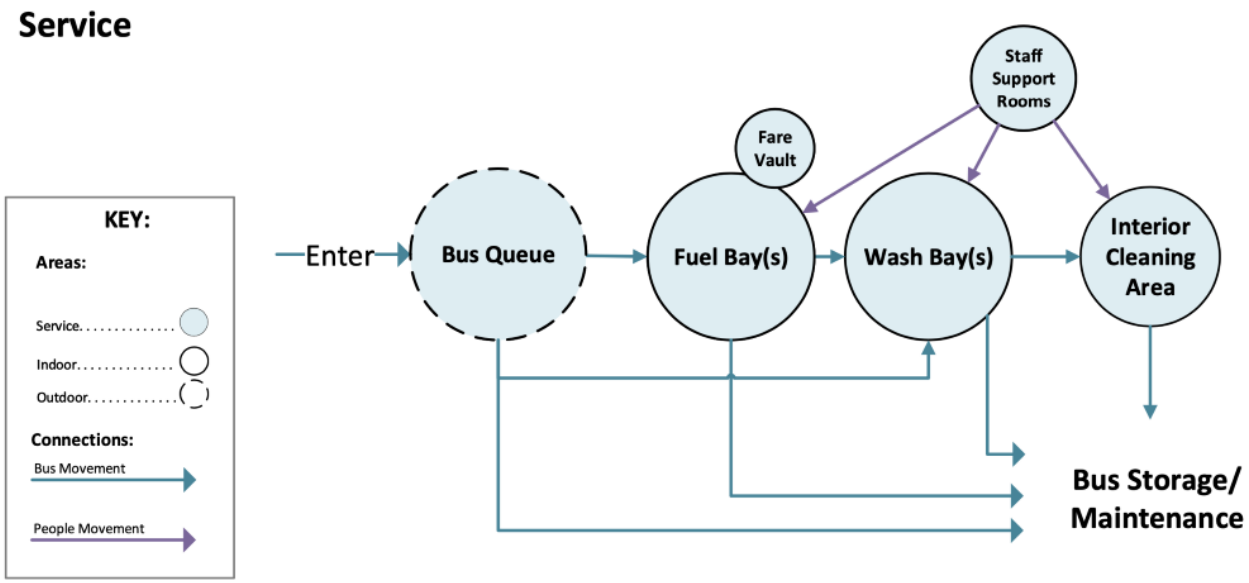
Fire Alarm

- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi

4.3 Servicing



4.3.1 Fueling Operation

Fueling Bay

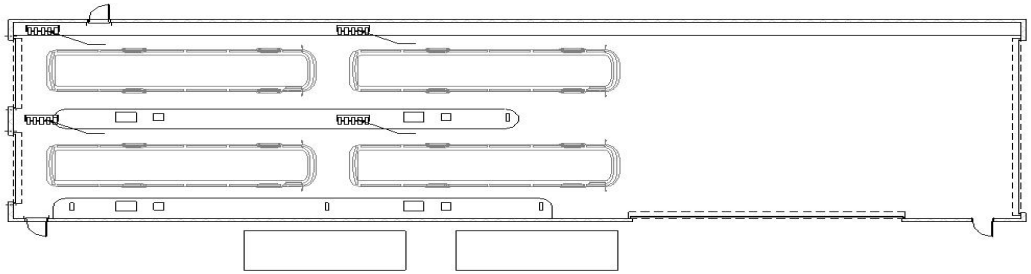
Function Characteristics

Function

- Diesel fueling and reels for topping off fluids
- Pull fares (Note: MBTA's current fare collection system uses a vault, but the future planned system will be fully electronic.)
- Extract engine and performance data from bus

Equipment/Furnishings

- Bus data collection system
- Diesel dispenser
- Diesel tank and leak detection system
- Diesel fuel tanks (below ground)
- Submersible diesel fuel pump, fluid reels, and compressed air



Design Features

Architectural

- Finishes
  - Floor: Soil, grease, water, slip-resistant concrete
  - Wall: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Epoxy painted exposed structure
- Doors
  - Electronic door hardware / Controlled Access entry at access doors
  - Bollards located at entrance to each lane and in front of fueling equipment
- Area
  - 60' X 30'
  - 1 per 40–60 buses (assume additional 3,000 SF if above ground fluid storage is needed)

Structural

- Sealed control joints in-floor slab at adequate spacing
- Structure as needed to support equipment
- Design canopy to prevent accumulation of explosive natural gas mixtures

Plumbing

- Trench drain with removable traffic rated grating to sediment/oil interceptor (1 per 2-bay lane)
- Lube reel banks with ATF, EC, EO1, EO2 and windshield washer fluid at end of bay
- 3/4" water hose bib with standard faucet at end of bay 2'-0" AFF
- Compressed air line with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnects (1/2" and 1") on columns between each bay at 4'-0" AFF
- Product and vapor recovery piping as required to and from fuel tanks and dispensers
- Water connection to emergency shower/eye wash
- Compressed air line with cut-off valve, separator, regulator with gauge, and quick disconnects between each lane and at 4'-0" AFF. Provide disconnects for 1/2" and 1" impact tools at locations to be determined during detailed design

<table>
<tr><th colspan="2">Fueling Bay</th></tr>
<tr><td></td><td>Electrical
• 3500 lumen LED vapor tight luminaires
• Convenience GFCI receptacles
• Power provided to room equipment
• Fuel Management System: Provide power and signal conduit from island terminals to Fuel Island office
• Methane gas detection system: Devices located near the canopy ceiling and interlocked to sound alarms</td></tr>
<tr><td>Mechanical</td><td>Systems</td></tr>
<tr><td>• Exhaust in compliance with IMC section 502 (inlets at 18” A.F.F.), with aluminum ductwork
• Ventilation to make up exhausted airflow quantity
• Heating, to maintain minimum temperature of 55 degrees Fahrenheit
Fire Protection Sprinklers
• Provide dry chemical fire suppression
Fire Alarm
• Manual pull stations
• Speaker and strobe devices</td><td rowspan="2">• Public address
• Tel/data jacks
• Telephones
• Wi-fi
• Bi-directional amplifier/distributed antenna system
• Electronic Access Control on exterior doors
• CCTV</td></tr>
</table>

Service Lubrication and Compressor Room

Function Characteristics

Function

- Storage and distribution of fluids for fueling positions with 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

Equipment/Furnishings

- Motor oil and transmission fluid pump
- DEF pump
- Coolant pump
- Windshield washer fluid pump
- Shelving units
- Above ground tank (250 gallons each) for transmission fluid
- Above ground tank (500 gallons each) for motor oil and windshield washer fluid
- Above ground tank (750 gallons each) for coolant/antifreeze
- Above ground tank (1,000 gallons each) for DEF
- Air compressor
- Refrigerator/dryer
- Emergency safety shower/eyewash

Design Features

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
- Doors
  - Personnel doors to meet applicable code exit requirements
  - 3’-0” wide hollow metal door with interior exit device
  - No thresholds
- Area
  - 600-800 SF (dependent on fleet size, fluid delivery schedule, and fluid storage and compressor location)

Structural

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

Plumbing

- 3/4” water hose bib with standard faucet 2’-0” AFF
- Compressed air system with cut-off valve, separator, regulator with gauge, lubricator, and quick disconnect on wall at 4’-0” AFF for each lubricant pump
- Tank mount all lubricant pumps except Chassis Grease which will be hoist mounted, and the Engine Coolant diaphragm pump which will be wall-mounted. Provide siphon kit for wall-mounted pump
- Water tank with float valve for water to EC diaphragm pump
- Provide floor drains on building oil water separator system
- As required by equipment

Service Lubrication and Compressor Room	
	Electrical
	• 3500 lumen LED vapor tight luminaires • Convenience GFCI receptacles • Power provided to room equipment
Mechanical	**Systems**
• Exhaust per IMC section 502 • Ventilation, for makeup to exhaust system • Heating, to maintain minimum temperature of 55°F	• Public address • Tel/data jacks
Fire Protection Sprinklers	
• Provide wet sprinklers maximum spacing 130 square feet per head, medium temperature heads	
Fire Alarm	
• Manual pull stations • Speaker and strobe devices	

4.3.2 Fueling Support

Fuelers' Work Area

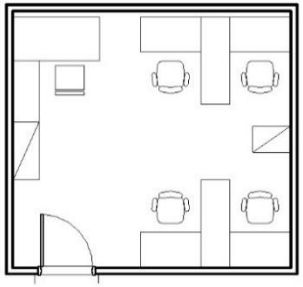
Function Characteristics

Function

- Work and break area for service area attendants (i.e., fuelers, fare staff, and interior cleaners) as needed
- Visual connection to fueling service areas

Equipment/Furnishings

- Desks/work surfaces and chairs
- Lateral and under surface vertical files
- Printer/copier/radio consoles
- A/V including wall-mounted TV monitor.



Design Features

Architectural

- Finishes
  - Floor: Sealed concrete or vinyl flooring slip-resistant
  - Walls: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Suspended acoustical ceiling
- Doors
  - Hollow metal doors and windows
  - Insulated tempered glass
- Area
  - 300 SF accommodates four (4) staff

Structural

Plumbing

Electrical

- 3500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Manual pull stations
- Speaker and strobe devices

- Public address
- Tel/data jacks
- Wi-fi

Fare Collection Room

Function Characteristics

Function

- Room for revenue department staff for counting and securing cash revenue prior to pickup (obsolete when fare collection system becomes fully electronic)
- Could also be in transportation office area with secondary vault for secure storage

Equipment/Furnishings

- Desks/work surfaces and chairs

Design Features

Architectural

- Finishes
  - Floor: Sealed concrete with vinyl or carpet flooring
  - Walls: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Suspended ceiling
- Doors
  - Electronic door hardware / controlled access
- Area
  - 120 SF accommodates two (2) staff

Structural

Plumbing

Electrical

- 3500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 225 square feet per head

Fire Alarm

- Manual pull stations
- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Electronic Access Control
- CCTV

Fare Vault Room

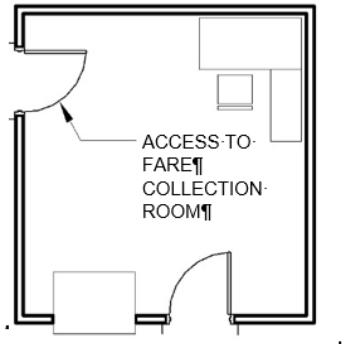
Function Characteristics

Function

- Vault for depositing cash from bus fare boxes (obsolete when fare collection system becomes fully electronic)
- Backside of fare vault opens with combination lock for accountants in transportation to count and bag cash for secure delivery to bank

Equipment/Furnishings

- Vault
- Worktable and chair
- Workspace, shelf unit and workbench for repairing fare boxes



Design Features

Architectural

- Finishes
  - Floor: Sealed concrete
  - Walls: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Suspended ceiling board ceiling
- Doors
  - Hollow metal (no window) secured
  - Electronic door hardware / Controlled Access
- Area
  - 120 SF

Mechanical

- Heated and air conditioned
- 74°F summer; 68°F winter

Fire Protection Sprinklers

- Provide wet sprinklers

Fire Alarm

Structural

Plumbing

Electrical

- LED lighting
- Desk office convenience outlets

System

- Public address
- Tel/data jacks
- Telephones
- Wi-fi
- Electronic Access Control
- CCTV

Fuelers Storage

Function Characteristics

Function

- Accommodates fuelers' work gear
- One full-size locker per fueler
- Metal storage shelving and cabinets (supplies, emergency equipment spill containment kit)

Equipment/Furnishings

- Storage cabinets for supplies
- Shelving units
- Waste receptacles

Design Features

Architectural

- Finishes
  - Floor: Concrete sealer; soil, grease, water and slip-resistant
  - Walls: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Epoxy painted gypsum board
- Doors
  - 3'-0" wide hollow metal door
- Area
  - 200 SF accommodates four (4) fuelers

Structural

Plumbing

Electrical

- 3500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 70°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Speaker and strobe devices

Systems

- Public address

4.3.3 Bus Wash Bays

Bus Wash Bays

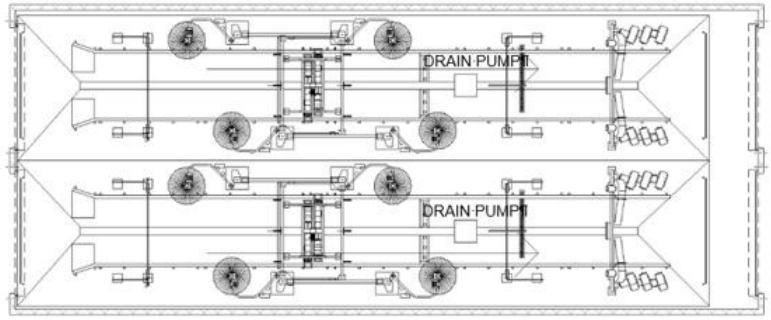
Function Characteristics

Function

- Automatic drive-through bus wash with tire guides and speed control light/audio signal

