Metrorail

Fleet Management Plan

Washington Metropolitan Area Transit Authority

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Revision 6	December 2021	Revise plan timeframe from 2015-2030 to 2020-2040 and update to reflect fleet retirements and procurement plans, ridership/service projections, changes to maintenance programs, and systems and facilities needs analysis

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Executive Summary

The Metrorail Fleet Management Plan details how Metro will modernize and grow its rail fleet and supporting systems and facilities to meet service demands between 2020 and 2040.

Metro Overview

Metro operates rail service over six lines totaling 117 two-track miles serving 91 stations throughout the Washington metropolitan area. Service delivery is made possible by a network of track infrastructure and systems for train control and traction power as well as facilities for railcar storage and maintenance. Two system expansion projects are currently underway. Silver Line Phase 2 extends service 11-miles along the Dulles corridor and will include six new stations. The Potomac Yard Station adds an infill station in the city of Alexandria, Virginia on the Blue and Yellow Lines.

Ridership and Service Projections

Metrorail ridership has traditionally grown with system expansion and regional population and job growth. Beginning in 2010, rail ridership declined due to changes in travel markets with the growth of telework and ride-hailing alternatives as well as declining reliability of Metrorail service. Ridership began to stabilize and, by 2019, return to growth with improved service reliability following system renewal investments and replacement of the oldest and least reliable railcars. Pre-pandemic peak service ran on an 8-minute system headway pattern[1] with a mix of six-car and eight-car trains. The early months of the coronavirus pandemic saw a sharp drop in Metrorail ridership as customers were urged to stay home and limit travel to essential trips. A prolonged and uncertain recovery period is expected but it is not currently anticipated to alter capacity demand projections in this plan's 2030 and 2040 milestone years.

Metro considers a range of factors to develop system and line-level ridership projections, including the pace and location of regional population and job growth. Metro anticipates approximately one percent annual growth over the plan's 20-year timeframe with a higher initial growth rate in the years following the opening of Silver Line Phase 2. Rail service standards target average peak hour loads at or below 100 passengers per railcar. Applying the standard to the ridership forecasts, Metro has identified a need to increase rail service to operate all eight-car trains and increase train frequencies to a 7-minute headway level by 2030. Increased service will be phased in based on demand by line and fleet acquisition schedules.

Vehicle Requirements

Following the completion of 7000-Series railcar deliveries in 2020, Metro has 1,278 railcars in its revenue fleet, consisting of 2000-Series, 3000-Series, 6000-Series, and 7000-Series cars.[2] Since 2015, Metro has decommissioned the 1000-Series, 4000-Series, and 5000-Series vehicles due to age and reliability issues.

[1] Metro's Red Line operates at half the system headway and interlined segments, where two or more lines overlap, have lower effective headways. An 8-minute system headway, for example, is a system service pattern where trains leave end-of-line terminals every 8-minutes except on the Red Line, where trains depart every 4 minutes. On interlined segments, the combined headway is 2.6 to 4 minutes.

[2] In addition to railcars used for revenue service, Metro operates and maintains a fleet of 186 maintenance of way vehicles and four revenue collection vehicles.

Based on projected service level requirements, Metro calculates the number of railcars needed to operate peak period service. Metro adds a spare factor at a ratio of 20% of peak vehicles, equivalent to approximately 17% of the total fleet, to account for maintenance and rehabilitation activities.

Meeting the demands for all eight-car train operations and 7-minute service frequencies requires a total fleet of 1,528 railcars by the conclusion of the 8000-Series delivery period:

- 2020 (8-minute headway with mixed six- and eight-car trains): 1,278 cars
- 2030 (7-minute headway with 100% eight-car trains): 1,528 cars

The procurement of 8000-Series railcars is underway to replace the 2000-Series and 3000-Series vehicles and enable fleet expansion. The procurement will enable acquisition of up to 800 railcars with a base and four options. Precise option quantities can be adjusted before execution to ensure flexibility to meet Metro's needs. The number of railcars needed to meet replacement and potential capacity expansion milestones is summarized in Table E-1.

TABLE E-1: METRO 8000-SERIES PROCUREMENT PURPOSES

Procurement Purpose	Incremental Railcars	Total Railcars
2000-Series and 3000-Series replacement	366	366
8-Minute Headway, 100% Eight-Car Trains	70	436
7-Minute Headway, 100% Eight-Car Trains	164	600
6-Minute Headway, 100% Eight-Car Trains or early 6000-Series replacement	184	784
Contingency railcars	16	800

By 2030, if Metro exercises the base procurement as well as option quantities sufficient to support 100% eight-car trains at a 7-minute system headway, the railcar fleet will consist of 1,528 railcars:

- 6000-Series: 180 railcars[3]
- 7000-Series: 748 railcars
- 8000-Series: 600 railcars

Beyond 2040, Metro projects there may be a need to run trains at 6-minute frequencies. Following the 8000-Series, the next railcar procurement is anticipated to align with the retirement of the 6000-Series railcars beginning in 2045. An accelerated timetable could be pursued to meet faster than anticipated ridership growth, acquire railcars compatible with a next-generation train control system, or pursue early retirement of existing vehicles.

[3] A total of four revenue collection vehicles are expected to be converted 6000-Series railcars by 2030 (out of 184 total).

Maintenance and Reliability

Since 2015, Metro has made changes to its maintenance practices and seen improvement in railcar reliability measures. There are three types of railcar maintenance used to ensure a state of good repair throughout the lifecycles of these vehicles: Scheduled Maintenance Program (SMP), Preventive Maintenance & Inspection (PMI) and Corrective Maintenance (CM). Metro is improving its railcar rehabilitation program by implementing the SMP to overhaul railcar systems and components on a six-year cycle in lieu of the midlife overhaul program. Metro also modified the timing and tasks associated with the PMI program. These changes, coupled with the replacement of older and less reliable railcars, has improved fleet reliability. Metro recorded an improvement across vehicle series in Mean Distance Between Delays (MDBD) from 2015 to 2019, including a 75 percent decrease in customer offloads.

System and Facilities Capacity

An assessment of existing and planned systems and facilities reveals gaps Metro will need to address to meet projected service levels. Railcar storage and shop space are also not optimally configured for eight-car train operations and maintenance and further efficiency and reliability improvements will be explored.

- Yard Capacity: Metro's railyards do not currently have sufficient railcar storage capacity in all locations it will be needed to support a 7-minute system headway with 100% eight-car trains. Additional storage capacity will be needed on the Red Line and Blue, Orange & Silver Lines, especially at New Carrollton Yard, by 2030 when the fleet is projected to grow to 1,528 railcars.
- Shop Capacity: Metro's current railcar maintenance shop capacity is not adequate to meet demand at 7-minute headway service with 100% eight-car trains (2030). Construction of the new Heavy Repair & Overhaul (HR&O) facility in Landover, Maryland addresses current and future needs for railcar rehabilitation and meets Red Line shop capacity needs by enabling conversion of existing heavy repair shop bays at Brentwood Yard to service and inspection (S&I) bays. Additional shop expansions at New Carrollton and Branch Avenue Yards are needed to address shop capacity constraints on the Blue, Orange & Silver Lines and Green & Yellow Lines.
- Traction Power: Existing traction power capacity allows operation of 100% eight-car trains at 8-minute headways and current projects underway or planned will meet requirements for up to a 6-minute headway.
- Throughput: While core throughput capacity of 26 trains per hour is sufficient on all lines to operate a 7-minute headway, Metro's current operating standard for train turning capacity at terminals is 15 trains per hour and will require operational adjustments for 7-minute headway operation (approximately 17 trains per hour) at terminals with the most frequent service – Shady Grove, Glenmont, Greenbelt, and Largo.

Figure E-1 summarizes the requirements and gaps Metro needs to address to deliver service at 8-minute, 7-minute, and 6-minute system headways. The 7-minute headway capability is expected to be sufficient to meet service demand for the 20-year timeframe of this fleet plan.

FIGURE E-1: SYSTEM CAPACITY CAPABILITIES TO DELIVER 100% 8-CAR TRAIN SERVICE BY HEADWAY

Key:
- Current capabilities meet requirements
- Current & planned major projects, operational changes meet requirements
- Additional capacity needed, currently unplanned

	8-Minute Headway	7-Minute Headway (2030)	6-Minute Headway (Beyond 2040)
Fleet Size	**1,364 railcars** 7000-Series delivery complete Delivery of **434** 8000-Series cars (Options 1 & 2)	**1,528 railcars** 7000-Series delivery complete Delivery of **600** 8000-Series railcars (Options 1, 2, & 3)	**1,712 railcars** Delivery of **784** 8000-Series railcars (Options 1, 2, 3, & 4)
Yard Capacity	**56** spaces New Carrollton	**112** spaces at New Carrollton **52** spaces at Red Line yards	**112** spaces at New Carrollton **132** spaces at Red Line yards **60** spaces at Dulles
Shop Capacity	**40** bays in Heavy Repair & Overhaul Facility **8** bays at New Carrollton **8** bays at Branch Avenue	**40** bays in Heavy Repair & Overhaul Facility **16** bays at New Carrollton **8** bays at Branch Avenue	**40** bays in Heavy Repair & Overhaul Facility **16** bays at New Carrollton **8** bays at Branch Avenue **8** additional bays at Branch Avenue or Greenbelt **8** bays at Dulles
Traction Power	**Completed** power upgrades sufficient on all lines	**BL/OR/SV** lines by **FY2022** **RD** line by **FY2026** **YL/GR** lines by **FY2030**	**BL/OR/SV** lines by **FY2022** **RD** line by **FY2026** **YL/GR** lines by **FY2030**
Throughput			
Core	**22.5** trains per hour on **BL/OR/SV** lines; **<26** trains per hour standard	**<26** trains per hour on **BL/OR/SV** lines; within standard	Requires capacity to run **30** trains per hour on **BL/OR/SV** lines or frequency reduction on at least one line
Terminal	**15** trains per hour at **4** terminals; at current maximum standard	**>17** trains per hour or turnbacks; operating changes required	**20** trains per hour or turnbacks; operating changes required

1 Introduction

The Metrorail Fleet Management Plan is a statement of the processes and practices by which the Washington Metropolitan Area Transit Authority (Metro) establishes its current and projected Metrorail fleet requirements. It explains how service goals are applied to ridership projections to develop peak vehicle requirements, how vehicle maintenance needs inform the target spare ratio, how these requirements are impacted by Metrorail system expansions and other factors, and describes implications for supporting systems and facilities.

1.1. Overview of Plan

The Metrorail Fleet Management Plan is organized as follows:

- Chapter 1: Introduction. Provides a plan overview and system context to understand later content.
- Chapter 2: Demand for Revenue Vehicles. 2A documents Metrorail's projected peak ridership demand and how much service is required to meet the demand. 2B provides the number of vehicles required to provide that service and supporting methodology and context.
- Chapter 3: Supply of Revenue Vehicles. Details how Metro will meet the projected vehicle demand through long-term vehicle procurement, rehabilitation, and retirement plans as well as what the fleet composition will be over the next 20 years.
- Chapter 4: Maintenance and Reliability. Explains how Metro maintains and stores the fleet on an ongoing basis, detailed information on maintenance practices and programs, and updates on reliability metrics.
- Chapter 5: System and Facilities Capacity. Describes gaps in the current system and facilities capacity and how Metro will address with underway and planned investments.
- Appendix. Defines acronyms and terms. Details additional tables, figures, and methodologies for analysis and findings found in the Plan.

1.2. Plan Timeframe

The Plan covers fleet requirements for a 20-year timeframe, from 2020 to 2040. This timeframe captures all existing and committed improvements to the Metrorail system and provides adequate lead time to adjust operating, maintenance, and procurement strategies to accommodate anticipated changes in revenue fleet supply and demand. The Plan is a living document that is based on current realities and assumptions, and it is therefore subject to future revision. It has been developed to be consistent with the guidelines established for fleet management plans by the Federal Transit Administration (FTA) in their 1999 *Dear Colleague* letter and in FTA's *Oversight Procedure 37 – Fleet Management Plan Review*.

1.3. Description of Current System

1.3.1 Operating Characteristics

The Metrorail system opened in 1976 and has grown to 91 passenger stations along 117 two-way route-miles of heavy rail rapid transit, serving the District of Columbia and adjoining areas of Maryland and Virginia. With the completion of the Silver Line Phase 2 and the addition of the Potomac Yard station, this will increase to 98 stations and 128 two-way route-miles. Most Metrorail stations provide multimodal transfer facilities, including Park-and-Ride and connections to the following transit services: Metrobus services operated by Metro, bus services operated by local jurisdictions, Amtrak, the MARC commuter rail service and the Virginia Railway Express (VRE). All station platforms are 600 feet long, and each platform can accommodate trains up to eight-cars in length.

The system operates along six double-tracked rail lines (Red, Yellow, Green, Blue, Orange, and Silver). Table 1-1 summarizes the key characteristics of each line. The service patterns and fleet requirements of each line are described in Section 2.

TABLE 1-1: SUMMARY OF METRORAIL LINES, 2020

Line	Length (mi.)	Number of Stations	Peak Period Headway (min.)	Total Peak Trains (incl. gap and tripper)
Red	31.9	27	4	40
Yellow	15.1	17	8	16
Green	23.0	21	8	18
Blue	30.3	27	8	20
Orange	26.4	26	8	21
Silver	29.6	28	8	21
System Total	**117**	**91**	**8**	**136**

Figure 1-1 illustrates the existing system and its stations. The Blue, Orange, and Silver Lines share tracks through the core area of the region, as do the Yellow and Green Lines. The Blue and Yellow Lines also share tracks in Alexandria, Arlington, and Fairfax Counties. The Orange and Silver Lines share tracks in Arlington and Fairfax Counties. Similarly, the Green and Yellow lines share track in Maryland, as do the Blue and Silver. These shared segments of track offer Metro flexibility in structuring service patterns to meet operational needs. The Red Line does not share track segments with other lines.

FIGURE 1-1: METRORAIL SYSTEM MAP

1.3.2 System Infrastructure and Non-Revenue Facilities

Metrorail also relies on an interconnected network of system infrastructure and non-revenue facilities to deliver service and maintain fleet reliability. Elements include:

- Automatic Train Control
- Traction Power
- Terminals
- Pocket Tracks
- Junctions
- Railcar Storage Yards and Tail Tracks
- Railcar Maintenance and Overhaul Facilities

1.3.2.1 Automatic Train Control

An automatic train control (ATC) system regulates train speed and spacing to ensure safe and efficient operations. The ATC system combines automated and manual elements located on the train, along the track, in stations, and at remote central facilities. The system includes several subsystems which work in tandem to manage and regulate train movements: automatic train protection (prevention of collisions and derailments), automatic train operation (control of train movement and stopping at stations), and automatic train supervision (monitoring and control of train schedule):

- *Automatic Train Protection (ATP)*. ATP assists in enforcement of safe operation of the system by imposing speed limits and ensuring train separation. At interlockings, ATP ensures that train movement is permitted only when a clear, uncontested route is available and the track switches are locked in position. In all cases where two or more trains are competing for the use of a common segment of track, the system allocates the track to one train at a time and locks out all others.
- *Automatic Train Operation (ATO)*. ATO performs many of the functions normally performed by the operator. Those functions are smooth acceleration of the train to running speed, regulation of that speed, and stopping the train smoothly at the proper position in the station. Trains are currently operated in manual mode.
- *Automatic Train Supervision (ATS)*. ATS controls and monitors train routing and scheduling. The subsystem supplies operating data to the Rail Operations Control Center and automatically makes minor scheduling adjustments to maintain traffic flow. ATS communication with the trains is provided by the Train-To-Wayside Communication (TWC) system.

1.3.2.2 Traction Power

The 750 Volts Direct Current (VDC) Traction Power System provides the power source for vehicle propulsion. The traction power system includes contact and running rails, associated conductor system, power substations and tie-breaker stations including transformers, rectifiers and switchgear for conversion and supply of power to the contact rail system. Each segment of contact third rail can be supplied by adjacent power substations and are supplied by separate power company substations wherever practicable for additional reliability.

1.3.2.3 Terminals

Metro has ten terminals where train lines originate and terminate service. [4] Trains generally reverse direction at terminals and the time it takes to reverse train operation represents a capacity constraint in the Metrorail system. All terminals have crossovers, allowing trains to move from one track to another on the revenue side of the platforms and most also have crossovers on the non-revenue side. Five of the terminals have yard leads that continue past the terminal tracks.

1.3.2.4 Pocket Tracks

The Metrorail system has eight pocket tracks, each of which is configured as a third track between the two

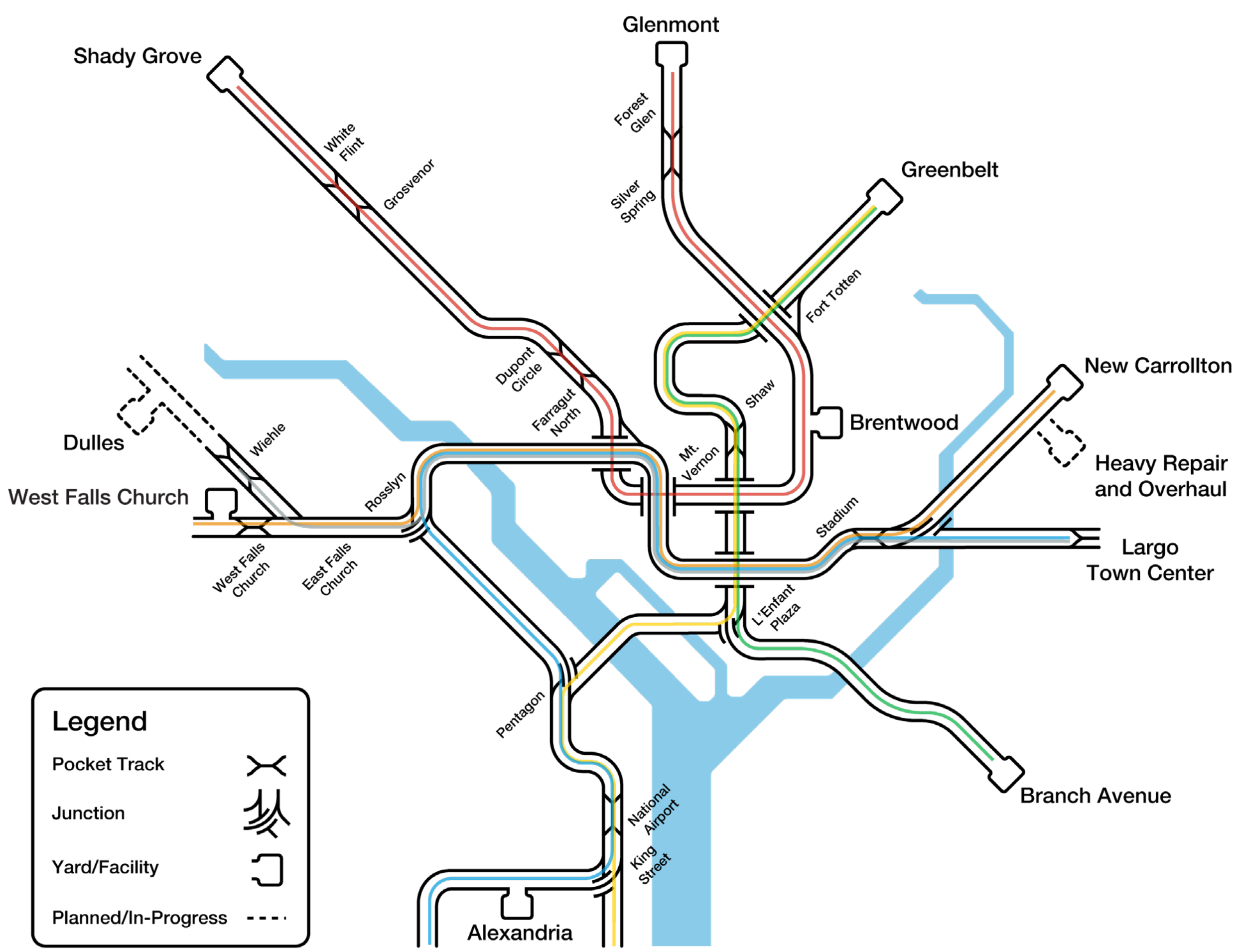
[4] Ashburn will replace Wiehle as the western terminal on the Silver Line with the opening of Silver Line Phase 2.

mainline tracks capable of storing an eight-car train.[5] These pocket tracks were incorporated into the design of the system for operational flexibility, such as to move disabled trains off the mainline and to allow for "short-lining", wherein certain scheduled trains turn back along the line rather than continuing service to the terminal station. Short-lining allows Metro to concentrate service capacity in the core of the system where demand is highest and to reduce service impacts from maintenance activities.