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
- Recycle system
- Industrial waste discharge to sewer line



Design Features

Architectural

- Finishes
  - Floor: Soil, grease, water, slip-resistant concrete
  - Wall: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Epoxy painted exposed structure
- Doors
  - Exterior overhead door: High-lifting sectional, poly, insulated, 14’ x 14’, 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)
- Area
  - 28’ X 75’ each, 1 per fuel lane (2 total for up to 250 buses)

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

Plumbing

- Trench drain down center of bay (with removable cover) to water reclamation system
- 3/4” water hose bib with standard faucet at 2’-0” AFF
- Water and compressed air connections to wash equipment
- As required by equipment

Electrical

- 3500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

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

Fire Protection Sprinklers and Alarm

- Provide wet sprinklers maximum spacing 130 square feet per head, medium temperature heads.
- Manual pull stations
- Speaker and strobe devices

Bus Wash Equipment Room and Industrial Waste System Space

Function Characteristics

Function

- Room for bus wash controls and equipment
- Includes approved water recycle system or reuse of water (such as rainwater) to recapture 85-95% of water used in the bus wash
- Industrial wastewater system (separate design and supplier) required to meet Massachusetts Water Resources Authority (MWRA) permitting

Design Features

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
- Doors
  - 3’-0” wide hollow metal door with interior exit device
- Arena
  - 15’ x 30’

Structural

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
- 3/4” water hose bib with standard faucet at 2’-0” AFF
- As required by equipment

Electrical

- 3500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC
- Heated to maintain minimum temperature of 55°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Manual pull stations
- Speaker and strobe devices

Systems

- Public address
- Tel/data jacks

4.3.4 Interior Cleaning and Detailing

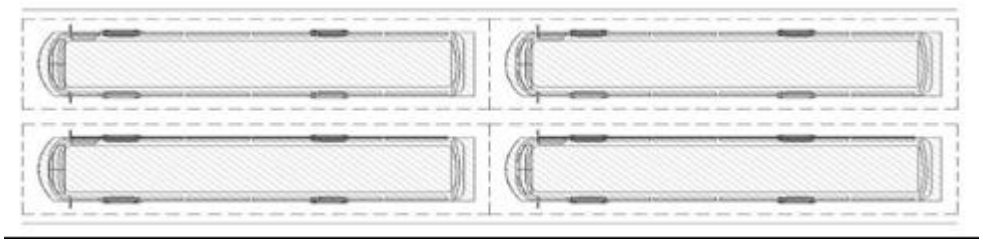
Bus Interior Cleaning and Queue Area

Function Characteristics

Function

- Separate cleaning position for interior cleaning and detailing of buses
- Drive lanes delineated by floor traffic striping

Equipment/Furnishings



Design Features

Architectural

- Finishes
  - Floor: Soil, grease, water, slip-resistant concrete
  - Wall: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Painted exposed structure (light color for natural and artificial light reflection)
- Area:
  - 5% of fleet for temporary parking

Structural

Plumbing

- Provide trench drain with sediment bucket on oil water separator system
- Provide water and compressed air connections as required by equipment
- Provide mop sink with water/sanitary/vent connections

Electrical

- 3500 lumen LED vapor tight luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

Mechanical

- Ventilated per IMC for a parking garage
- Heated to maintain minimum temperature of 55°F

Fire Protection Sprinklers

- Provide wet sprinklers maximum spacing 130 square feet per head

Fire Alarm

- Manual pull stations
- Speaker and strobe devices

Systems

- Public address
- Wi-fi
- Bi-directional amplifier/distributed antenna system

Bus Cleaning Storage and Lockers

Function Characteristics

Function

- Storage room for bus interior cleaning staff with lockers and storage for equipment and cleaning supplies (bus interior cleaning staff are currently contractors so space must allow for full operation)
- Provide dedicated restroom in close proximity

Equipment/Furnishings

- Mop sink and toilets
- Metal storage shelving

Design Features

Architectural

- Finishes
  - Floor: Sealed, soil, grease, water, slip-resistant concrete
  - Walls: Epoxy painted masonry; soil and grease resistant
  - Ceiling: Epoxy painted exposed structure
- Doors
  - Single/double as required hollow metal doors
- Area
  - 400 SF + single occupancy washroom

Structural

Plumbing

Electrical

- 3800 lumen Recessed LED luminaires
- Convenience GFCI receptacles
- Power provided to room equipment

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

Fire Alarm

- Strobe devices

Systems

- Public address
- Tel/data jacks
- Wi-fi

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APPENDIX A
SUSTAINABILITY AND RESILIENCE SUPPLEMENT

CONTENTS

TABLES

FIGURES

A.1 SUSTAINABILITY AND RESILIENCE

The content below is a continuation of Section 2.4 Sustainability and Resilience. These sections contain additional details necessary to clarify the full sustainability and resilience requirements 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 MBTA Request for Proposal for architectural / engineering services and construction bids, both sustainability and resilience leads must be included as specifically defined key roles. The designated 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 both Leadership in Energy and Environmental Design (LEED) and Envision 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 stand-alone document or it may be incorporated into larger project management plans. The SRMP must manage the scope, scale, and complexity of the project's sustainability and resilience (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 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 Plan 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 sustainability and resilience and all aspects that require tracking, reporting, or other documentation. Consider using a table similar to the example provided below (sustainability and resilience management plan content tracker), summarizing basic project information and all applicable components and responsible party(ies).
- 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 PM. Methods include workshops, internal design coordination meetings, design QC reviews, milestone deliverable reviews by MBTA technical staff, review of draft SRMP documents. Document alternatives considered, data reviewed, decisions made, action items generated, 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 PSP or 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. Example: List instances of use of design criteria exceeding minimum code requirements, or encompassing criteria not required by code (the Envision rating system in particular, rewards exceeding code minimums and broadening the boundaries of design considerations). 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.

- 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 the tracking table.

The SRMP must be included in design package submissions to the MBTA in its entirety and containing 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 basis of design (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 Plan satisfactory complete. The contractor's Coordinator must update the SRMP on an ongoing basis and provide regular updates (quarterly, 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 sustainability and resilience requirements.

Refer to *Envision Sustainable Infrastructure Framework (v3)*, *LD1.1 Provide Effective Leadership and Commitments; LD2.1 Establish a Sustainability Management Plan; QL1.1 Improve Community Quality of Life; QL3.1 Advance Equity and Social Justice; LD2.2 Plan for Sustainable Communities; and LEED BD+C (v4/4.1): IP Cr 1 Integrative Process*.

Table A-1. Sustainability and Resilience Management Plan Content Tracker

SRMP Content Tracker			
Project Name:			
Project Type (e.g. new building construction)			
Project Site Size (SF):			
Project Building Size (SF)			
Project Address			
Design Team Project Manager:			
Construction Team Project Manager:			
MBTA Representative:			
S+R Administrator (Design + Construction):			
S+R Coordinator (Construction):			
SRMP Components	**Project Phase**	**Primary Responsible Party**	**Notes**
Stakeholder Engagement Plan	Planning - Operation	Public Involvement Specialist (MBTA)	Related to Envision
Environmental Documentation (i.e, ENF, CE)	15% - Cnst	Environmental Manager	Related to Envision
Leading by Example Tracking Form	100%, CC	S+R Leads	For MBTA tracking; include any associated, supporting documentation.
Integrative Process Documentation	15, 30, 60, 90, & 100%	Design Project Manager	Related to Envision & LEED

Table A-1. Sustainability and Resilience Management Plan Content Tracker

Carbon Reduction Plan (CRP): Operational and Embodied Carbon	15, 30, 60, 90, & 100%	Mechanical & Electrical Engineers, Architect	Identify main aspects of embodied carbon here; details to be included in the MPP. Related to Envision & LEED
Energy Conservation Report (ECR)	30%	Mechanical Engineer	Related to Envision & LEED
MassDEP GWSA GHGAT	100%	Mechanical & Electrical Engineers	For MBTA tracking
Water Performance Plan (WPP)	30, 60, 90 & 100%	Plumbing, Civil, & Process Engineers	Related to Envision & LEED
Baseline Greenhouse Gas Emissions Assessment (BGGEA)	15%-100%	S+R Leads	Related to Envision & LEED
Universal Design Documentation	30%	Architect	Related to LEED
Flexible Building Study (FBS)	30%	Architect	Related to LEED
Acoustical Implementation Plan (AIP)	100%	Architect	Related to Envision & LEED
Light Pollution Reduction calculations, documentation	90%	Electrical Engineer / Lighting Designer	Related to Envision & 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 Envision & LEED
Material and Product Plan (MPP)	100%, Cnst	Design Team	Related to Envision & LEED
Project Safety Plan (PSP)	100%, Cnst	Architect / Contractor	Related to Envision & LEED
Stormwater Pollution Prevention Plan (SWPPP) including Erosion and Sedimentation Control (ESC) Plan	100%, Cnst	Civil Engineer / Contractor	Related to Envision & LEED
Construction Energy and Water Use Documentation	Cnst	Contractor	Related to LEED
Construction Impact Mitigation Plan (CIMP)	Cnst	Contractor	Related to Envision
Construction and Demolition Waste Management Plan (CDWMP)	Cnst	Contractor	Related to Envision & LEED
Indoor Air Quality Plan (IAQP)	Cnst	Contractor	Related to LEED
Commissioning Plan (CxP)	60 & 90%, Cnst, Cx, CC	Commissioning Authority	Related to Envision & LEED
Landscape Tracking Plan	Cnst	Contractor	For MBTA tracking, Related to Envision & LEED
Risk and Resilience Management Plan	15%-100%	S+R Leads	Related to Envision & LEED
MBTA Resilience Forms (see Appendix A – Section A.1.2)	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 = Operations & Maintenance

A.1.1.3 Pursuit of Third-party Certifications: Envision and LEED

A.1.1.3.1 Envision Sustainable Infrastructure Framework

The Envision Sustainable Infrastructure Framework (Envision) is a third-party project certification process that allows for infrastructure projects that have achieved high levels of sustainability and resilience to receive recognition awards (Verified, Silver, Gold, or Platinum) based on final levels of achievement. Envision is an objective framework of five categories – Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Resilience – within which 64 individual credits are organized. These credits collectively address human wellbeing, mobility, community development, collaboration, planning, economy, materials, energy, water, siting, conservation, ecology, emissions, and resilience. There are also Envision credits that relate to community impact and stakeholder involvement that extend beyond the property boundaries. The levels of achievement within the Envision rating system reward more extensive review and mitigation of project impacts, and external partnerships. MBTA will lead on these issues with the assistance of the design team incorporating related elements into the design.

Components of the Envision framework include:

- The Envision pre-assessment checklist - intended to support incorporating Envision early in the planning and conceptual design project phases by helping the project team quickly identify whether they are addressing the full range of sustainability criteria.
- Envision Online Scoresheet – The detailed online assessment tool and calculator. The online scoresheet includes the full guidance manual within the tool.
- Envision Verification – Independent third-party project review process.
- Envision Awards – Recognition for qualifying verified projects.
- Envision Sustainability Professional Credential (ENV SP) – Professional training in Envision use.

In the event that a project has more than one occupied facility, each facility must be designed and constructed to the same level of requirements; the project will pursue a single certification for the project in its entirety. Requirements must be documented as a holistic effort.

References:

- Institute for Sustainable Infrastructure (website) (Institute for Sustainable Infrastructure, 2018)
- Envision Sustainable Infrastructure Framework Guidance Manual (v3 or most recent version) (Institute for Sustainable Infrastructure, 2020)

A.1.1.3.2 Leadership in Energy and Environmental Design (LEED)

LEED serves as a consensus-based sustainability guideline and assessment mechanism for green building design, construction, operations, and maintenance. Both Envision and LEED add value to the bus maintenance facilities by providing frameworks through which to integrate sustainability and resilience practices into projects, and LEED also encourages in-depth engagement with the surrounding community, stakeholders, team members, and long-term operators. The frameworks provide ways to directly address and enhance practices that are already in place in other MBTA facilities and interspersed within existing policies, as well as create opportunities for expansion of these practices.

While the two rating systems have a number of similar topics covering a wide range of sustainability and resilience threats and hazards (Figure A-1), they differ in application. Where Envision allows

designers to evaluate the systemic impact of infrastructure projects on the community and community assets, LEED is used to incorporate sustainability and resilience priorities to occupied buildings, specifically. At a high level, LEED certification is based on compliance with prerequisites and an accumulation of points; the final certification level achieved is tiered based on the number of points achieved.

Components of the LEED framework include:

- 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 Envision and LEED align with several of MBTA's own plans and policies mentioned above. 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. The elements incorporated at these facilities will set the bar for sustainability and resilience at future MBTA facilities; these projects are well-suited to guide other projects towards a more sustainable and resilient future.

In the event that a project has more than one occupied facility, each facility must be designed and constructed to the same level of requirements; 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)

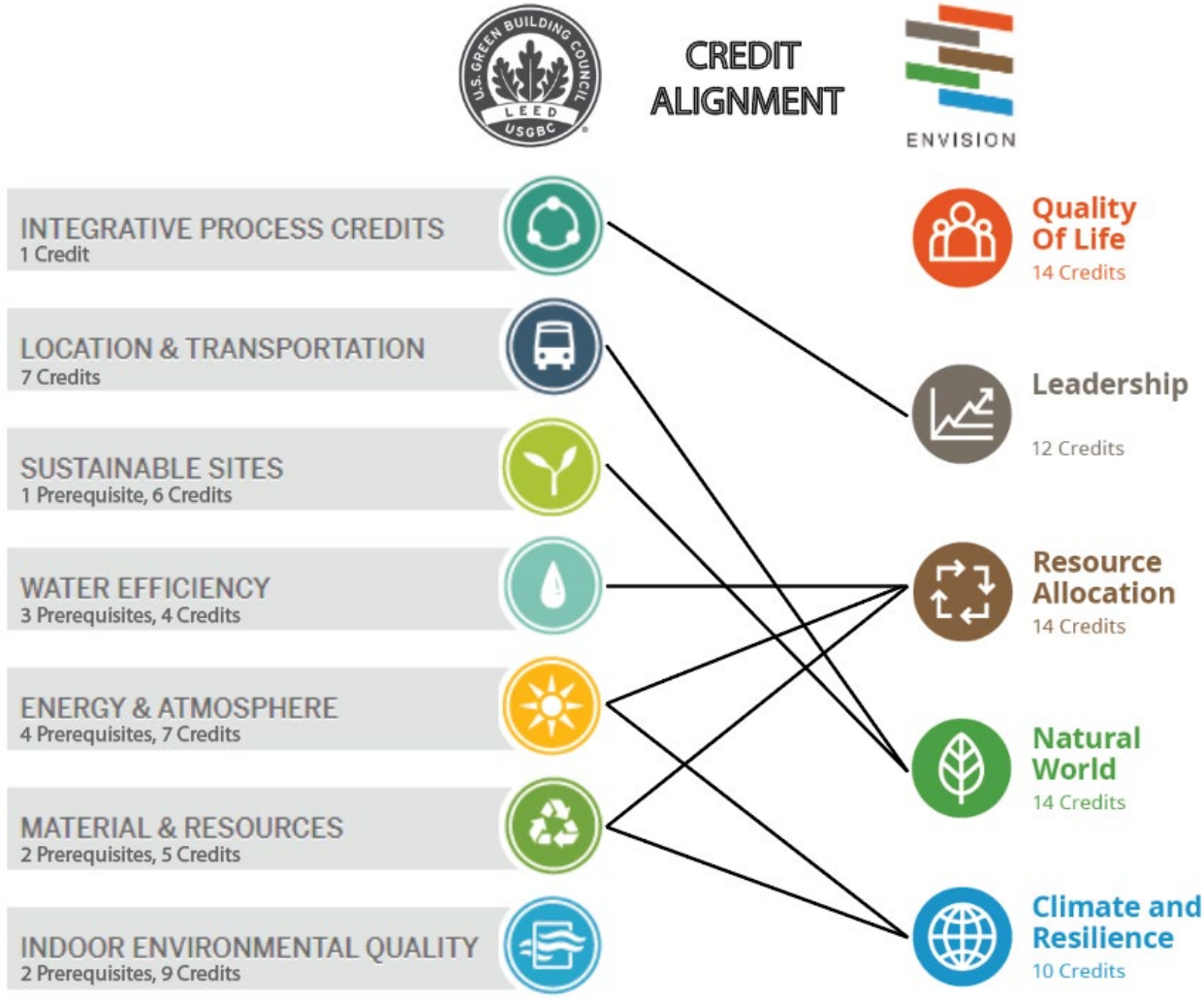

Figure A-1. LEED and Envision Crosswalk

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), basis of design (BOD), design documents, and construction documents. For greater insight on integrative process procedures, review the Integrative Process ANSI Consensus National Standard Guide© 2.0 for Design and Construction of Sustainable Buildings and Communities, which provides step-by-step guidance and a methodology for improving building design, construction, and operations through a replicable, integrative process. Also review 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. Documentation of extending external impact analysis, stakeholder input and satisfaction with the project contributes to higher levels of achievement for at least 14 Envision credits. Consider allowing use of meeting space in the buildings to be available to

community groups, or other partners. Consider other training or operational partnerships with other public and private entities who are also transitioning from fossil fuel to electric vehicles.

Compile all Integrative Process (IP) documentation required above 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 *Envision Sustainable Infrastructure Framework* (v3), *QL1.1 Improve Community Quality of Life; QL3.1 Advance Equity & Social Justice; LD1.2 Foster Collaboration and Teamwork; LD1.3 Provide for Stakeholder Involvement; and CR2.6 Improve Infrastructure Integration; and 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.

- A comprehensive signage program built into the building's spaces to educate the occupants and visitors of the benefits of green buildings. This program may include windows to view energy-saving mechanical equipment or signs to call attention to water-conserving landscape features.
- 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.
- Educational web site (URL to be provided at submission) that shares information about the design, construction, and operation of the facility. Performance metrics are encouraged to be included.
- An educational video describing the project's environmental features; the video may be shown on digital displays in the building or throughout the building, or on web-based platforms and social media as appropriate.
- At least one annual "open day" for at the facility to educate the public about the different project types and applicable achievements. This "open day" should be publicized to the community at large, and should be considered for inclusion of the general public if it can be executed in a manner that does not impact security or other operational concerns.

Refer to *Envision Sustainable Infrastructure Framework (v3)*, *LD0.0 Innovate or Exceed Credit Requirements*; and LEED BD+C v4/4.1: IN Credit Green Building Education (USGBC 2020c).

A.1.1.6 Construction Activities Requirements

As referenced in Section 2.4.1.6.

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.

The design team must include requirements within contract documents that require the contractor to submit documentation based on Envision Sustainable Infrastructure Framework (v3), RA3.3 Reduce Construction Water Consumption. A minimum level of achievement of Superior is recommended. 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 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 team must include requirements within contract documents that require the contractor to submit documentation based on *Envision Sustainable Infrastructure Framework (v3)*, *RA2.2 Reduce Construction Energy Consumption.* A minimum level of achievement of Superior is recommended. 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 Health and Safety Special Procedures

<u>Construction Team</u>

The Project Safety Plan (PSP) is broader than a contractor's typical hazard analysis or safety plan to protect construction workers. The PSP includes implementation of design features to improve the safety for future users and maintainers of the completed project, such as increased arc flash safety setbacks from electrical equipment. The PSP has input from future building users, the designers, the constructors, and is archived for use by the building users and maintainers.

In coordination with the MBTA's Safety Department, and referencing the MBTA 2020 Construction Monitoring Programs Directive, the contractor's Safety Officer and management team members must develop a PSP representative of the entire duration of the project and includes the following minimum components (MBTA 2020):

- Documentation that the Owner and contractor have a site-specific safety plan and/or a PSP. This plan may include, but is not limited to, contractor background checks on personnel working on the

project, and 24-hour security monitoring on the project (physical/electronic). The security plan should be appropriate to the size and scope of the project.

- A short narrative that describes the goals of the PSP and how the PSP will be implemented and used to manage safety on the project. Include documentation showing the Owner and contractors developed a proactive investigative process that focuses on root-cause and corrective actions rather than disciplinary actions and financial penalties.
- A list or table of all major construction operations occurring within the work zone, including dates and locations of each operation.
- Documentation of safety and/or security competency training programs, either online or in person, for field personnel, including type of training provided and how they specifically target health and safety. Training may include task-specific safety training or general awareness training.
- Documentation of minimum training requirements for health and safety programs, such as occupational safety and health, first aid, cardio-pulmonary resuscitation, emergency response, and active shooter training.
- A description of the sequence for each operation.
- A list or table that identifies all potential hazards associated with each step in the sequence of each operation.
- A list of preventive actions for each potential hazard.
- A list of any individuals or parties responsible for implementing preventive actions.
- Include documentation showing contractors developed program requirements to ensure subcontractors maintain a high level of safety per the contract.
- Include documentation showing Owners and contractors have an incident review process that involves all levels of management to validate corrective measures to minimize future injuries and incidents on the job site.
- Documentation that contractors develop “lessons learned” reports that allow other contractors and projects the opportunity to review the fact-finding of an incident and implement processes and procedures to minimize similar incidents on the job site.
- A description of miscellaneous or additional hazards that may be present within or adjacent to the work zone and an appropriate means of abatement or prevention. Pandemic mitigation must be included.

Record any changes to the PSP throughout the construction process with an explanatory narrative describing circumstances, if necessary. Compile the above documentation into an organized format and provide to the design S+R Administrator and MBTA PM for record as a part of closeout phase documentation.

Refer to *Envision Sustainable Infrastructure Framework (v3)*, *QL1.2 Enhance Public Health and Safety, QL1.3 Improve Construction Safety, QL1.6 Minimize Construction Impacts;* and LEED BD+C v4/4.1 Pilot Credits, *Prevention through Design* (USGBC 2020d).

A.1.1.6.4 Construction and Demolition Waste Management and Disposal

All projects must develop and implement a Construction and Demolition Waste Management Plan (CDWMP). The design team must include requirements within contract documents that require the

contractor to submit documentation based the Envision and 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 (ADC), 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 Envision and LEED credit references for required documentation and suggested implementation strategies.

All projects must pursue an overall diversion rate of at least 75 percent, striving for 85 percent 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 percent; 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 *Envision Sustainable Infrastructure Framework (v3)*, *RA1.4 Reduce Construction Waste;* and 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.1.1.6.5 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 IAQ Management Plan:

- Identify the key players and someone responsible for implementing the IAQ Management Plan, 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 IAQ Management Plan requirements in contract agreements with subcontractors.
- As subcontractors are selected and deployed on site, 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 IAQ progress check-ins as a regular item in weekly subcontractor meetings and safety meetings.
- Provide a copy of the plan on site, 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 IAQ Management Plan 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 stand-alone 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 IAQ 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.1.1.6.6 Indoor Air Quality Assurance

In addition to the requirements above, 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. Since there is a point difference for the LEED credit related to this requirement, 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 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 IAQ Management Plan 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 IAQ Management Plan 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 IAQ Plan 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.1.1.6.7 Temporary Construction Facilities and Controls

Construction projects for the MBTA must reduce and prevent disturbances to surrounding environments and communities due to construction activities. Such efforts must address noise, vibration, light, glare, safety/wayfinding, access/mobility, and construction vehicle emissions. All projects impact their surrounding environments; however, infrastructure projects are often long-term projects that may take years to complete construction. During this time, it is important for the project to have minimal negative impacts on the immediate and surrounding community.

The contractor must therefore establish, implement, and maintain a formal Construction Impact Mitigation Plan (CIMP) during construction for the prime contractor. The CIMP must be drafted prior to start of construction for discussion, in place at the beginning of construction activities, and cover all project activities, including anticipated subcontractor work. The CIMP acts as continuance of the project impact reporting established during the design phase in the Environmental reports, especially those in the Environmental Notification Form (ENF) and Categorical Exclusion (CE) documents.

The CIMP must address, at a minimum, the following construction impacts together as one plan or as separate plans as appropriate: noise, vibration, light, glare, safety/wayfinding, access/mobility, construction vehicle emissions, and other activities anticipated to create nuisance or disturbance to surrounding communities. These measures may overlap with other environmental project requirements, though it is unlikely to interfere; in the event of a conflict, environmental or other requirements take precedent.