1.3.2.5 Junctions

Metrorail has junctions where lines meet to allow two rail lines to merge into one or trains to move from one line to another. Metro's Blue, Orange, and Silver Lines as well as Yellow and Green lines all merge into trunk lines and operate as interlined service. Junction configurations constrain system capacity because each merge point is a potential delay location. All three Metrorail capacity-critical junctions (Rosslyn, L'Enfant Plaza and Stadium-Armory) are "flying junctions" – configured with flyover track that avoids movement conflicts between trains moving in opposite directions.

FIGURE 1-2: LOCATION OF KEY SYSTEM INFRASTRUCTURE AND NON-REVENUE FACILITIES



5 Pocket tracks are located at or near Wiehle, West Falls Church, Grosvenor, Silver Spring, Mt. Vernon Square, Stadium-Armory, and Reagan National Airport.

1.3.2.6 Railcar Storage and Maintenance

Metro has nine railcar storage locations and seven maintenance facilities across the system to house its revenue and non-revenue fleets when not in service. These yards are equipped with electrified third rail track to store and maneuver vehicles as well as non-electrified track to store Maintenance of Way (MoW) equipment. Size and capacity vary by yard based on the available real estate and needs of the system at the time of construction. The facilities are summarized in Table 1-2.

TABLE 1-2: CURRENT RAILCAR MAINTENANCE AND STORAGE FACILITIES[6]

Name	Line(s)	Revenue Storage	Maintenance Bays	Year opened	Functions
Alexandria	Blue and Yellow Lines	176	20	1981	Railcar storage, scheduled inspections, corrective maintenance
Branch Avenue	Green Line	174	8	2002	Railcar storage, corrective maintenance
Brentwood	Red Line	90	42	1974 (expanded 2007)	Railcar storage, corrective maintenance, heavy repair and overhaul
Glenmont	Red Line	132	0	1998	Railcar storage (no shops)
Greenbelt	Green and Yellow Lines	270	20	1995 (expanded 2007)	Railcar storage, scheduled inspections, corrective maintenance, heavy repair and overhaul, commissioning
Largo	Blue and Silver Lines	38	0	2004	Railcar storage (no shops)
New Carrollton	Orange Line	120	16	1978 (expanded 2006)	Railcar storage, scheduled inspections, corrective maintenance
Shady Grove	Red Line	166	36	1983 (expanded 2007)	Railcar storage, scheduled inspections, corrective maintenance
West Falls Church	Orange and Silver Lines	188	28	1986 (expanded 2014)	Railcar storage, scheduled inspections, corrective maintenance
Total		**1,354**	**170**		

All locations provide railcar storage and are a base of operations for daily rail service. The maintenance facilities perform a variety of functions but can be split into three overarching groups: Service and Inspection, Heavy Repair and Overhaul, and Car Track Equipment Maintenance.

- Service and Inspection (S&I) shops perform routine preventive maintenance and carry out the

[6] Table does not include Dulles Yard or the Heavy Repair & Overhaul Facility, which have not yet opened.

inspection schedule for the railcar fleet

- Heavy Repair and Overhaul facilities triage and service railcars that require extensive repair as well as perform railcar overhauls on a six-year cycle
- Car Track Equipment Maintenance (CTEM) facilities perform all Maintenance of Way equipment repairs and maintenance.

Additionally, two new facilities are planned to increase storage and maintenance capacity. Dulles Yard includes a railcar S&I shop and a CTEM facility and will open with Silver Line Phase 2. The construction of the Heavy Repair and Overhaul Facility in Landover, Maryland will consolidate most heavy repair and overhaul operations currently performed at Brentwood and Greenbelt Yards and enable Metro to meet current and future fleet overhaul needs.

1.4. Vehicle Inventory

Metro maintains two types of vehicle fleets: revenue and non-revenue. Following the delivery of the final 7000-Series railcars, Metro's revenue fleet consists of 1,278 vehicles used for passenger service. The non-revenue fleet provides operational support as revenue collection vehicles and maintenance of way equipment.

1.4.1 Revenue Vehicle Inventory

Metrorail's fleet of revenue vehicles consists of 1,278 railcars. All railcars are configured in permanently married pairs, consisting of an A-car and a B-car. All car series except for the 7000-Series have an operating cab at each end of each married pair, while on the 7000-Series only A-cars have a full operating cab.

Metro acquired seven car fleets through a series of procurements from 1974 to the present. The first six series of cars were fully compatible and interoperable with one another and could be coupled both mechanically and electrically for operations. Meanwhile, the new 7000-Series have all new control systems, meaning they cannot be operated in a trainline with the older car series. Since 2015, Metro has decommissioned the 1000-Series, 4000-Series, and 5000-Series as 7000-Series cars have arrived and entered service. Additionally, Metro's 8000-Series base procurement of 256 railcars, along with an optional expansion of an additional 100 railcars, will deliver 366 cars to replace the 2000-Series and 3000-Series cars. An additional three options delivering up to 434 cars will be available for potential expansion of the fleet.

All cars are capable of operating on all lines within the Metrorail system; older car series can operate in train consists composed of two, four, six, or eight cars, while the new 7000-Series operate in four or eight car consists. All Metrorail vehicles are compliant with the Americans with Disabilities Act (ADA). Table 1-3 summarizes the key characteristics of each car series; further discussion of each may be found in Section 3.

TABLE 1-3: CURRENT METRORAIL FLEET [7, 8]

Manufacturer	Series	Seats Available	Years Entered Service	Years Overhauled	# Purchased	# in Service
Rohr Industries	1000	80	1976-1981	1994-1997	300	No longer in service
Breda Construzioni Ferroviarie	2000	68	1984-1985	2003-2004	76	74
	3000	68	1985-1989	2004-2008	290	276
	4000	68	1992-1994		100	No longer in service
Construcciones y Auxiliar de Ferrocarriles, S.A. (AAI/CAF)	5000	68	2002-2005		192	No longer in service
Alstom	6000	64 (A-car) 66 (B-car)	2007-2009		184	180
Kawasaki	7000	62 (A-car) 68 (B-car)	2015-2020		748	748
Total					**1,890**	**1,278**

1.4.2 Non-Revenue Inventory

Much like Metro has support facilities in its network to support operations, it also maintains a non-revenue rail vehicle fleet to maintain infrastructure and collect fares. Currently Metro has 186 Maintenance of Way fleet vehicles and four revenue collection cars that operate on its lines.

1.5. System Expansion Plans

Two major Metrorail system expansion projects are committed for implementation during the 20-year timeframe of the Metrorail Fleet Management Plan: Silver Phase 2 serving Dulles Airport, and the Potomac Yard Metrorail Station, a new infill station serving the Blue and Yellow Lines between the existing National Airport and Braddock Road stations. In 2019, Metro launched the Blue/Orange/Silver Corridor Capacity and Reliability Study to identify potential solutions to address capacity, reliability, and customer needs on the Blue, Orange, and Silver lines. Alternatives under evaluation include system expansion concepts and a locally preferred alternative may be selected in 2022.

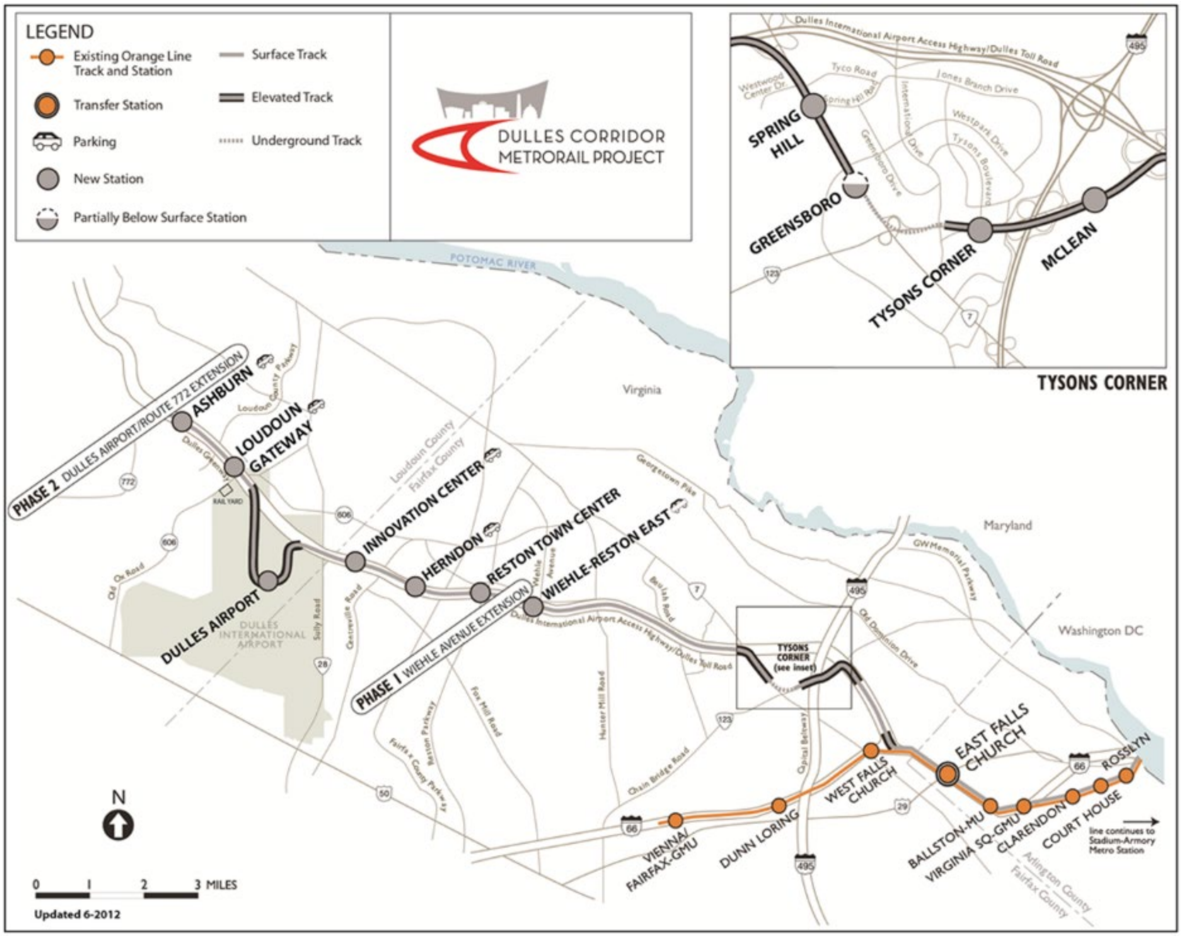
1.5.1 Silver Line Phase 2

Phase 1 of the Silver Line Expansion, comprising a new branch off the Orange Line near West Falls Church and extending roughly 12 miles through Tysons Corner to Wiehle-Reston East in Reston, Virginia, commenced operations in July 2014 as the new Silver Line. Phase 2 of the project, extending an additional 11 miles beyond Wiehle, through Herndon, Dulles Airport, and beyond to Ashburn in Loudoun County, is expected to begin operations in 2022. Phase 2 includes a new rail yard and maintenance facility west of

[7] Reflects completion of 7000-Series procurement in early 2020 and usage of two 2000-Series railcars and two 6000-Series railcars as revenue collection vehicles.
[8] Table includes retired vehicles series.