For each type of impact, the CIMP must accomplish the following:

- Identify the responsible party for mitigation activities, their contact information, their responsibilities, and their qualifications. Include information if any portions of the CIMP were prepared by an outside party.
- Identify the location and distance to the closest receptors for noise, vibration, light, glare, and air pollution.
- Describe the surrounding land use information (for example, active missions, security zones, access to buildings, and sensitive habitat).
- Address safety and wayfinding for pedestrians and vehicles during construction activities.
- List proposed construction activities (for example, demolition, excavation, paving, mass concrete pours, notable truck hauling operations, foundations, and finishing).
- Identify dates and working hours of proposed construction activities.
- List noise-, vibration-, light-, glare- or other nuisance-generating devices used during construction.
- List mitigating devices and reduction strategies used during each construction activity, including:
  - For noise and vibration, specifically, specifications for minimizing construction noise and vibration should meet or exceed accepted local practices.
  - PPE requirements for all site employees.
  - A site plan or map showing the locations of any approved limits of disturbance and installed controls (include mitigating devices or strategies for construction phase activities only).
  - Signage details and locations communicating construction vehicle idling limits. Vehicle idling is prohibited; exceptions may be granted for specialty vehicles or circumstances by the MBTA PM.
- Identify procedures for inspection and maintenance of preventive measures and site controls.

- Include permit numbers and agency or local authority policies associated with construction work, as applicable.
- Describe monitoring standards, methods, and acceptable levels.
- Describe corrective procedures for non-compliance. Document feedback mechanisms in place for receiving and responding to public and stakeholder concerns during construction. The construction contractor is expected to work with affected neighbors to develop construction plans as well as monitoring and corrective action programs.
- Resilience contingency plans to prepare for, and recover from severe weather disruptions, pandemic, etc.
- Outline expected staff training needs.

The initial CIMP must be provided to the S+R Administrator for review and inclusion in the larger SRMP. Include the signature of the responsible party or parties.

During construction, the contractor must record any modifications to the CIMP and provide supporting evidence of the monitoring activities that occur throughout construction. The contractor must maintain changes to the CIMP in the document so the reader can see how the CIMP has evolved throughout the project. As part of closeout phase documentation, the contractor must submit a final CIMP to the S+R Administrator to update the SRMP, and MBTA PM for record.

Refer to *Envision Sustainable Infrastructure Framework (v3)*, *QL1.6 Minimize Construction Impacts*.

A.1.1.6.8 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 (USEPA) 2017 General Permit for Discharges from Construction Activities (CGP), as modified in 2019. The CGP outlines the provisions necessary to comply with the USEPA National Pollutant Discharge Elimination System program, which is administered by USEPA in Massachusetts.

The design team must create and implement a Stormwater Pollution Prevention Plan (SWPPP) that includes an Erosion and Sediment Control Plan (ESCP) for all construction activities associated with the project. Best management practices (BMPs) 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 USEPA 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 USEPA CGP and related documents are at: https://www.epa.gov/npdes/epas-2017-construction-general-permit-cgp-and-related-documents

The USEPA SWPPP template and guidance are at: https://www.epa.gov/npdes/construction-general-permit-resources-tools-and-templates#swppp

The ESCP must graphically show on site plans the limits of disturbance, BMP locations, BMP details, phasing, topography and drainage patterns prior to and after site grading, stormwater conveyances, and permanent stormwater management practices. During construction, the following documentation must be provided to support the SWPPP:

- Videos, photos, and inspection logs that document any issues that arise, as well as documentation showing their corrective actions; include information regarding the timeframe of corrections.

- Completed and signed SWPPP inspection forms. In accordance with the SWPPP, inspections and corrective actions are to be documented at least once per week and within 24 hours of the end of a storm event that is 0.25 inch or greater.

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 maintain changes to the SWPPP / ESCP in the document so the reader can see how the SWPPP / ESCP has evolved throughout the project. The contractor must submit a final SWPPP / ESCP to the S+R Administrator to update the SRMP, and MBTA PM for record.

Refer *to Envision Sustainable Infrastructure Framework (v3)*, *NW2.2 Manage Stormwater, NW2.4 Protect Surface and Groundwater;* and LEED v4/v4.1 SS Prerequisite *Construction Activity Pollution Prevention*.

A.1.1.6.9 Post-design Commissioning

It is not enough to have each subsystem checked by its responsible contractor. Commissioning 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 understand what systems are installed and how they function. 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.

<u>Construction Phase</u>

- 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 commissioning 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 commissioning process should verify that all assets are fully integrated into the EAMS/CMMS and BMS. 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.

- 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 building automation system configuration for all systems and equipment being commissioned.
- Equipment Start-up: Is the first chance to observe the equipment in its operating condition and is an essential part of the Cx process.
- Testing, Adjusting, and Balancing (TAB) Review: TAB is a critical element of the project delivery process. The 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.

<u>Testing and Training</u>

- Attend Planning Meetings: The Cx team schedules, organizes, leads, and supervises the functional performance testing, 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.
- Functional Performance Testing: 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:
    - 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
    1. Security
    2. Mass notification
    3. Distributed antennae
    4. 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 (CIRs) 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 close-out 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 excellence 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 standard operating procedures, 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 close-out 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
- 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 [kW/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 above elements 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

This section provides detailed content expanding on the topics presented in Section 2.4.2.

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 below to determine if additional criteria exist and applies.

Table A-1. Local and Regional Sustainability and Resilience Initiatives

Document	Description
Statewide Climate Resilience Design Standards and Guidelines for the Resilient Massachusetts Action Team (2020)[a]	Recommended design standards and guidelines on how to use them to incorporate climate resilience into projects with physical assets. MBTA is part of the Resilient Massachusetts Action Team (RMAT) and a key stakeholder in this resource.
Boston Planning and Development Agency's Coastal Flood Resilience Design Guidelines (2019)	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 project outside of Boston located in coastal areas. Provides in depth technical considerations for buildings.
Medford Climate Vulnerability Assessment (2019)	Designers may look at the plan to preliminary view areas that are modelled 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.
Statewide Hazard Mitigation and Climate Adaptation Plan (SHMCAP) (2018)	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.
BPWD Climate Resilient Design Guidelines for Public Rights of Way (2018)	Guidelines for designing flood protection within the City of Boston and for impacts to the public right of way

Table A-1. Local and Regional Sustainability and Resilience Initiatives

Document	Description
Boston Planning & Development Agency Climate Change Checklist (2017)	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 (on-going)[a]	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 application.
Cambridge Climate Plans and Reports Climate Change Vulnerability Assessment Part 1 (2015) Part 2 (20117) Climate Change Preparedness and Resilience Plan (coming 2020)	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
State-wide Resilience Master Plan (SRMP) for the MA Division of Capital Assets Management and Maintenance (DCAMM) (2016)	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.
MA Global Warming Solutions Act (2008)[b]	This Act required the MassDEP to establish mandatory greenhouse gas (GHG) 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.
Metropolitan Boston Climate Preparedness Commitment (2016)[c]	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.
Carbon Free Boston[d]	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[e]	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[f]	A plan to protect Boston's neighbourhoods from sea level rise and flooding due to climate change. The plan includes strategies for adapted infrastructure, protecting waterfront parks and utilizing elevated harborwalks.
Cambridge 2020 Climate Action Plan[g]	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.

Table A-1. Local and Regional Sustainability and Resilience Initiatives

Document	Description
Cambridge Net Zero Action Plan[h]	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[i]	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[j]	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.

Notes:

[a] Mass.gov. 2020. *Climate Resilience Design Standards and Guidelines Project*. https://www.mass.gov/info-details/resilient-ma-action-team-rmat

[a] Greenovate Boston. 2020. *Prepared City*. https://www.greenovateboston.org/prepared_city/

[b] Mass.gov. 2020. *Global Warming Solutions Act Background.* https://www.mass.gov/service-details/global-warming-solutions-act-background

[c] Metropolitan Area Planning Council. 2020. *Metro Mayors Climate Preparedness Taskforce*. https://www.mapc.org/our-work/expertise/climate/mmc/

[d] Boston.gov. 2020. *Reducing Emissions*. https://www.boston.gov/environment-and-energy/reducing-emissions

[e] Boston.gov. 2020. *Zero Waste Boston*. https://www.boston.gov/environment-and-energy/zero-waste-boston

[f] Boston.gov. 2020. *Resilient Boston Harbor*. https://www.boston.gov/environment-and-energy/resilient-boston-harbor

[g] Cambridgema.gov. 2020. *Climate Change Planning.* https://www.cambridgema.gov/CDD/climateandenergy/climatechangeplanning

[h] Cambridgema.gov. 2020. *Net Zero Action Plan.* https://www.cambridgema.gov/CDD/Projects/Climate/netzerotaskforce

i Sommervillema.gov. 2020. *Somerville's Community Climate Change Plan.* https://www.somervillema.gov/departments/programs/somerville-climate-forward

[j] Somervision2040.com. 2018. SomerVision 2040. https://www.somervision2040.com/

[k] Metropolitan Area Planning Council. 2020. *Promoting Smart Growth & Regional Planning.* https://www.mapc.org/resource-library/medford-local-energy-action-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 & Resilience Plans and Policies

The MBTA is committed to minimizing their impact on the environment and has taken steps to reduce their greenhouse gas (GHG) emissions, energy use, and water consumption. The reports and directives below have been published by the MBTA or their memberships and focus on sustainability:

- APTA Sustainability Commitment & Guidelines (APTA 2016)
- Storm Water Pollution Prevention Plan (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)
- 2017 Engineering and Architectural Design Guidelines (The VHB/HNTB Team 2017)
- 2018 Transit Asset Management Plan (MBTA 2018)
- 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)
- 2021 Drainage Directive (placeholder for upcoming directive)

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 continues their commitment to addressing environmental concerns so that they can minimize their impact to the environment, as well as its vulnerabilities in the face of climate change related events as they occur.

To date, the MBTA has made significant progress addressing how their facilities and operations mitigate and adapt to climate change, including efforts to reduce their GHG emissions and water consumption, investments in coastal erosion control and flood protection systems, prioritizing energy efficiency strategies, and centralizing utility data. In the future the MBTA aims to continue to assess facility vulnerabilities to current and future climate trends in alignment with other metropolitan organizations, 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.

The MBTA is advancing resilience through policies, plans, and projects. Designers should coordinate with the Energy and Environment Department for updates on current policies and plans. A preliminary list is included in Table A-2 below.

Table A-2. MBTA Resilience Initiatives

Document	Description
MBTA Flood Resiliency Design Directive (2019)	Directive to minimize risk of MBTA assets to flooding, maximize resiliency, minimize downtime and prevent disruptions, protect the safety of the system users, works, and environment
Massachusetts Coast Flood Risk Model (MC-FRM) (2020) (**MassDOT**)	Current and future flood model that considers sea level rise and storm surge extents. Outputs include probability maps (annual exceedance probabilities), flood depths, tidal benchmarks, still water surface elevations, wave heights, water velocities, and wind speeds. Developed by MassDOT.
MBTA Fiscal Management Control Board Strategic Plan Update (2017)	Prioritizes environmental stewardship and climate resiliency Key principles: - Cost-effective climate change adaptation planning, implementation and reporting - Embed resiliency into capital programs - Develop and use climate risk vulnerability assessments to identify critical locations

Table A-2. MBTA Resilience Initiatives

Document	Description
Focus40	Goals: Cultural change to incorporate resiliency into all activities. Plan ahead, rather than reacting to acute events (e.g., minimize reliance on sandbags during flooding)
Design and Construction Projects	Required to assess climate/weather-related vulnerabilities; evaluation of resiliency options Ex. Systemwide climate vulnerability assessment of the MBTA Orange Line
Capital Improvement Plans	Requests need to indicate if the project will improve resilience and factors into prioritization

A.1.2.1.1 "Leading By Example"

The Massachusetts Department of Energy Resources (MassDOER) runs the Leading By Example (LBE) Program, which "facilitates and promotes state government clean energy and sustainability initiatives" 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.

LBE Tracking

Under the current version of EO 484, all state construction must meet the Massachusetts LEED Plus Standard, which requires 20% better energy performance than the state building energy code (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 track progress by the required participating entities, including the MBTA. To assist in this effort, the electrical and mechanical engineers must report on the following related aspects and provide the data to the MBTA, utilizing the LBE Tracking Form as the mechanism for reporting:

- 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 Division of Capital Asset Management and Maintenance (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 (https://www.mass.gov/service-details/leading-by-example-renewable-energy-initiatives), 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 on-site generation at buildings. Provide all consumption information for all non-electric building energy use, including natural gas, oil, propane, etc.
- Information about EV charging stations as outlined in the form.