Dulles Airport. Figure 1-3 provides a map of the Dulles Corridor rail extension.

FIGURE 1-3: DULLES CORRIDOR METRORAIL EXTENSION [9, 10]



The opening of Silver Line Phase 2 will have three major impacts on the Metrorail system:

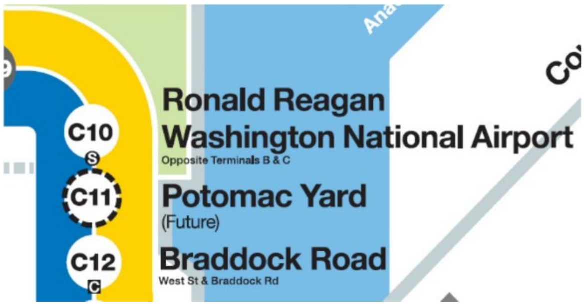
- Increased ridership. The opening of new stations will increase ridership and crowding as Silver Line trains enter the core of the system near Rosslyn.
- Increased fleet requirements. The route extension will add 21 minutes to the one-way running time of the Silver Line, thereby increasing the required number of trains. Likewise, ridership growth will warrant increasing deployment of eight-car trains.
- Increased railcar maintenance and storage requirements. The increased number of peak vehicles and increase in total service mileage will necessitate a commensurate increase in maintenance activities. An annex to the West Falls Church S&I facility was constructed as part of Silver Line Phase 1. A new maintenance and storage facility to the west of the Dulles Airport Station, Dulles Yard, will deliver an additional 168 storage spaces and 20 maintenance bays once completed.

[9] From Metropolitan Washington Airport Authority (MWAA).
[10] Referred to alternatively as the Silver Line Expansion.

1.5.2 Potomac Yard Station

Starting in 2011, the City of Alexandria, in cooperation with the Federal Transit Administration (FTA), Metro, and the National Park Service, sponsored an Environmental Impact Statement for the construction of "infill" station on Metro's Yellow and Blue Lines, serving the Potomac Yard area, a former railroad yard and now mixed-use neighborhood located between the existing Braddock Road and National Airport stations.

FIGURE 1-4: LOCATION OF NEW POTOMAC YARD STATION



Metro's Board of Directors approved the addition of the Potomac Yard station to the adopted regional system in 2015. In April 2018 the City of Alexandria and the Metro Board both approved the design-build construction project. Construction is underway and the new station is projected to open in 2022. The station is expected to add one minute of running time to the one-way travel times of Blue and Yellow Line services due to the additional station stop.

2 Demand for Revenue Vehicles

This section documents Metro's approach to determining demand for revenue vehicles. First, peak passenger demand is projected and service standards are used to determine service requirements. Second, a total vehicle requirement is determined by calculating the vehicles required for peak service and accounting for spares.

As of this document's publication, the coronavirus pandemic was ongoing, leading Metro to initially ramp down service in spring 2020 in response to decreased travel demand and to protect the health of Metro employees and later realign service levels to provide improved all day frequencies in fall 2021. While the ridership implications of this pandemic remain uncertain, the forecasts discussed within this document are long-term, reflecting anticipated trends over 5-year, 10-year, and 20-year periods. Metro's previous Rail Fleet Management Plan projected that ridership demand would support a 6-minute system headway and 100% eight-car trains by 2030. In light of revised forecasts, this document has been updated reflect the anticipated need for a 7-minute system headway with 100% eight-car trains by 2030.

As a result of the pandemic, it is possible that travel behavior and demand will be affected for a sustained period. The implications of these changes are not yet known and have the potential to alter ridership trends in multiple ways. Rider expectations of public transit capacity and tolerance for crowding may also shift over time. The impacts of these potential changes will be revisited in the coming years.

2A Passenger Demand and Service Levels

2.1. Peak Passenger Demand

Current and future peak ridership levels are the primary driver of fleet requirements. Capacity requirements of a rail line are driven by the number of riders traversing the busiest segment during its busiest hour of the day, known as maximum load points. Metro projects ridership at key maximum load points and applies service standards for passenger loads to determine future service level requirements.

2.1.1 Ridership Trends

Currently, of the 20 million trips taken in the Washington, DC metro area each weekday, 1.3 million are taken by Metrorail, bus, or commuter rail, accounting for 20% of commute trips and 3% of non-commute trips. Metrobus serves approximately 70% of bus trips in the region and other local agencies serve the remaining bus and all commuter rail trips.

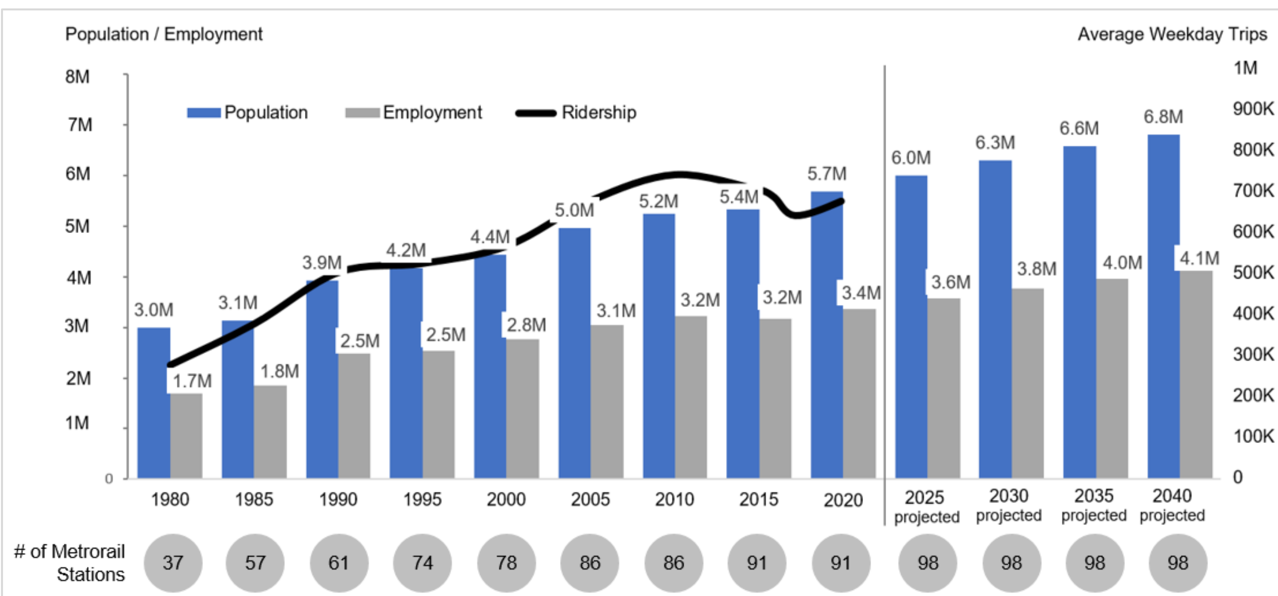
TABLE 2-1: WASHINGTON METROPOLITAN AREA DAILY TRIPS BY TRAVEL MODE, 2019[11]

Trip type	Total	Car	Transit	Walk	Bike	Ride-hailing	Telework	School bus
Commute	**4 million**	66%	20%	2%	1%	1%	10%	-
Non-commute	**16 million**	81%	3%	9%	<1%	2%	-	5%

Long-term Metrorail ridership is largely driven by population and job growth in the service area the level of mobility provided by the transit network. Metrorail ridership grew with the build-out of the originally planned 103-mile regional system, which was completed in 2001, and sustained growth of population and jobs in the Washington metropolitan region. Over the last 30 years, Metrorail ridership has grown at an average annual rate of approximately 1%, including as high as 3% in the 2000s and -2% in the past decade.

The past decade's ridership decline, beginning with modest decreases and escalating to significant drops in 2015 and 2016, was driven in part by changes in the regional travel market. These changes included the introduction of competing ride-hailing options and the growth of telework. Declines in Metrorail service reliability and increased planned service disruptions for system renewal also impacted ridership. Peak rail ridership, where work commutes make up a larger share of trips, experienced a lesser decline than off-peak ridership. Rail ridership began to stabilize in 2017 as service reliability improved and by 2019 was returning to growth, increasing approximately 7% over the prior year.

FIGURE 2-1: RIDERSHIP IN RELATION TO POPULATION AND EMPLOYMENT GROWTH, 1980-2020[12]



[11] Metro analysis; data from Metropolitan Washington Council of Governments (MWCOG), Regional Travel Survey and State of the Commute survey.

[12] Ridership data from Metro Office of Planning. Population and employment data from MWCOG, reflects Round 9.2 update published September 2020. https://www.mwcog.org/documents/2018/10/17/cooperative-forecasts-employment-population-and-household-forecasts-by-transportation-analysis-zone-cooperative-forecast-demographics-housing-population/.

In the last several years, safety and state of good repair investments including track rehabilitation and railcar replacement have led to improvements in service reliability. In 2016, Metro launched SafeTrack, a 13-month system-wide renewal initiative that required weekday service disruptions to accommodate multi-week surges of repair and renewal work. Since the conclusion of SafeTrack, major capital work requiring weekday service disruptions has continued to occur episodically, including the Platform Improvement Project's closure of six stations on the Blue and Yellow Lines in 2019 and four stations on the Orange Line in 2020. These major events usually cause immediate declines in ridership at affected stations and may also have residual impacts.

As commute trips are a major driver in transit ridership, employment trends including the number and location of jobs are important. The Washington metropolitan region continues to see growth in households and jobs, particularly in areas served by Metrorail such as the District of Columbia and Arlington County, and in several major transit-served areas such as Tysons Corner in Fairfax County, Eisenhower Avenue in Alexandria, and Bethesda and New Carrollton in Maryland. Silver Line Phase 2 is planned to open in 2022, which will add six new stations and bring additional connectivity to the Metrorail system. Figure 2-1 tracks ridership with historic population and employment growth. Regional population is forecast to grow to 6.8 million by 2040 with 4.1 million jobs, an increase of over one million residents and 750,000 jobs.

2.1.2 Metrorail Ridership Forecasts

Metro uses two models to develop its ridership forecast. For near-term forecasting, Metro uses a Short-Term Ridership Forecast (STRF) model based on demonstrated ridership drivers. For longer-term forecasts, Metro applies forecast growth rates from the travel demand model maintained by the National Capital Region Transportation Planning Board (TPB), the region's Metropolitan Planning Organization. This approach ensures Metro is using the best data about baseline ridership levels (up to fiscal year 2019) and applying common assumptions about future growth and development consistent with other local and federal agencies in the region.

Ridership methodology and assumptions

To estimate ridership for this Plan, Metro begins with the FY2017-2023 Short Term Ridership Forecast (STRF). In 2018, Metro developed the Short-Term Ridership Forecast model to project passenger demand through 2023. This forecast model was developed by analyzing previous years' data through a regression model. A set of machine-based learning and data mining procedures (e.g., regression trees and random forests) were used to inform the selection of variables to account for non-linear relationships within the data. The modeling determined the most important variables were population within walking distance of a station, service reliability at a given station, the number of hotel rooms, and employment. Regional forecasts of growth in households and jobs were used as inputs to Metro's in-house transit forecasting model. The modeling process considers major transportation improvements, such as the opening of Phase 2 of the Silver Line to Dulles Airport and Ashburn, and the new Potomac Yard station on the Blue and Yellow Lines.

Metro extends the short-term forecasts by applying the growth rates implied in from the TPB travel demand model's ridership growth outputs. To estimate ridership beyond fiscal year 2023, Metro begins at the end of the STRF, and applies station-level compound annual growth rates to the years through 2040. These figures are derived from the forecasted rail ridership of the regional travel demand model maintained by the TPB. The growth rates consider how projected changes in population and employment across the region will affect regional travel patterns and transit ridership.

Line and segment-specific growth projections are then developed and applied to the LineLoad application, a network assignment program that collects origin-to-destination data from Metro's farebox, creates a scheduled representation of the Metrorail network, and accurately reflects station-to-station ridership and direction of travel. The tool makes assumptions about the specifics of when, and to what destination, passengers will travel in the future, to develop link-load forecasts.

Metrorail system-wide passenger demand is generally projected to grow at an average annual rate of 1.4% from 2020 to 2025 and 0.7% from 2025 to 2030 with differences by line. Ridership is expected to grow more rapidly in the early years of the plan primarily due to the openings of the Silver Line Phase 2 and Potomac Yard Station, which will add a combined seven stations to the Metrorail System.

As peak hour, peak direction line specific forecasts determine future fleet requirements, Table 2-2 translates and summarizes the system-wide forecasts into ridership growth rates for peak hour, peak-direction segments of the Metrorail system. These rates are consistent with long-term historical growth rates and assumes the short-term trends and annual fluctuations may be higher or lower than the average rate. All lines are assumed, in this analysis, to see their maximum passenger flow in the AM peak hour. As such, Metro uses the AM peak hour to define maximum service requirements and as the basis for projected future peak demand.

TABLE 2-2: FORECAST ANNUAL GROWTH RATES FOR PEAK HOUR RIDERSHIP AT MAX LOAD POINTS

		Forecast Average Annual Growth Rates		
Line	**Segment (From-To)**	**2020-2025**	**2025-2030**	**2030-2040**
Red	Judiciary Square - Gallery Place/Chinatown	2.2%	0.8%	0.7%
	Dupont Circle - Farragut North	1.3%	0.6%	0.4%
	Gallery Place/Chinatown - Metro Center	1.2%	0.7%	0.6%
Yellow	Pentagon - L'Enfant Plaza	1.7%	0.5%	0.7%
Green	Waterfront - L'Enfant Plaza	2.5%	1.2%	1.2%
	Shaw-Howard - Mt. Vernon Square	1.1%	0.8%	0.5%
Blue	Rosslyn - Foggy Bottom-GWU	2.2%	1.0%	0.6%
	L'Enfant – Smithsonian	0.6%	1.6%	1.2%
	Pentagon - Arlington Cemetery	2.5%	0.9%	0.9%
Orange	Courthouse – Rosslyn	1.8%	0.6%	0.5%
	L'Enfant – Smithsonian	2.4%	0.7%	0.8%
Silver	Courthouse – Rosslyn	1.1%	0.2%	0.4%
	L'Enfant – Smithsonian	1.7%	0.2%	1.0%
All	**System-Wide Average**	**1.4%**	**0.7%**	**0.7%**

Appendix Table A-4 shows the projected peak hour maximum passenger flow for each line in Metro's system from 2020 through 2040.

2.2. Service Levels to Meet Demand

Ridership demand drives the scheduling of peak headways and train lengths. Headways are the departure frequencies of trains originating from a given terminal and are not defined by overlapping lines. Given the interwoven, "spoke-and-wheel," system design of Metrorail, all lines except the Red Line must operate at compatible frequencies to ensure that trains can merge and diverge from interlined segments on schedule.

2.2.1 Metrorail Service Standards

To ensure that Metrorail remains a desirable choice for existing and future passengers, Metro places a premium on providing high quality service and meeting the needs of the Washington metropolitan region. Providing sufficient service to meet service standards is critical to Metro's success and fulfillment of its mission to move the region.

Metro's target revenue vehicle load for service planning purposes is at or below 100 passengers per car, which is calculated as the average passenger load over the course of one hour. 100 passengers approximately represent all seats occupied with an additional half as many standing. Metro applies the passenger load standard to the busiest segment of each route during the peak hour. The Metro Board of Directors codified this standard in adopted resolution 2012-29 on October 25, 2012 (Table 2-3):

TABLE 2-3: METRORAIL RUSH PERIOD SERVICE STANDARD

Rush Period Service Standard	Location
Passenger loads below an average of **100** passengers per car (PPC) and shall not exceed 120 PPC or fall below 80 PPC	At locations in the system where vehicle passenger loads are the greatest

Where passengers per car (PPC) exceeds an average of 100 passengers per hour across one or more maximum load points, Metro looks to provide more capacity. Consistently offering service exceeding passenger loading guidelines results in deterioration of customer satisfaction and customers foregoing trips, less reliable service as crowded trains have longer and less predictable station dwell times, and potential safety issues.

2.2.2 Service Level Requirements

Applying the 100-passenger per car service standard to the ridership forecast, Metro can estimate when additional service will be needed to meet demand. Additional capacity can be provided by increasing train lengths (up to eight cars), increasing the standard service frequency, or scheduling supplemental "tripper" trains at specific times and locations. Train frequency and system capacity impact Metro's ability to serve riders as well as the overall customer experience. With increased capacity, riders are likely to experience shorter wait times, less crowding, have a better chance of boarding, and have the option to sit more often. Over the long term, the level and quality of service customers experience also affects ridership demand.

Operating more eight-car trains, delivering more car-capacity per scheduled train, is generally preferred before increasing frequency, as explained below in section 2.3.1. Reducing headway (i.e., reduce time between trains arriving at a platform during peak service) increases the trains per hour serving a line and changes must be compatible across interconnected lines. Additionally, Metro may deploy up to two tripper trains per line to temporarily increase capacity but doing so on more than two lines is generally less practical and efficient than increasing the overall scheduled peak frequency. The crowding relief provided is uneven, only affecting a narrow window between trains in the regular schedule, and operating more than a limited number of supplemental trains can interfere with delivering reliable service due to the interconnected nature of the Metrorail network and need for compatible frequencies at system merge points.

The designated system headway level (i.e. 8-minute, 7-minute, 6-minute) is shorthand, referencing the headway for most single line segments but is not the uniform headway for all parts of the system. Notably, the Red Line operates at half the system headway and interlined segments of the Yellow, Green, Blue, Orange and Silver Lines, where two or more lines overlap, have lower effective headways. An 8-minute system headway, for example, is a system service pattern where trains leave end-of-line terminals every 8-minutes except on the Red Line, where trains depart every 4 minutes. On interlined segments, the combined headway is 2.6 to 4 minutes.

For long-term planning purposes, capacity is assumed to progress in lockstep with changes to the overall system headway. In practice, system-wide changes could be phased in over multiple years (e.g., Red Line implementation in a different year than the rest of the system) so long as compatibility is ensured between the interconnected elements of the system on the Blue, Orange, and Silver and Yellow and Green Lines.

Table 2-4 details the hourly capacity for each considered headway for two-line patterns and one-line patterns. Appendix Table A-4 shows the expected growth in hourly ridership demand from 2020 to 2040 at each maximum load point. Analyzing the forecast demand against capacity levels of different system service patterns is the basis for determining the level of service required.

TABLE 2-4: SERVICE PATTERN CAPACITY PER LINE, PASSENGERS PER HOUR

	System Headway, 100% 8-Car Trains		
Service pattern	**8-minute**	**7-minute**	**6-minute**
Two-line pattern	12,000	13,714	16,000
With 2 added trippers	*15,200*	*16,914*	*19,200*
One-line pattern	6,000	6,857	8,000
With 2 added trippers	*7,600*	*8,457*	*9,600*

Projected Metrorail ridership from 2020 through 2040 indicate the implementation of a 7-minute headway with 100% eight-car trains is needed by 2030. It enables Metro to meet demand requirements and maintain service standards while making efficient use of assets and capital investments. The 7-minute peak headway keeps all lines near 100 passengers per car and within the bounds of Metro's service standards, with limited use of trippers, through 2040. Table 2-5 summarizes historical and projected peak hour passenger flow on each trunk segment.