Additionally, the following team members must also populate the LBE Tracking Form as appropriate for project aspects as listed below:

- Architect and/or project manager 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 PV canopies, as applicable. Project design requirements related to energy metering and analytics are provided in Section 3.5.2.5.

The S+R Admin must facilitate team compliance with the above requirements and assist the team in collecting the required information.

A.1.2.1.2 Resilient Massachusetts Action Team and MBTA

The MBTA is also a member of the Statewide Resilient Massachusetts Action Team (RMAT), which is an inter-agency team led by the Executive Office of Energy and Environmental Affairs (EEA) and the Massachusetts Emergency Management Agency (MEMA). The RMAT has established Statewide Climate Resilience Design Standards & Guidelines, which are expected to be publicly released and accessible through a web-based tool (the "Tool") in early 2021. 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 on-going 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 & municipalities.

The RMAT Tool will provide users with a Climate Risk Screening output and recommended Climate Resilience Design Standards output, based on calculated analysis of user inputs and GIS-based spatial queries. These outputs are organized on the project and asset level, by the following climate parameters: sea level rise & storm surge, extreme precipitation (urban and riverine), and extreme heat. The Climate Risk Screening output will include preliminary project exposure ratings, asset risk ratings, and an overall project Ecosystem Services Benefits (ESB) Score. The Climate Resilience Design Standards Output will include a recommended planning horizon, return period (or percentile), design criteria, and tiered methodology (based on level of effort) for calculating design criteria values. The Tool does not provide numerical values for design, only consistent methodologies to calculate design criteria values, unique to the project and its physical assets and the recommended level of effort associated with calculating design criteria. The outputs from the RMAT Tool provide the means to calculate the primary thresholds included as Resilience Performance Requirements and Goals.

The RMAT has developed Climate Resilience Design Guidelines that are intended to be overarching climate resilience principles that are not specific to project/asset type or climate hazards. These Guidelines are illustrated through specific best practices, which may include case studies and/or existing published resources that exemplify the Guidelines. Forms are provided to guide users through the Guidelines' considerations and document design and decision making throughout the process. These forms prompt design consideration of site suitability, regional coordination, and flexible adaption pathways, in the context of the Tool output and unique project conditions.

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 project homepage for more detailed information regarding the Statewide RMAT Climate Resilience Design Standards & Guidelines.

A.1.3 General Sustainability Requirements

The content below is a continuation of topics referenced in Section 2.4.3.

A.1.3.1 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 at https://www.usgbc.org/innovationcatalog?Version=%22v4%22&Rating+System=%22New+Construction%22.

- Community Outreach and Involvement
- Walkable Project Site
- Parksmart Measures
- Solar Access to Green Space
- Offsite Rainwater Management
- Offsite Financial Support for Habitat Protection

A.1.3.2 Towards Net Zero Carbon

Much of the design and construction industry is focusing on carbon emissions associated with both facility operational carbon (that is, energy use) as well as the embodied carbon associated with product extraction, manufacturing, transport, install, and end-of-life. MBTA projects also acknowledge their contribution to carbon emissions and take actions to raise awareness while lowering generation though evaluation of the embodied carbon oftheir facilities; as part of this effort, the project teams will document efforts towards 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.1.3.2.1 Carbon Reduction Plan

Develop a Carbon Reduction Plan (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. The project will use the ILFI Zero Carbon Certification guidance as a model of how to implement appropriate strategies. 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 electric busses, 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. 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 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 Energy Use Intensity (EUI).
  - Provide confirmation that operational design strategies reduce emissions 25 percent 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 percent 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 kg -$CO2_e$ / m^2.
- 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 roof-top 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 requirements below 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 ASCE7 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. Roof top 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 percent clean energy to operate its facilities and transit systems.

A.1.3.2.2 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 aspects below:

- 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.
- Envelope Airtightness: Meet or exceed envelope airtightness criteria as identified in PHIUS+ for project scale and construction. Verify envelope airtightness through post-construction / pre-occupancy whole-building blower-door airtightness test. Ensure air barrier continuity across the entire building envelope.
- 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.

ASHRAE / IECC / DOE North American Climate Zone	Overall installed window U-value Btu/h.ft^2.F	Center-of-glass U-value Btu / h.ft^2.F	SHGC - South	SHGC - North, East, West
5	≤ 0.14	≤ 0.13	≤ 0.50	Any

1PHIUS+ Window Standard. Refer to website link for all climate zones. https://www.phius.org/phius-certification-for-buildings-products/phius-verified-window-performance-data-program/performance-criteria-by-climate-zone

- Energy Recovery / Ventilation: Ventilation is required to provide fresh air for building occupants and to remove indoor pollutants in accordance with ASHRAE Standard 62.1. The ventilation air requirements should be provided by a Dedicated Outside Air System (DOAS). With a DOAS the sensible space heating and cooling is decoupled from the ventilation requirements, and outstanding indoor air quality can be achieved at significantly lower energy consumption rates. The use of energy recovery in the DOAS must be evaluated as an additional energy efficiency measure.
- 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 / pre-occupancy 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 (https://wufi.de/en/). WUFI stands for “heat and moisture transiency” in German (Wärme Und Feuchte Instationär).
- 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 system and component 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.1.3.2.3 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 (http://app.climatepositivedesign.com/) provides data on carbon intensity of materials and carbon sequestration capacity by vegetation. This tool enables project teams to track 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 (https://living-future.org/zero-carbon-certification/#resources)
- Boston Society of Architects resource page for Embodied Carbon in Buildings (https://www.architects.org/embodied-carbon-in-buildings-conference-program/conference-resources),.

Plans addressing the carbon exploration and any potential change must be included in the Carbon Reduction Plan (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 Material and Product Plan (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 include the following:

- Athena Impact Estimator. Whole Building LCA tool. (https://calculatelca.com/software/impact-estimator/download-impact-estimator/
- One Click LCA: Web-based Whole Building LCA tool. https://www.oneclicklca.com/
- Tally. Revit-based Whole-Building LCA tool. https://choosetally.com/
- eTool. Web-based Whole Building LCA tool. (https://etoolglobal.com/about-etoollcd/)
- Embodied Carbon in Construction Calculator (EC3) tool: A tool for carbon evaluation of product specific EPDs https://carbonleadershipforum.org/what-we-do/initiatives/ec3/

Reference: ILFI Zero Carbon Certification, p.11. Passive House (PHIUS+) Certification

Refer to *Envision Sustainable Infrastructure Framework (v3)*, *CR1.1. Reduce Net Embodied Carbon; LEED BD+C v4/4.1: MR Pilot Credit 132 Procurement of Low Carbon Construction Materials* (USGBC 2020e).

A.1.3.3 Energy Efficiency Performance

The content below is a continuation of topics referenced in Section 2.4.3.3.

A.1.3.3.1 Demand Response

In addition to energy efficiency at the individual project level, each project must participate 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 building automation system 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.1.3.3.2 Life-Cycle Cost Analysis

Independent of a life-cycle assessment (as described above), a *life-cycle cost analysis* (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 American Society of Heating, Refrigerating and Air Conditioning Engineers (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 (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 with regard to 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 Sustainability and Resilience Administrator for inclusion in the SRMP (described below) 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 *Envision Sustainable Infrastructure Framework (v3), LD3.3 Conduct a Life-Cycle Economic Evaluation; RA2. Reduce Operational Energy Consumption;* and LEED BD+C v4/4.1: EA Prerequisite, *Fundamental Commissioning and Verification, and EA Credit: Enhanced Commissioning; EA Credit: Optimize Energy Performance.*

A.1.3.3.3 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 percent or more of the total annual consumption of the building.

Additional metering requirements are identified in the Electrical and Plumbing sections of the main document.

Refer to *Envision Sustainable Infrastructure Framework (v3), RA2.1 Reduce Operational Energy Consumption; RA2.3 Use Renewable Energy; RA2.4 Commission and Monitor Energy Systems; CR1.3 Reduce Greenhouse Gas Emissions;* LEED BD+C v4/4.1: EA Credit, *Optimize Energy Performance; EA Prerequisite: Building-Level Energy Metering and Credit: Advanced Energy Metering*.

A.1.3.3.4 Energy Simulation and Energy Conservation Report

For all energy-consuming projects, design teams must provide an Energy Conservation Report that summarizes the building / project anticipated energy consumption and describes the energy conservation measures (ECMs) considered for the project. 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.

Additionally, in alignment with the Massachusetts Global Warming Solutions Act (GWSA), the design team must complete a Greenhouse Gas Reporting Applicability Screening Tool (GHGAT) spreadsheet to determine if the facility will be required to report GHG emissions once operational (MassDEP 2020).

The design team must provide the Energy Conservation Report and the populated GHGAT spreadsheet to the S+R Admin for inclusion in the SRMP and to the MBTA PM for record.

Refer to *Envision Sustainable Infrastructure Framework (v3), RA2. Reduce Operational Energy Consumption;* LEED BD+C v4/4.1: EA Credit, *Optimize Energy Performance*.

A.1.3.4 Water Performance

Water Performance Plan (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.1.3.4.1 Indoor Water Quality

Meet the following water quality parameters to the greatest extent possible for all water systems intended for human use.

Sediment & Microorganisms

Sediment filters should be installed to reduce the turbidity of water by removing suspended solids. Once the water is of low turbidity, UV disinfection systems are effective at destroying coliforms and other microbes. Water delivered to the project for human consumption, handwashing, and showers/baths must meet the following thresholds:

- Turbidity less than or equal to 1.0 NTU.
- Contains 0 CFU/ 100 mL total coliforms (including E. coli)

Dissolved Metals, Organic Pollutants, Disinfectants, Herbicide/Pesticide, Fertilizer & Additives

Activated carbon filters and reverse osmosis (RO) systems should be installed to remove the building's harmful waterborne contaminants that conventional systems may not remove. Thresholds for water delivered to the project for human consumption, handwashing, and showers/baths must meet the following thresholds:

- Dissolved Metals
  - Lead less than 0.01 mg/L
  - Arsenic less than 0.01 mg/L
  - Antimony less than 0.006 mg/L
  - Mercury less than 0.002 mg/L.
  - Nickel less than 0.07 mg/L.
  - Copper less than 1.0 mg/L.

  - Cadmium less than 0.005 mg/L.
  - Chromium (total) less than 0.1 mg/L.
- Organic Pollutants
  - Styrene less than 0.02 mg/L
  - Benzene less than 0.005 mg/L
  - Ethylbenzene less than 0.3 mg/L.
  - Vinyl chloride less than 0.002 mg/L.
  - Toluene less than 0.7 mg/L.
  - Xylenes (total: m, p and o) less than 0.5 mg/L.
  - Tetrachloroethylene less than 0.005 mg/L.
- Disinfectant Byproducts
  - Total trihalomethanes (sum of dibromochloromethane, bromodichloromethane, chloroform and bromoform) less than 0.08 mg/L.
  - Total haloacetic acids (sum of chloroacetic, dichloroacetic, trichloroacetic, bromoacetic and dibromoacetic acids) less than 0.06 mg/L.
- Herbicide and Pesticide
  - Atrazine less than 0.003 mg/L.
  - Simazine less than 0.002 mg/L.
  - 2,4-Dichlorophenoxyacetic acid less than 0.07 mg/L.
- Fertilizer Thresholds
  - Nitrate less than 50 mg/L (11 mg/L as nitrogen).
- Public Water Additive
  - Fluoride less than 4 mg/L.
  - Total chlorine less than 4 mg/L.
  - Chloramine less than 4 mg/L.

Drinking Water Taste Properties

Nuisance chemicals should be eliminated from water through reverse osmosis systems to make it more appealing and palatable drinking water. Water delivered to the project for human consumption should meet the following thresholds:

- Aluminum less than or equal to 0.2 mg/L.
- Chloride less than 250 mg/L.
- Fluoride less than 2 mg/L.
- Manganese less than 0.05 mg/L.
- Sodium less than 270 mg/L.
- Sulfate less than 250 mg/L.

- Iron less than 0.3 mg/L.
- Zinc less than 5 mg/L.
- Total Dissolved Solids less than 500 mg/L.

Drinking Water Quality

Water should be regularly monitored to ensure the necessary sediment filters, UV disinfection systems, and reverse osmosis are successfully eliminating contaminants. Most recent water quality testing results should be displayed near sources of drinking water.