TABLE 2-5: PEAK HOUR PASSENGER FLOW AT MAXIMUM LOAD POINTS BY TRUNK SEGMENT, 2000-2040

Trunk Segment [13]	2000 (actual)	2005 (actual)	2010 (actual)	2015 (actual)	2020 (actual) [14]	2025 (forecast)	2030 (forecast)	2035 (forecast)	2040 (forecast)
Gallery Place – Red	12,900	12,700	12,100	11,600	12,765	13,200	13,720	14,190	14,660
L'Enfant Plaza – Yellow/Green	8,900	13,600	13,000	13,700	12,390	12,400	12,820	13,400	14,050
Rosslyn – Blue/Orange/Silver	15,500	16,100	16,800	15,400	15,375	20,910	21,530	22,075	22,620

[13] Exact maximum load points by trunk segment have shifted over time but in recent history have been located at Gallery Place, L'Enfant Plaza, and Rosslyn.

[14] Fiscal year 2020 actual ridership is based on weekday ridership in October 2019.

Even with 100% eight-car trains, demand begins to outgrow the 8-minute headway by 2027 and all lines exceed 100 passengers per car by 2030, making the transition to a 7-minute headway necessary. Developing capacity for a 6-minute headway would ensure the ability to meet levels through 2040 and beyond. Although this level of service would ensure no trippers would be needed until at least 2037, it would incur capital investment and operating costs beyond what the service standard indicates is necessary. Metro currently intends to plan capital investments to the 7-minute headway capacity level but develop options to meet a future need for 6-minute headway capacity and not take any actions that would preclude a future decision to advance it. Metro will have an opportunity to re-evaluate ridership forecasts and service needs before decisions on exercising 8000-Series expansion options must be made.

In Table 2-6, the anticipated passengers per car at the maximum load point on each line are summarized for 8-minute, 7-minute, and 6-minute headway service scenarios, with and without tripper trains. The projections use the peak hour maximum passenger flow figures for the highest volume segment on each line. Actual 2020 passenger loads are included for comparative purposes.

TABLE 2-6: FORECAST PEAK HOUR PASSENGERS PER CAR AT MAXIMUM LOAD POINTS, 2020-2040

Line	System-wide headway pattern and train lengths	2020 Actual [15]	2025 Forecast	2030 Forecast	2035 Forecast	2040 Forecast
Red	8-min headways, 6- and 8-car trains (2020 conditions)	121	127	132	136	141
	8-min headways, 100% 8-car trains		110	114	118	122
	8-min headways, 100% 8-car trains, with 2 trippers		87	90	93	96
	7-min headways, 100% 8-car trains		96	100	103	107
	7-min headways, 100% 8-car trains, with 2 trippers		78	81	84	87
	6-min headways, 100% 8-car trains		83	86	89	92
	6-min headways, 100% 8-car trains, with 2 trippers		69	71	74	76
Yellow	8-min headways, 100% 8-car trains (2020 conditions)	107	99	102	105	109
	8-min headways, 100% 8-car trains		99	102	105	109
	8-min headways, 100% 8-car trains, with 2 trippers		78	80	83	86
	7-min headways, 100% 8-car trains		87	89	92	95
	7-min headways, 100% 8-car trains, with 2 trippers		70	72	75	77
	6-min headways, 100% 8-car trains		74	76	79	82
	6-min headways, 100% 8-car trains, with 2 trippers		62	63	66	68
Green	8-min headways, 100% 8-car trains (2020 conditions)	105	108	112	118	125
	8-min headways, 100% 8-car trains		108	112	118	125
	8-min headways, 100% 8-car trains, with 2 trippers		85	89	93	99
	7-min headways, 100% 8-car trains		94	98	103	110
	7-min headways, 100% 8-car trains, with 2 trippers		76	80	84	89
	6-min headways, 100% 8-car trains		81	84	89	94
	6-min headways, 100% 8-car trains, with 2 trippers		67	70	74	78
Blue	8-min headways, 6- and 8-car trains (2020 conditions)	89	114	119	123	127
	8-min headways, 100% 8-car trains		96	101	104	107
	8-min headways, 100% 8-car trains, with 2 trippers		76	79	82	84
	7-min headways, 100% 8-car trains		84	88	91	93
	7-min headways, 100% 8-car trains, with 2 trippers		68	71	74	76
	6-min headways, 100% 8-car trains		72	76	78	80
	6-min headways, 100% 8-car trains, with 2 trippers		60	63	65	67
Orange	8-min headways, 6- and 8-car trains (2020 conditions)	109	154	158	163	167
	8-min headways, 100% 8-car trains		138	142	146	150
	8-min headways, 100% 8-car trains, with 2 trippers		109	112	115	119
	7-min headways, 100% 8-car trains		121	125	128	131
	7-min headways, 100% 8-car trains, with 2 trippers		98	101	104	107
	6-min headways, 100% 8-car trains		104	107	110	113
	6-min headways, 100% 8-car trains, with 2 trippers		86	89	91	94
Silver	8-min headways, 6- and 8-car trains (2020 conditions)	107	141	143	145	148
	8-min headways, 100% 8-car trains		115	116	118	120
	8-min headways, 100% 8-car trains, with 2 trippers		90	91	93	95
	7-min headways, 100% 8-car trains		100	101	103	105
	7-min headways, 100% 8-car trains, with 2 trippers		81	82	84	85
	6-min headways, 100% 8-car trains		86	87	89	90
	6-min headways, 100% 8-car trains, with 2 trippers		72	72	74	75

PPC < 100   PPC 100-120   PPC > 120

[15] Fiscal year 2020 actual ridership is based on weekday ridership in October 2019 and was higher than forecast levels on some lines as ridership overall increased 7% year-over-year.

2B Total Vehicle Requirements

Metro calculates the peak vehicle requirements (PVR) necessary to meet the service levels identified as necessary in future milestone years, deriving the number of trains and railcars necessary to provide a given level of service aligned with ridership demand and accepted service standards. This requirement is then used to guide decisions for fleet size, service patterns, maintenance, and infrastructure.

2.3. Peak Vehicle Requirements

Metro's Peak Vehicle Requirement (PVR) is defined as the total number of revenue vehicles required for scheduled service plus revenue vehicles required to serve as gap trains.

The total scheduled vehicle requirements for each line are a result of:

1. The scheduled train headways and number of cars per train operating on the line
2. The end-to-end running time of the line, including recovery time;
3. Allocation of vehicles for strategic gap or standby trains.

2.3.1 System Headway and Train Length Operating Plan

Metrorail service standards, the physical layout of the Metrorail System, and operational considerations largely define the operating plan by line. Metro can reliably schedule a minimum operable headway of 2.3 minutes, or a maximum of 26 trains per hour over any one segment. In practice, headways are impacted by several operating factors including junction and terminal capacity constraints, vehicle availability, station dwell times and end-of-line recovery time. Additionally, where multiple routes converge and diverge through junctions, their headways must be coordinated to ensure efficient operations.

Metro operates two types of route patterns across its six colored lines:

- Primary routes on Metrorail lines are operated from one terminal of the line to the other, stopping at all stations in between.
- Tripper trains are used where there is a sharp imbalance in passenger volumes in the peak and off-peak directions of a line, and an additional train is needed in one direction only at specific times to accommodate a regular surge in demand.

Metro previously operated short line routes to take advantage of the mid-route turnbacks (i.e. pocket tracks) built along a line to provide a higher level of service closer to the core of the system where passenger capacity is generally highest. These included short-line Red Line trips between Grosvenor and Silver Spring and using Mt. Vernon Square as a northern terminal on the Yellow Line. The short turns at Grosvenor were eliminated in January 2019 and the Silver Spring and Mt. Vernon Square turnbacks eliminated in July 2019 with service continuing to end-of-line terminals. Metro continues to operate short-line routes in certain circumstances to accommodate track work or supplement service for special events.

Metrorail service currently includes a mix of six- car and eight-car trains, varying by route, as Metro progresses to 100% eight-car train operations. The current fleet is sufficient for operation of approximately

75% eight-car trains until the 8000-Series acquisition enables fleet expansion. As peak headways already provide reasonably frequent service, increasing train lengths is preferred as the first option for adding incremental capacity before shortening the system headway, considering the following factors:

1. System design. The Metrorail system was designed to ultimately operate with eight-car trains – each station platform is 600 feet long, allowing a maximum of eight, 75-foot cars to berth at each station platform. Additionally, a number of the busiest stations, including Farragut North, Gallery Place, and Union Station, have platforms configured with entrances at the far ends. This leaves some customers more than 150 feet away from the closest rear six-car train door once on the platform, creating frustrating and potentially hazardous situations as customers hurry to try to catch trains.
2. Cost effectiveness. Lengthening trains is a cost-effective way to increase capacity as train operators account for a large share of the marginal cost of train operations. The incremental cost of adding more cars in service is lower with fewer, longer trains. For example, 24 railcars could be operated as four six-car trains or three eight-car trains; operating the cars as eight-car trains increases operator productivity and enables delivery of a higher amount of overall passenger service volume given a specific funding level.
3. Reliability and incident recovery. Prioritizing increasing train length at a given car-capacity level enables maintaining wider train spacing, allowing for more incident recovery time and a reduction in cascading delays.
4. Predictability and comfort for customers. Customers consistently respond favorably to the prospect of eight-car train operations, associating longer cars with reduced crowding. Metro has found this is more than just perception. When mixed train lengths are operated on a line, the last two cars of eight-car trains are underused as customers choose to wait on parts of platforms where they know a train will come.
5. Railcar configuration. The newest 7000-Series and forthcoming 8000-Series railcars are configured for quad operations with operator cabs only located on one end of each married pair. This complicates building consists in non-quad configurations, increasing the operational preference for eight-car train operations.

Table 2-7 shows the current scheduled and projected percentage of eight-car trains on each line. While the completion of 7000-Series deliveries will enable increases in eight-car train operations up to at least 75%, full eight-car train deployment will require additional investments in fleet, facilities and infrastructure; these improvements are discussed in further detail in Chapter 5.

TABLE 2-7: CARS PER TRAIN CONSIST

Line	% 8-Car Trains 2020	2025-2040
Red	47%	100%
Yellow	100%	100%
Green	100%	100%
Blue	37%	100%
Orange	60%	100%
Silver	25%	100%

Table 2-8 summarizes the current and projected operating plan for the milestone years of the Plan to reflect planned expansions and adherence to the current service standards. The table demonstrates the service changes projected to occur with the opening of Silver Line Phase 2.