All water from drinking water dispensers must be treated within the building with the following:

- A filter designed to remove suspended solids tested with standard NSF 42 or EN 13443-2.
- A UV disinfection system rated by NSF/ANSI Standard 55 (Class A or B) or a device rated by NSF/ANSI Standard 53 or 58 for cyst removal or reduction.
- A device rated by NSF/ANSI Standard 53 or 58 for copper or lead reduction.

A.1.3.5 Commissioning Activities (Design Phase)

Commissioning is often discussed in the context of the construction phase of a project; there are many crucial aspects of commissioning, 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 commissioning authority (CxA) contributes to the project's overall integrative process and ensures that the architects' and engineers' designs meet the owner's project requirements. Each project must engage a third-party CxA (independent of the design and construction teams) by or before the 30 percent 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:

- Develop the Owner's Project Requirements (OPR): Include the overall goals of the project; quality standards; operational and warranty requirements; training expectations (Basis of Design, equipment level, and system level); cost considerations; and measurable performance criteria.
- Develop the Basis of Design (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 Commissioning (Cx) Specification: Define the administrative requirements of the Commissioning 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 commissioning must be included in the project specification.
- Develop the Cx Plan: Describe responsibilities of the commissioning 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 Measurement and Verification 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.1.3.6 Health and Safety Procedures

A.1.3.6.1 Project Safety Plan

As introduced in Section 2.4.3.6, the design team must include the aspects listed below in the project's PSP.

Design Team

Beginning in pre-design and continuing throughout the design phases, the PSP must identify and use opportunities to achieve safety and health synergies across disciplines and across two key building life-cycle stages described below. The design team should use the analyses to inform the OPR, BOD, design documents, and construction documents.

Perform safety design reviews before the completion of schematic design to explore how the completed building will be operated and maintained over its expected lifetime. Use a life-cycle safety approach to explore how to reduce hazards and improve efficiency and well-being for building O&M personnel. Assess each of the following systems where applicable:

- Roof Systems. Assess how personnel will access the roof for operations, inspection, and maintenance; the distance of equipment and feature locations (including some types of cool roofs, and other installations) to roof edge; equipment installation and replacement access (including point loading); and the need for installation of fall protection measures.
- Equipment Rooms and Systems. Assess how personnel will access equipment and controls needing servicing; any work at height or in confined spaces; need for sufficient clearances to electrical or other equipment; equipment installation and replacement access; chemical storage needs; and fall protection, eye wash, or other safety feature needs.
- Building Exterior Enclosure and Daylighting Systems. Assess how personnel will clean exterior (e.g. cladding including windows and exterior shading devices) and interior atria features.
- Storage and Collection of Recyclables. Assess the need for O&M workers to manually handle recyclables. Assess measures needed for handling of hazardous waste streams that could contain batteries, sharp edges, mercury-containing lamps, or similar items.
- Special Features. If applicable, assess rainwater management cisterns, energy recovery wheels, or other specialty systems for confined space hazards. Assess access, confined space, and fall exposures for underfloor air distribution systems.

Document in narrative form how the reviews led to incorporating at least one protective measure for each system into design and building feature decisions in the project's OPR and BOD, including the following, as applicable:

- Building roof designs (for example, use of parapets, guard rails, setbacks, fall protection)
- Equipment room and recyclable storage area design and layout
- Exterior enclosure, daylighting, and special feature designs

- Safe O&M plans for submittal to Owner, including recommendations where applicable for use of personal protective equipment (PPE) such as foot, head, eye and face, ear, respiratory, and fall protection

Have a construction safety specialist perform safety constructability reviews before the completion of schematic design to explore and plan how safety and efficiency can be optimized during construction. If feasible, engage a general contractor and key trade contractors and suppliers improves planning and allows consideration of options such as prefabrication and modularization that can improve construction employee safety, construction efficiency, and downstream maintenance efficiency and safety. Assess the following topic areas where applicable:

- Site Conditions. Assess site hazards such as presence of overhead power lines or brownfield-related soil exposures relevant to foundation work.
- Building Reuse. Assess potential hazards arising out of reuse, ranging from structural safety and deconstruction safety to the presence of hazardous materials such as lead, asbestos, or mold.
- Construction Activity Pollution Prevention. Assess how the Pollution Prevention Plan can be used to further reduce exposures to construction employees. For example, use local exhaust ventilated tools and/or wet method controls on all outdoor dust-generating tools and equipment to reduce exposures from silica, welding, and other construction contaminants at the source.
- Construction Indoor Air Quality Management. Assess how the Indoor Air Quality Management Plan can be used to further reduce exposures to construction employees. For example, use local exhaust ventilated tools and/or wet method controls on all indoor dust-generating tools and equipment to reduce exposures from silica, welding, and other construction contaminants at the source.
- Waste Recycling Management. Assess construction worker handling of construction wastes, and incorporate measures (for example, the use of motorized equipment) to minimize potential for manual handling injuries into waste management plans.
- Materials and Resources. Assess the utility of low-emitting materials, material ingredient reporting, chemical of concern avoidance, and source reduction approaches to further reduce construction worker exposures.
- Working at Heights. Assess and minimize the need for working at heights. Where appropriate, use permanent fall prevention features developed during O&M safety design review. Plan for general contractors to employ 100 percent fall protection during the construction phase.
- Special Features. If applicable, assess construction safety and sequence issues (for example, fall hazards, and confined space hazards) related to cool roofs, installation of solar panels, rainwater management cisterns, energy recovery wheels, underfloor air distribution systems, or other special features.
- Document how the above reviews led to incorporating at least one protective measure strategy for each of the applicable topic areas above into the project's design and construction documents, such as those listed below:
  - Construction plan describing key construction stages
  - Building and temporary structure designs
  - Construction PSP describing safety expectations, roles, procedures, and goals, including recommendations, where applicable, for use of PPE, such as foot, head, eye, ear, respiratory, and fall protection

- Construction Activity Pollution Prevention Plan (SWPPP, ESCP)
- Construction Indoor Air Quality Management Plan (describe additional worker safety measures)
- Construction and Demolition Waste Management Plan (describe additional worker safety measures)

Compile the above documentation into an organized format and provide to the MBTA PM for record. Refer to Attachment 3, Project Safety Plan (PSP) Life Cycle Safety and Health Worksheet, for an example documentation template. Provide an electronic, editable copy to the construction team for perpetuation of development and implementation. Design and construction team members must contribute to the documentation; the S+R Admin is responsible for guiding the process.

Refer to LEED v4/4.1 Pilot Credit, *Prevention Through Design* (USGBC 2020d).

A.1.3.7 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 Material and Product Plan (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 below.

A.1.3.7.1 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.1.3.7.2 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 below. 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 percent (by cost) of all materials and products in the Divisions identified above 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 FTA 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 at least one of the above
  - 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 (NSC) 373 Standard by quarries and / or manufacturers, per Living Building Challenge v4 – p 53. https://naturalstonecouncil.org/sustainability

A.1.3.7.3 Red List Compliant Materials

The project team must specify materials that meet the Red List components of the Living Building Challenge's Imperative 13 Red List Compliant: Projects must avoid chemical components identified in from the Living Building Challenge's Red List in at least 70 percent of the project's new materials by cost.

https://living-future.org/declare/declare-about/red-list/

A.1.3.7.4 Reduce VOC (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.1.3.7.5 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 percent (by cost) of the following building products and material types contain less than 100 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 percent (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 1000 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 1000 ppm.
- Mercury (Hg): less than 1000 ppm.
- Cadmium (Cd): less than 100 ppm.
- Hexavalent Chromium: (Cr VI) less than 1000 ppm.

A.1.3.7.6 Embodied Carbon Materials

MPP must also identify materials cross-referenced with the materials portion of the Carbon Reduction Plan (CRP).

A.1.3.7.7 MPP 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.1.3.8 Indoor Environmental Quality Performance

A.1.3.8.1 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. $PM_{2.5}$ or PM_{10} (accuracy 5 µg/m³ + 15 percent of reading at values between 0 and 50 µg/m³).
    b. Carbon dioxide (accuracy 50 ppm + 3% of reading at values between 400 and 2000 ppm).
    c. Carbon monoxide (accuracy 1 ppm at values between 0 and 10 ppm). 4. Ozone (accuracy 10 ppb at values between 0 and 100 ppb).
    d. Ozone (accuracy 10 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 percent of reading at values between 150 and 2000 µg/m³).
    g. Formaldehyde (accuracy 20 ppb at values between 0 and 100 ppb). b.
2. Monitor density is minimum one per floor or one every 3,500 ft, whichever is more stringent. Monitors are sited at locations compliant with the following requirements:
    a. Between 3.6 to 5.6 ft above the finished floor at locations where occupants would typically be seated or standing.
    b. Sampling points must be at least 3.3 ft 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.

<u>Environmental Measures Display</u>

Real-time display of air pollutants measured by air quality monitors mentioned above 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 ft per 10,000 ft^2 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 ft^2 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 above. A 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.1.3.8.2 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.1.3.9 Interior and Exterior Quality of Life

A.1.3.9.1 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 (http://universaldesign.ie/Built-Environment/Building-for-Everyone/)

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 ADA 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 percent 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, performances, spectator sport 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 required above 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.2 SAMPLE RESILIENCE FORMS

The resilience forms below 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 2.4.4. These forms should be used to supplement the forms provided in the Resilient Massachusetts Action Team (RMAT) Statewide Climate Resilience Design Standards and Guidelines (Resilient MA 2020).

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 off-site assets that may have interdependencies with this facility; for example, off-site power transformers that supply the site with power or mobile generators at other facilities that this site may rely on*.
2. **Design & 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.2.1 Critical Asset List Form

Complete this table for each critical asset. Add additional rows as necessary. Refer to notes and definitions section below the table 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 and definitions:

- **Critical Asset** – Name of on-site 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 on-site 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.2.2 Design & Performance Thresholds Form

A.2.2.1 Overall Design

Complete this table 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 (www.resilientma.org).

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-hr period.	
	5 inches or less of snowfall within a 24-hr 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-hr 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-hr rainfall depth and peak intensity for a 25-year design storm.	Current	Current and future (2070 planning horizon) 24-hr 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 (CDD) and heating degree days (HDD)	Current	Events that exceed the primary threshold by cooling degree days and heating degree days up to 10 percent	
		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 percent	
		Future		
	Current and future (2070 planning horizon) days below 32°F	Current	Events that exceed the primary threshold listed above for days below 32°F by up to 10 percent	
		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 Center for Disease Control (CDC) for acceptable performance requirements under pandemic conditions, as well as different phases.	

A.2.2.2 Critical Asset Design

Please copy this form and complete for all critical assets identified in the Critical Asset List form. Refer to Section 2.4.4 of the Design Guidelines for additional information and description of terms.

Asset 1: (Identify Asset and Discipline here)

	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 the section above.			**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 (see following page for questions to support establishing acceptable downtime duration). Please refer to the design values listed in the section above.					
Resilience Disruptor	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 (hrs)	Acceptable recovery time (hrs)	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 box provided below.

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 section below offers guiding questions for reference and more space to detail downtimes, conditions, and consequences. Describe the operational activities--to prepare, respond, recovery, re-assess, and monitor--that are associated with meeting the design values and under the secondary threshold condition in the table below.

Identify key stakeholders. *This may include MBTA staff from operations and control center (OCC), bus maintenance, bus operations, security & 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 back-up equipment is available to maintain and operate critical systems if the equipment is damaged/inoperable? What is the availability and capacity of the back-up 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 back-up 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 above table.*

A.2.3 Applied Design Strategies Form

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. Refer to Section 2.4.4 of the Design Guideline for additional information.

A.2.3.1 Discipline: Structural

Asset 1: (Identify Asset and Discipline here)

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		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
Coastal Flooding			
Accelerated deterioration and possible structural damages due to ocean water or water containing chemicals, sewage, oil, debris, and/or sediment.	☐ 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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

Disruptor Consequence	Structural Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
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		
Flooding of basement facilities.	☐ Dry floodproof and reinforced walls. ☐ Install permanent flood barriers around site to prevent flooding. ☐ Other		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

A.2.3.2 Discipline: Mechanical

Asset 1: (Identify Asset and Discipline here)

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		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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.		

Disruptor Consequence	Mechanical Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
	☐ 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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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 (DOAS) 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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
Disease/Pandemic			
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.		

Disruptor Consequence	Mechanical Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
	☐ 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 UV and bipolar-ionization. ☐ Other		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

A.2.3.3 Discipline: Electrical

Asset 1: (Identify Asset and Discipline here)

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		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

Disruptor Consequence	Electrical Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

A.2.3.4 Discipline: Civil and Landscaping

Asset 1: (Identify Asset and Discipline here)

Disruptor Consequence	Civil/Landscaping Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Extreme Storms			
Accelerated deterioration of pavement design, pathways, above ground utility connections, and slopes. Damages to above ground 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). ☐ Utilize preferred design of subsurface utilities. ☐ Other		
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		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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 lev rise. ☐ Other		
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		
Site flooding from tailwater elevations exceeding design criteria.	☐ Implement backflow preventer valves and sump pumps with water level sensors. ☐ Other		

Disruptor Consequence	Civil/Landscaping Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Damages to above ground 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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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		
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		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			

Disruptor Consequence	Civil/Landscaping Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
	☐		
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		
Human health impacts.	☐ Adequate shade/shelter for workforce and site occupants. ☐ Other		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
Disease/Pandemic			
Human health impacts.	☐ Design site walkways for incorporation of sanitary stations and space for social-distancing. ☐ Other		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

A.2.3.5 Discipline: Architectural

Asset 1: (Identify Asset and Discipline here)

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		
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.		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

Disruptor Consequence	Architectural Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
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		
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		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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		

Disruptor Consequence	Architectural Design Strategies Applied	Description	Operational Capacity and/or Maintenance Needs
Increased surface temperature of impervious surfaces (urban heat island effect) with potential human health concerns.	☐ Consider reflective materials and solar facades. ☐ Other		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		
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.		
Other. Please identify other consequences, strategies, and/or operational capacities/maintenance considerations that may not be listed but are applied in design.			
	☐		

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APPENDIX B
FACILITY PROGRAM MATRIX

The following table 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.

Facility Program Matrix

Section	Room / Space Name	Minimum Area	Quantities	Notes
4.1	Maintenance			
4.1.1	Bus Maintenance Area			
	Bus Work Row (Down line/Ready line)	40-ft bus: 15' x 45' 60-ft bus: 15' x 65'	0.7-1 parking spots per maintenance bay	Industry standard: 0.3-0.5 per maintenance bay
	Maintenance Bay	40-ft bus: 20' x 60' 60-ft bus: 20' x 80'		
	Roof Access Bay	40-ft bus: 24' x 50' 60-ft bus: 24' x 75'	1 bay per 150 buses	Quantity dependent on roof equipment type and associated maintenance requirements
	Inspection Bay	40-ft bus: 25' x 60' 60-ft bus: 25' x 80'	1 bay per 100-120 buses	
4.1.2	Steam Clean Bay (Chassis Wash)			
	Steam Clean Bay (Chassis Wash)	40-ft bus: 25' x 60' 60-ft bus: 25' x 80'	1 bay per 150-200 buses	
	Chassis Wash Steam Equipment Room	80 SF		
4.1.3	Maintenance Support Shops and Spaces			
	Common Work Area and Specialized Shops	Machine Shop: 20' x 30' Brake Shop: 400-600 SF	per 100 buses	Varies depending on use and bay layout
	Tire Storage	600-800 SF		Dependent on outside service
	Battery Room and Storage	Diesel-hybrid bus: 80 SF BEB: 300-500 SF		Dependent on fleet size. BEB will have greater space needs.
	Portable Equipment Storage	80-100 SF	per bay	Dependent on equipment list. Area may be distributed as needed based on equipment.
	Secured Tool Storage	10 SF	per bay	
	Toolbox Storage	30 SF	per mechanic	
	Fluid Distribution and Waste Storage	800-1,000 SF (20' x 40')		May be larger for waste and service lane fluids

Facility Program Matrix

Section	Room / Space Name	Minimum Area	Quantities	Notes
4.1.4	Parts Storage			
	Loading Dock/Shipping/Receiving Area	1,600 SF		Can be combined with parts storage
	Parts Management Office	120-150 SF		
	Parts Storage Room	25% of maintenance area		
	Parts Room Consumable Distribution Area	80-90 SF	Minimum 2 spaces (parts room and end of maintenance bay row)	Distributed within the maintenance area
4.1.5	Bus Maintenance Support Area			
	Maintenance Management Suite Superintendent's Office	200 SF		
	Administrative Workstation(s)	80 SF		
	Conference Room	350 SF		
	Copy/Print/Supplies/Storage Room	80 SF		
	Mechanics and Forepersons Support Area Toilets, Lockers and Showers	20-30 SF	per mechanic	
	Uniform Pick Up / Drop Off	4 SF	per mechanic	
	Mechanics Break Room	50 SF	per mechanic (peak shift)	
	Foreperson's Office and Assistant Foreperson's Work Area	600-800 SF		
	Copy/Scanner, File, and Library	120 SF		
	Mechanics Kiosk Niche	15 SF	1 per bay	
	Mechanics Training Room	600-1200 SF		
	Mechanics Trainers Office	120 SF		
	Mechanics Training Storage	150 SF		
4.2	Transportation			
4.2.1	Transportation Operations Area			
	Interior Bus Storage	40-ft bus: 12' x 45' 60-ft bus: 12' x 65'	per bus	Drive aisle 75' for turning 90°; 18'-wide drive lane between every 3-4 rows
	Desk Inspector's Office	200 SF		
	Pull Out Inspector's Office	150 SF		Accommodates 4 dispatch inspectors
	Inspectors' Toilets, Lockers and Showers	20-30 SF	per inspector	
	Operators' Picking Room	200 SF		Need changes if procedure becomes computerized
	Time-Keeping Kiosk	12 SF		Integrated into operator's entrance or alcove

Facility Program Matrix

Section	Room / Space Name	Minimum Area	Quantities	Notes
	Transportation Management Suite	800 SF		
	Superintendent's Office	250 SF		Accommodates 1 superintendent and 4 guests
	Supervisor's Office(s)	175 SF		Accommodates 1 supervisor and 2 guests
	Administrative Workstation(s)	80 SF	per 2-4 staff	
	Facility Manager's Office	275 SF		Accommodates 1 staff and 2 guests
	Safety Manager's Office	150 SF		Accommodates 1 staff and 2 guests
	Guest and Privacy Room	120 SF		
	Conference Room	375 SF		
	Copy/Print/File Storage	100 SF		
	Management Break Area	250 SF		
4.2.2	Operator Support Areas			
	Operators' Day Room	110 SF	per operator	
	Operators' Toilets, Lockers and Showers	Full Locker: 15 SF Half locker: 10 SF	per operator	
	Wellness Room	200 SF	Large facilities may need more than 1	
	Operators' Training Room and Storage	Training Room: 1200-1800 SF Storage: 300-400 SF	based on operator shift numbers	Dependent on whether the facility will be a local or central training site
	Instructors' Office	120 SF		
4.3	Servicing			
4.3.1	Fueling Operation			
	Fueling Bay	60' x 30'	1 per 40-60 buses	Assume additional 3,000 SF if above ground fluid storage is needed
	Service Lubrication and Compressor Room	600-800 SF		Dependent on fleet size, fluid delivery schedule, and fluid storage and compressor location
4.3.2	Fueling Support			
	Fuelers' Work Area	300 SF		
	Fare Collection Room	120 SF		
	Fare Vault Room	120 SF		
	Fuelers' Storage	200 SF		

Facility Program Matrix

Section	Room / Space Name	Minimum Area	Quantities	Notes
4.3.3	Bus Wash Bays			
	Bus Wash Bay	28' x 75'	1 per fuel lane (2 total for up to 250 buses)	
	Bus Wash Equipment Room and Industrial Waste System Space	15' x 30'		
4.3.4	Interior Cleaning and Detailing			
	Bus Interior Cleaning and Queue Area	5% of fleet for temporary parking		Or per industry standards where space is constrained
	Bus Cleaning Storage and Lockers	400 SF plus Unisex Washroom		Dependent on staff number
	General Building Factors for Site and Concept Plans			
	Support room walls, utility spaces, and circulation corridors	35% of support areas		
	Maintenance and bus storage walls, utility spaces, and staff access aisles	8% of maintenance and bus storage areas		
	Interior bus circulation aisles	45-50% of bus storage and maintenance bay areas		
	Site Spaces			
	Employee Parking	9' x 18' 300 SF	per space per employee with shift change	
	Visitor Parking	9' x 18' 380 SF	per space per employee with shift change	
	ADA Parking	14' x 20'	Per space	
	Bus queuing	40-ft bus: 14' x 50' 60-ft bus: 14' x 70'	5-8% of fleet	Dependent on peak return and bus route schedule
	Non revenue vehicle parking	10' x 20'	3% of staff	i.e., tow truck, tug, vans, pickups, service truck
	Loading dock site area	4000 SF		Includes space for trash/recycle
	Landscaping	8-15% of all other site areas	Lower if combined with easements	Dependent on zoning requirements
	Easements, setbacks, public way	8-15 % of all other site areas		Dependent on site and utilities
	Storm water retention	Suburban: 5-7% of site Urban: 1% of site		
	Site circulation (drive aisles, access roads)	Suburban: 50% of site Urban: 25% (or less) of site		If intercity with limited site, area may be marginal

APPENDIX C
EXTERIOR FINISHES SUPPLEMENT

CONTENTS

TABLES

Table C-1. Roofing Materials

Criteria	Modified Bitumen Built-Up Roofing System	EPDM Roofing System
General material properties (Master Spec)	SECTION 07550T	SECTION 075323
Warranty	20-year no-dollar-limit (NDL), 2-year membrane warranty required	20, 25, and 30-year limited warranty available
Maintenance		
Cost of maintenance	Minimal	Minimal
Frequency of maintenance	Annual warranty inspections for the life of the warranty	Annual warranty inspections for the life of the warranty
Ease of maintenance	Qualified contractor is required to maintain warranty	Qualified contractor is required to maintain warranty
Durability:		
Impact resistance	3-Ply with 115 mil top ply is very durable	Vulnerable to punctures from sharp and falling objects
Traffic and Vandal resistance	Subject to damage from maintenance traffic	Subject to damage from maintenance traffic
Corrosion resistance	Very resistant (exception for petroleum products)	Very resistant (exception for petroleum products)
Ease of repair	Membrane patch and repair work may require torch	Patch or replace damaged membrane heat weld or adhesive
Constructability:		
Quality control	Qualified installer, roof manufacturer inspections	Qualified installer, roof manufacturer inspections
Contractor pool	Several in New England with experience requirements	Several in New England with experience requirements
Ease of transport	3’ wide rolls, all materials easy to transport	10’ wide rolls, all materials easy to transport
Ease of assembly	Multiple layer system, qualified installer required	Single ply system, qualified installer required
Availability/lead time	Readily available	Readily available
MBTA standards adherence	See MBTA performance specification	No MBTA specification
Risk/insurance recommendation	FM Class 1-90	FM Class 1-90
Environmental impact	Materials are not recyclable	Recyclable but not economical
Cleaning		Requires cleaning to maintain performance