TABLE 2-8: CURRENT AND PROJECTED SYSTEM PEAK HEADWAYS

Line	Terminal 1	Terminal 2	Pattern	# Peak Hour Peak Dir. Trips		Peak Hour Avg. Headway (min)	
				2020, 2025	2030, 2040	2020, 2025	2030, 2040
Red	Shady Grove	Glenmont	Red	15	17.1	4	3.5
	Shady Grove	Glenmont	Red Tripper	n/a	1	n/a	60
			Combined Red	15	18.1	4	33
Yellow	Huntington	Greenbelt	Yellow	7.5	8.6	8	7
Green	Greenbelt	Branch Avenue	Green	7.5	8.6	8	7
	Greenbelt	Branch Avenue	Green tripper	1	1	60	60
			Combined Green	8.5	9.6	7.1	6.3
			Combined Yellow + Green through L'Enfant Junction	16	18	3.5	3.3
Blue	Franconia	Largo	Blue	7.5	8.6	8	7
Orange	Vienna	New Carrollton	Orange A	7.5	8.6	8	7
	Vienna	New Carrollton	Orange Tripper	2	1	30	60
			Combined Orange	9.5	9.6	6.3	6.3
Silver	Wiehle	Largo	Silver Phase 1	7.5	n/a	8	n/a
	Ashburn	Largo	Silver Phase 2	7.5	8.6	8	7
			Combined Blue + Orange + Silver through Rosslyn Junction	24.5	26.7	2.4	2.2

The associated capacity, expressed in trunk segment railcars per hour during the peak hour at maximum load points, is summarized in Table 2-9.

TABLE 2-9: PEAK HOUR CAPACITY DELIVERED BY TRUNK SEGMENT AT MAXIMUM LOAD POINTS, RAILCARS PER HOUR, 2000-2040

Trunk Segment	2000 (actual)	2005 (actual)	2010 (actual)	2015 (actual)	2020 (actual) [16]	2025 (forecast)	2030 (forecast)	2035 (forecast)	2040 (forecast)
Gallery Place – Red	126	141	140	128	105	128	145	145	145
L'Enfant Plaza – Yellow/Green	80	138	141	166	116	128	145	145	145
Rosslyn – Blue/Orange/Silver	142	170	173	155	150	188	214	214	214

Table 2-10 outlines historical and projected average passengers per car by trunk segment at maximum load points, assuming Metro were to adopt 100% eight-car trains by 2025 and a 7-minute system headway by 2030.

TABLE 2-10: PEAK HOUR PASSENGERS PER CAR AT MAXIMUM LOAD POINTS BY TRUNK SEGMENT, 2000-2040

Trunk Segment	2000 (actual)	2005 (actual)	2010 (actual)	2015 (actual)	2020 (actual) [17]	2025 (forecast)	2030 (forecast)	2035 (forecast)	2040 (forecast)
Gallery Place – Red	102	90	86	91	121	103	95	98	101
L'Enfant Plaza – Yellow/Green	113	99	92	83	107	97	88	92	97
Rosslyn – Blue/Orange/Silver	109	95	98	103	103	111	101	103	106

2.3.2 Vehicle Run Times

The time required to run a route from end to end, including recovery time at each terminal, determines how many trains are required to operate a certain service frequency. Table 2-11 lists one-way travel times:

[16] Fiscal year 2020 actual capacity is based on weekday ridership in October 2019.
[17] Fiscal year 2020 actual passengers per car is based on weekday ridership in October 2019.

TABLE 2-11: ONE WAY TRAVEL TIMES OF METRORAIL ROUTES[18]

			Travel Time (minutes)		
Terminal 1	**Terminal 2**	**Line**	**Pre-Silver Line Phase 2**	**Post-Silver Line Phase 2**	**Post-Potomac Yard opening**
Red					
Shady Grove	Glenmont	Red	70	70	70
L'Enfant Junction Routes					
Huntington	Greenbelt	Yellow	51	51	52
Greenbelt	Branch Avenue	Green	51	51	51
Rosslyn/Stadium-Armory Junction Routes					
Franconia	Largo	Blue	68	68	69
Vienna	New Carrollton	Orange	62	62	62
Wiehle	Largo	Silver Line (Ph. 1)	70	n/a	n/a
Ashburn	Largo	Silver Line (Ph. 2)	n/a	93	93

2.3.3 Gap Trains

Metro stages gap trains at strategic locations in rail yards and pocket tracks for rapid deployment as needed to maintain service quality. Gap trains mitigate the impact of trains removed from service, filling "gaps" in scheduled service to avoid missed trips, or address unanticipated crowding. The trains are scheduled with assigned operators, staged ready for service, and considered part of Metrorail's peak vehicle requirement.

The majority of gap train deployments are to replace trains with in-service failures, which include mechanical problems and vandalism. Gap trains are also deployed for non-mechanical problems, including to relieve occasional unanticipated platform overcrowding and to maintain scheduled headways under degraded operation conditions, especially those that sometimes remain even after a malfunctioning train has been replaced.

Because of the later-than-expected delivery of the 7000-Series railcars, Metro reduced the number of gap trains in 2014 with the start of the Silver Line from five to three. Combined with other factors, including a reduced spare ratio, the lack of gap trains contributed to decreased service reliability during this period. As new 7000-Series railcars were placed into service from 2016 to 2020, Metro increased the number of gap trains to seven to allow for sufficient distribution across the system.

For this plan's milestone years, Metro expects to operate a combined total of ten gap and tripper trains. This is currently projected to consist of seven gap trains and three tripper trains but the allocation could change depending on the balance of needs between providing supplemental capacity (tripper trains) and supporting service reliability (gaps trains). Gap trains currently operate as a mix of six-car and eight-car trains. By 2025, all gap trains are expected to be eight-car consists, as shown in Table 2-12.

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[18] Recovery time is not included in the run-time calculation.

TABLE 2-12: GAP TRAIN REQUIREMENTS, ALL LINES

	2020	2025	2030	2040
Scheduled Gap Trains	7	7	7	7
Gap Train Vehicle Requirements	44	56	56	56

2.3.4 Peak Vehicle Calculations

Total peak period vehicle requirements are developed from peak hour, peak direction vehicle requirements, considering each route's running time, train consist requirements, and use of trippers to accommodate imbalanced peak demand. Table 2-13 summarizes, for each milestone year from 2020 to 2040, the total scheduled peak vehicle requirements by line:

TABLE 2-13: PEAK VEHICLE REQUIREMENTS, ALL LINES

Type of Service	Peak Vehicles Required for Service							
	2020		2025		2030		2040	
	Trains	Cars	Trains	Cars	Trains	Cars	Trains	Cars
Red Line Scheduled	38	264	38	304	43	344	43	344
Red Line Tripper	n/a	n/a	1	8	1	8	1	8
Gap Train	2	12	2	16	2	16	2	16
Subtotal: Red Line	**40**	**276**	**41**	**328**	**46**	**368**	**46**	**368**
Yellow Line Scheduled	15	120	15	120	17	136	17	136
Yellow Line Tripper	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gap Train	1	6	1	8	1	8	1	8
Subtotal: Yellow Line	**16**	**126**	**16**	**128**	**18**	**144**	**18**	**144**
Green Line Scheduled	15	120	15	136	17	136	17	136
Green Line Tripper	2	16	1	8	1	8	1	8
Gap Train	1	8	1	8	1	8	1	8
Subtotal: Green Line	**18**	**144**	**17**	**152**	**19**	**152**	**19**	**152**
Blue Line Scheduled	19	128	19	152	22	176	22	176
Blue Line Tripper	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gap Train	1	6	1	8	1	8	1	8
Subtotal: Blue Line	**20**	**134**	**20**	**160**	**23**	**184**	**23**	**184**
Orange Line Scheduled	18	132	19	152	21	168	21	168
Orange Line Tripper	2	12	1	8	1	8	1	8
Gap Train	1	6	1	8	1	8	1	8
Subtotal: Orange Line	**21**	**150**	**21**	**168**	**23**	**184**	**23**	**184**
Silver Line Scheduled	20	130	26	208	29	232	29	232
Silver Line Tripper	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gap Train	1	6	1	8	1	8	1	8
Subtotal: Silver Line	**21**	**136**	**27**	**216**	**30**	**240**	**30**	**240**
Total: All Lines	**136**	**966**	**142**	**1,136**	**159**	**1,272**	**159**	**1,272**
With 20% Operating Spares Ratio	*164*	*1,162*	*170.5*	*1,364*	*191*	*1,528*	*191*	*1,528*

2.4. Provision of Spare Vehicles

The operating spares ratio (OSR) is defined by the Federal Transit Administration as:

$$OSR = \frac{[TAF]-[PVR]}{PVR}$$

Where:

OSR is the Operating Spares Ratio

TAF is the Total Active Fleet

PVR is the Peak Vehicle Requirement

Providing for a sufficient quantity of spare vehicles is essential to delivering reliable service and performing a cost-effective maintenance program; meanwhile, providing too many spare vehicles would mean underutilization of high-value, long lived capital assets and suboptimal resource allocation.

The FTA establishes no formal OSR goal for rail transit fleets, allowing individual agencies to tailor their fleet requirements to meet the unique operational characteristics and service goals of each agency's environment. Metro calculates its target spare ratio based on an analysis of the vehicle requirements for various maintenance activities over the course of a typical year, and a target of meeting the full peak vehicle requirement, including gap trains, on a minimum of 95% of weekdays.

2.4.1 Requirements for Maintenance

Since 2015, Metro has made significant changes to its maintenance operations and fleet to improve service reliability and reduce unscheduled maintenance. As a result, the share of cars out of service for corrective maintenance decreased more than 30% between September 2016 and September 2019. Metro's target operating spares ratio is 20%, which is equivalent to approximately 17% of the total fleet. This target is based on the full procurement of the 8000-Series trains and continued maintenance practices improvement. The target operating spares ratio can be separated into components, expressed here as target percentages of scheduled peak vehicles based on historic rates and anticipated need.

- Out of service for Rehabilitation under the Scheduled Maintenance Program (SMP) – <u>Allow for 1.5% of peak vehicles</u>

  In following industry best practice, Metro has implemented a new Scheduled Maintenance Program (SMP) in its Railcar Rehabilitation Program. This is a continual overhaul program based on 6-year cycles for each fleet series as opposed to a traditional mid-life overhaul. At times, rehabilitation activities with overlap with legacy fleet vehicles undergoing SMP during the same years as 7000-Series railcars.