Table C-2. Wall Panel/Rain Screen Analysis

Criteria	Metal Panel (single skin, preformed)	Fiber Cement	Terra Cotta Cladding	High Pressure Laminate (HPL)	Metal Panel (4mm MCM)
General material properties (Master Spec)	SECTION 074213.13	SECTION 074243	SECTION 074246	SECTION 074243	SECTION 074213.23
Warranty	30 years	20 years	5 to 75 years	20 years	5 to 30 years (finish)
Substrate and insulation	Requires panel subframing and continuous insulation subframing	Requires panel subframing and continuous insulation subframing	Requires panel subframing and continuous insulation subframing	Requires panel subframing and continuous insulation subframing	Requires panel subframing and continuous insulation subframing
Maintenance:					
Cost of maintenance	Dry seal maintenance cost minimal, wet seal systems require inspection	Dry seal maintenance cost is minimal	Dry seal maintenance cost is minimal	Low maintenance cost and easy to clean	Minimal cost for dry seal
Frequency of maintenance	Infrequent for dry seal, periodic inspections and reseal for wet seal	Inspection and adjustment as required	Power wash every 10 years	None expected	Infrequent with dry seal, periodic inspections and resealing with wet seal (moderate cost)
Ease of maintenance	Qualified contractor required	Qualified contractor required	Qualified contractor required	Qualified contractor required to maintain warranty	Labor cost and time variable
Durability:					
Impact resistance	Vulnerable to vehicles, should not be installed where contact possible	Vulnerable to vehicles, should not be installed where contact possible	Vulnerable to vehicles, should not be installed where contact possible	Vulnerable to vehicles, should not be installed where contact possible	Vulnerable to vehicles, should not be installed where contact possible
Vandal resistance	Very good, non-porous panels can be cleaned	Vulnerable to graffiti	Vulnerable to graffiti	Very good, non-porous panels can be cleaned	Very good, non-porous panels can be cleaned
Corrosion resistance	Resistant to corrosion	Panel subframing is corrosion resistant, panel is non-corrosive	Panel subframing is corrosion resistant, panel is non-corrosive	Resistant to corrosion	Resistant to corrosion
Ease of repair	Qualified contractor required to maintain warranty	Qualified contractor required	Qualified contractor required	Qualified contractor required to maintain warranty	Qualified contractor required to maintain warranty
Constructability:					
Quality control	Factory applied coatings and fabrication	Factory applied coatings and fabrication	Fired clay product	Factory produced panels and substrate	Factory produced panels and substrate
Contractor pool	Multiple qualified contractors in the Boston area	Multiple qualified contractors in the Boston area	Multiple qualified contractors in the NE Region	Multiple qualified contractors in the Boston area	Multiple qualified contractors in the Boston area
Ease of transport	Panel sizes up to 25’ length	Panel sizes up to 12’ length	24” x 60” panel sizes, approx. 12# each	Panel sizes up to 12’ length	Panel sizes up to 12’ length
Ease of assembly	Panels are supported with engineered framing system, qualified installer required	Panels are supported with engineered framing system; qualified installer is required	Panels are supported with engineered framing system; qualified installer is required	Panels are supported with engineered framing system, qualified installer required	Panels are supported with engineered framing system, qualified installer required
Availability/lead time	Available in standard thicknesses and finish; custom colors have a longer lead time	Available in standard thicknesses and finish; custom colors have a longer lead time	May have lead time issues depending on where it’s produced	Available in standard thicknesses and finish; custom colors have a longer lead time	Available in standard thicknesses and finish; custom colors have a longer lead time
MBTA standards adherence	No MBTA specification	No MBTA specification	No MBTA specification	No MBTA specification	No MBTA specification
Risk/insurance recommendation	FM 4411 Cavity Wall recommendations	FM 4411 Cavity Wall recommendations	FM 4411 Cavity Wall recommendations	FM 4411 Cavity Wall recommendations	FM 4411 Cavity Wall recommendations
Environmental impact	Materials are recyclable	Materials are recyclable	Materials are recyclable	Materials are recyclable	Materials are recyclable

Table C-3. Masonry or Concrete Wall Analysis

Criteria	Brick Veneer	Precast Architectural Concrete	Tilt Wall Concrete
General material properties (Master Spec)	SECTION 04800T	SECTION 034500	SECTION 034713
	Face Brick and Decorative CMU	Cladding and load bearing units	Monolithic or insulated sandwich panel
	Backup wall either metal stud or CMU	Insulated precast units	Can be load bearing
	Non-load bearing veneer requires cavity wall construction	Cladding requires structural backup wall	Brace and attachment to permanent structure during erection
<u>Maintenance:</u>			
Cost of maintenance	Masonry is cleaned either with water, chemical, or mechanical abrasive	Low maintenance cost and cleanable	Low maintenance cost cleanable
Frequency of maintenance	None expected	None expected	None expected
Ease of maintenance	Qualified contractor required to maintain warranty	Qualified contractor required to maintain warranty	Qualified contractor required
<u>Durability:</u>			
Impact resistance	Good for hurricane projectile resistance	Good for hurricane projectile resistance	Good for hurricane projectile resistance
Traffic and vandal resistance	Vulnerable to vehicle impact and graffiti	Good for vehicle impact, vulnerable to graffiti	Good for vehicle impact, vulnerable to graffiti
Corrosion resistance	Brick will not corrode, but non-galvanized wall ties and reinforcing is subject to corrosion	Will not corrode	Will not corrode
Ease of repair	Qualified mason required	Qualified contractor required to maintain panel joints	Qualified contractor required to maintain panel joints
<u>Constructability:</u>			
Quality control	High quality with factory produced units	High quality with factory produced units	Lower quality finishes if produced on site
Contractor pool	Multiple qualified contractors in the Boston area	Multiple qualified contractors in the Boston area	Not a common method of construction in the Boston area
Ease of transport	Palletized material easily transported to site	Palletized material easily transported to site	.
Ease of assembly	Scaffolding required for work above ground level	Cranes required	
Availability/lead time	Available in standard sizes and finish; custom colors have a longer lead time	Available in standard sizes and finish; custom colors have a longer lead time	
MBTA standards adherence	No MBTA specification	No MBTA specification	No MBTA specification
Risk/insurance recommendation	None for non-combustible material	None for non-combustible material	None for non-combustible material
Environmental impact	Materials are recyclable	Materials are recyclable	Materials are recyclable

Table C-4. Panel Wall Analysis

Criteria	Metal Wall Panel	Panelized Wall System
General material properties (Master Spec)	SECTION 074213	SECTION 072411
	Insulated Metal Wall Panels, R-8/in per ASTM C518	Rainscreen barrier assemblies shop applied over AVB, sheathing, and metal framing
Warranty	Limited 2 years (panel), 20 years (finish)	15 years
Maintenance:		
Cost of maintenance	Minimal labor and time for cleaning	Minimal labor and time for cleaning
Frequency of maintenance	TBD	Sealant durability will determine frequency
Ease of maintenance	Require man lift above ground level	Require man lift above ground level
Durability:		
Impact resistance	Moderate and dependent on gauge of exterior metal skin	Good for hurricane projectile resistance
Vandal resistance	Specify graffiti resistant finishes for ground level	Good for vehicle impact, but vulnerable to graffiti
Corrosion resistance	Specify galvanized metal substrate	Will not corrode
Ease of repair	Qualified contractor required to maintain panel joints	Qualified contractor required to maintain panel joints
Constructability:		
Quality control	High quality with factory produced units	High quality with factory produced units
Contractor pool	Multiple qualified contractors in the Boston area	Multiple qualified contractors in the Boston area
Ease of transport	3’ x 6’ x 3” panel size	9’-6” x 32’ panel size, cranes required
Ease of assembly	Interlocking gasketed joint	Double sealant joint between panels
Availability/lead time	Available in standard sizes and finishes; custom colors have a longer lead time	Panel is custom shop fabricated to reduce time of construction
MBTA standards adherence	No MBTA specification	No MBTA specification
Risk/insurance recommendation	FM 4880 - Class 1 / FM 4881	FM 4880 - Class 1 / FM 4881

Table C-5. Glazing Analysis

Criteria	Curtain Wall	Channel Glass	Translucent Fiberglas Panel
General material properties (Master Spec)	SECTION 081413	SECTION 088100	SECTION 084413
Warranty	10 years	Limited 10 years	10 to 20 years
	Unitized – factory assembled	Translucent Channel Glass System - Pilkington “Profilit”	Polycarbonate Curtain Wall System
	Stick Frame – field assembled from components		Assembled in an aluminum curtain wall frame
Design R-Value	R-5.9 (minimum) to R-7	R-2 to R-5 depends on coating	R-3.0 to R-3.7
Maintenance:			
Cost of maintenance	Minimal	Minimal	Minimal
Frequency of maintenance	Infrequent	Infrequent	Infrequent
Ease of maintenance	Qualified contractor required	Qualified contractor required	Qualified contractor required
Durability:			
Impact resistance	Must be laminated or impact-resistant glass	Must specify impact-resistant glass	Yes
Vandal resistance	Subject to breakage and scratching	Subject to breakage	Subject to breakage and scratching
Corrosion resistance	Will not corrode	Will not corrode	Will not corrode
Ease of repair	Requires qualified contractor to install and replace lights	Requires qualified contractor to install and replace channels	Requires qualified contractor to install and replace lights
Constructability:			
Quality control	High quality with factory produced units	High quality with factory produced units	Factory produced units and installed in aluminum frames
Contractor pool	Multiple qualified contractors in the Boston area	Limited qualified contractors in the Boston area	Limited qualified contractors in the Boston area
Ease of transport	Material easily transported to site	Material easily transported to site	Material easily transported to site
Ease of assembly	Scaffolding and lifts required	Scaffolding and lifts required	Scaffolding and lifts required
Availability/lead time	Lead time for small project is short	Limited installations and lead time may be long	Lead time is not expected to be critical
MBTA standards adherence	MBTA performance specification	No MBTA specification	No MBTA specification
Risk/insurance recommendation	Glass breakage and replacement		
Environmental impact	Materials are recyclable	Materials are recyclable	Materials are recyclable

Table C-6. Skylight Analysis

Criteria	Skylight
General material properties (Master Spec)	SECTION 086300
Warranty	20-year warranty (glass) 15-year warranty (polycarbonate) Unitized – factory assembled
<u>Maintenance:</u> Cost of maintenance Frequency of maintenance Ease of maintenance	 Minimal Infrequent Qualified contractor required
<u>Durability:</u> Impact resistance Vandal resistance Corrosion resistance Ease of repair	 Must be impact-resistant glass or polycarbonate Subject to breakage and scratching Will not corrode Requires qualified contractor to install and replace lights
<u>Constructability:</u> Quality control Contractor pool Ease of transport Ease of assembly Availability/lead time	 High quality with factory produced units Multiple qualified contractors in the Boston area Material easily transported to site Lifts required Product is available lead time for small project is short
MBTA standards adherence	MBTA performance specification
Risk/insurance recommendation	Glass breakage and replacement
Environmental impact	Materials are recyclable

APPENDIX D
OPTIONAL STANDBY POWER GENERATOR EQUIPMENT

The optional standby power generator serves facility operational loads in the event of a power failure. The MBTA will decide which equipment shall be supported by standby power to ensure the continuity of essential operations during a power failure. The following is a list of baseline equipment to be considered for standby power.

Maintenance Service and Repair Equipment

- Fuel pumps and fuel dispensing equipment
- Minimum two (2) platform lifts and two (2) post lifts
- General machine and brake shop area equipment
- Fluid room and fueling area compressor
- Fluid room and maintenance area compressors
- Inspection bay (lights and power)
- Fueling bay support area (excluding exterior wash bays)

HVAC Systems

- Security system cooling system
- Communications rooms HVAC system
- Energy Recovery Ventilator Units (ERVs) serving the bus storage space if required by AHJ to be used for post-event smoke removal
- All air handling units (PRTUs, ERVs, MAUs and HVs)
- Exhaust and makeup air system serving the fueling area
- Source capture exhaust fans and makeup air system(s) in a minimum of four (4) maintenance bays

Plumbing Systems

- Emergency diesel generator fuel tank leak detection and heater
- POU electric water heaters for toilets in the maintenance area
- POU electric hot water heaters for fuel service area toilets
- Domestic water heater control circuits

General Lighting and Power

- Building Management System
- Data and communications systems
- Fueling area and fuelers' work area
- Building elevators and elevator sump pumps
- Inspectors' offices
- Transportation and maintenance management offices
- Bus storage
- Exterior and interior overhead door operators for bus vehicles

- Toilet rooms near the pull-out inspector office, operators' area, and maintenance area
- Bus operators' area and picking room kiosk equipment
- Lights in parts storage
- Mechanics break room
- Site and exterior building lighting

APPENDIX E
MAINTENANCE LIFT SUPPLEMENT

CONTENTS

E.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 of 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.

E.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 lifts designed for smaller vehicles will not be considered.

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.

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 place 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.

Portable lifts: These can be 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.

E.3 VENDORS

There are two main venders in the United States for Bus lifts in all configurations described above. These venders include Stertile-Koni and Rotary. There are other venders 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.

E.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 ICC's 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.

E.4.1 Code Interpretation from ICC

The International Building Codes 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) / ALI Automotive Lift Construction, Testing and Validation (ALCTV) standards and for auto lifts and ANSI/ American Society of Mechanical Engineers (ASME) 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 a number of 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 auto 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.

E.4.2 Industry Standards and Other Requirements

The American Public Transportation Association (APTA) 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

E.5 PROGRAMMING

The following table is a guideline for sizing new facilities for preventive bus maintenance facilities. It should be used for initial space programing and determining facility size and site requirements for site selection. Any heavy maintenance activities such as body work, painting, decaling, engine, transmission, or fleet overhauls space is not included. Initial program should cover both site and building and apply proper percentage factors for vehicle circulation, walls, site amenities, unitalities, easements landscaping, halls, entries, data, mechanical and electrical spaces. Both initial and future spaces should be considered in separate columns. It should be tested and updated as needed during site analysis, layout alternatives, final concept development and the initial basis of design report. 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 this preliminary assumptions for a specific base.