- Out of service for Periodic Maintenance and Inspection (PMI) – <u>Allow for 2% of peak vehicles</u>

  Vehicles out of service for periodic maintenance and inspections are steady and predictable due to the scheduled nature of the preventive maintenance program, and scale directly with the number of vehicles in the fleet and how much they are being operated.

- Out of service for Engineering – Allow for 1% of peak vehicles

  Metro removes cars from service to complete analysis or campaign-based modifications to correct defects and improve reliability. Although much of this activity is planned in advance to limit the impact on overall fleet availability, unpredictable systemic defects that occur throughout a car series can cause this number to shoot up significantly.

- Out of service for Parts – Allow for 2% of peak vehicles

  Metro must hold a certain number of vehicles out of service awaiting delivery of necessary parts for repair. This number fluctuates over time and does not show a cyclical or seasonal pattern. Potential spikes are considered areas for consistent management attention rather than accommodation through the spare ratio.

- Out of service for Corrective Maintenance (Repair) – Allow for 12.5% of peak vehicles

  Although Metro has reduced the number of vehicles held out of peak service for repairs, this remains the largest category of out of service vehicles. This target anticipates continued improvements in fleet availability due improvements in preventive maintenance and the railcar rehabilitation program and ongoing benefits of the replacement of the least reliable legacy railcars.

- Out of service for Miscellaneous Issues – Allow for 1% of peak vehicles

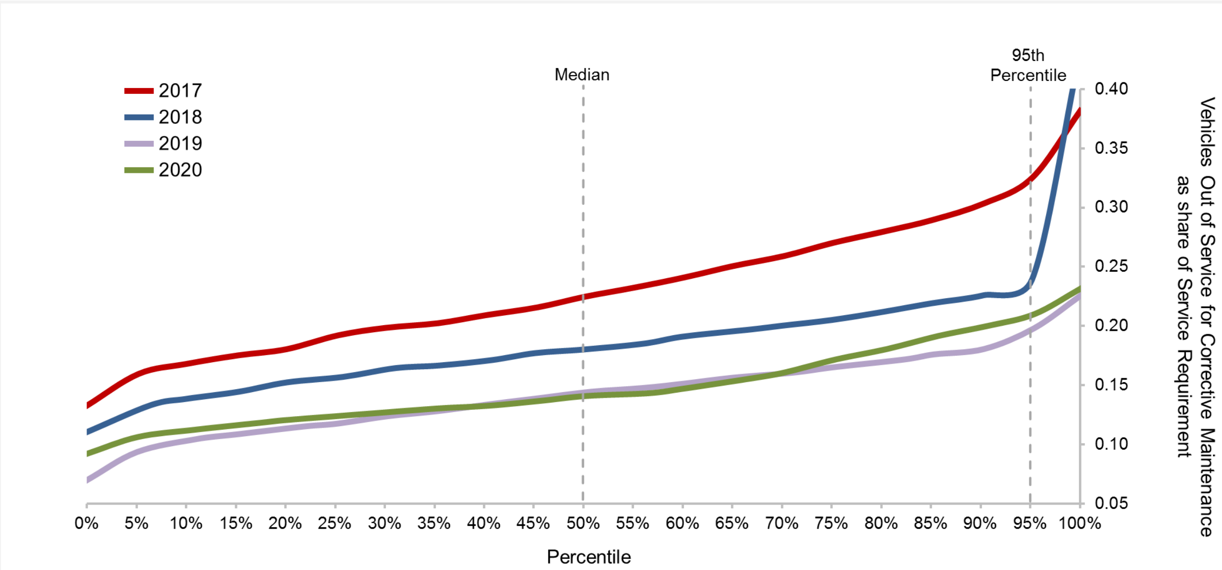
  Vehicles are held out of service for a variety of other reasons, many of which affect the availability of vehicles during peak periods due to either the urgency of the issue or the length of time needed to complete the task. Examples include downloading video footage following an onboard incident and installing advertising wraps.

To monitor vehicle availability, Metro tracks vehicle status daily using reports from its enterprise asset management system, Maximo. This provides a source of historical data for the typical vehicle requirements for various maintenance activities during AM Peak periods. Analysis of actual AM Peak vehicle status data covering multiple years shows Metro's continued improvement in corrective maintenance levels and variability. Reliability trends are described in more detail in Chapter 4.

Trainline compatibility is an additional factor affecting the operating spare ratio as 7000-Series cars cannot be mixed with other car series in a single train consist and Metro prefers to operate other cars in single-series consists due to increased reliability. This can result in having quantities of spares cleared for service that are not sufficient to assemble a full trainset of a single-series.

Figure 2-2 shows the share of revenue vehicles out of service for corrective maintenance as a share of the total vehicles required for daily service.

FIGURE 2-2: REVENUE VEHICLES OUT OF SERVICE FOR CORRECTIVE MAINTENANCE AS SHARE OF DAILY SERVICE REQUIREMENT, FY2017-FY2020[19]



As shown in this figure, there is a sharp increase in the number of vehicles required to meet peak vehicle service requirements more than 95% of weekdays. To achieve a fleet size sufficient to meet these service requirements while accounting for vehicles out of service for corrective maintenance, Metro seeks to balance efficient use of resources while providing reliable service the vast majority of days throughout the year. These considerations inform Metro's target operating spares ratio of 20% of vehicles required for peak service.

2.4.2 Total Projected Fleet Demand

The total fleet demand is calculated by combining projected peak service requirements, maintenance requirements (according to the above OSR component ratios and rounded where appropriate to reflect that railcars are permanently mated married pairs). This is provided for major milestone years from 2020 through 2040 in Table 2-14.

[19] Data shown for non-holiday weekdays with daily service requirement equal to or greater than 800 vehicles. Figure does not include vehicles out of service for parts, engineering, or periodic maintenance and inspection.

TABLE 2-14: TOTAL PROJECTED FLEET DEMAND AND SUPPLY/DEMAND BALANCE

	Total Fleet Requirements by Milestone Year			
Vehicle Requirement	**2020**	**2025**	**2030**	**2040**
Peak Vehicle Requirement (Service)	**966**	**1,136**	**1,272**	**1,272**
Out of Service for Rehabilitation (1.5%)	14	18	20	20
Out of Service for Periodic Maintenance and Inspection (2%)	20	22	26	26
Out of Service for Engineering (1%)	10	12	12	12
Out of Service for Parts (2%)	20	22	26	26
Out of Service for Miscellaneous (1%)	10	12	12	12
Out of Service for Corrective Maintenance (12.5%)	122	142	160	160
Total Maintenance Requirement	**196**	**228**	**256**	**256**
Total Fleet Demand	**1,162**	**1,364**	**1,528**	**1,528**
Projected Out of Service Ratio (% of total fleet demand)	*17%*	*17%*	*17%*	*17%*
Projected Operating Spares Ratio (% of peak vehicles)	*20%*	*20%*	*20%*	*20%*
Projected Vehicle Supply	**1,278**	**1,418**	**1,528**	**1,528**
Supply/Demand Balance [20]	116	54	0	0

[20] The surplus vehicles at the end of FY2020 include expansion vehicles to operate Silver Line Phase 2 and increase the share of trains operated as eight-car trainsets to 75% in subsequent years. A surplus is also expected at year-end 2025 as 8000-Series will be entering service during the buffer, or contingency, period before 2000-Series and 3000-Series railcars are decommissioned to account for burn in issues and the potential need for modifications.

3 Supply of Revenue Vehicles

Meeting the projected demand for revenue vehicles requires an assessment of the existing vehicle fleet to meet demand and identify potential gaps requiring resolution over the 20-year horizon of the Plan. Following the entry into service of the final 7000-Series railcars in May 2020 and the earlier retirement of the 1000-Series, 4000-Series, and 5000-Series vehicles, Metro's fleet consists of 1,278 revenue units and 190 non-revenue units (186 Maintenance of Way units and 4 revenue collection cars).

The 1000-Series through 6000-Series were designed to be fully compatible with one another, maximizing the flexibility Metro has in deploying vehicles for service. The 7000-Series represents a significant advancement in technology and cannot be fully electrically coupled with older cars for operations; rather they can only be mechanically coupled with older cars. All Metrorail vehicles are compliant with the Americans with Disabilities Act (ADA) and can operate on all revenue and non- revenue track throughout the Metrorail system.

The Federal Transit Administration establishes standards for vehicle useful life, which begins on the date a vehicle is placed in revenue service and ends when the same vehicle is removed from revenue service. For purposes of grant applications and accounting, railcars which have been purchased with federal assistance have a minimum useful life of 25 years.[21] Transit providers may also establish a National Transit Asset Management (TAM) Useful Life Benchmark, defined as the "expected lifecycle of a capital asset for a particular transit provider's operating environment, or the acceptable period of use in service for a particular transit provider's operating environment."[22] Useful life benchmarks represent the anticipated years of service for a given vehicle. Metrorail cars are considered to have a useful life benchmark of 40 years.

The actual years of service to be obtained from each railcar series varies depending on the most cost-effective strategy available to maximize their reliable service lives.[23] Figure 3-1 summarizes key characteristics of each vehicle series and further discussion of each series is provided in the following paragraphs.

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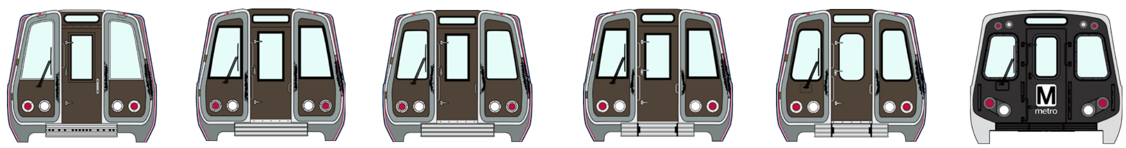
[21] Source: FTA Circular 5010 https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/32136/5010-1e-circular-award-management-requirements-7-21-2017.pdf

[22] Source: FTA Final Rule 2132-AB07 https://www.federalregister.gov/documents/2016/07/26/2016-16883/transit-asset-management-national-transit-database

[23] The vehicle specifications for the 1000-, 2000/3000-, 4000-, and 5000-Series called for a design life of 35 years; the specifications for the 6000- and 7000-Series called for a design life of 40 years. 1000-Series railcars remained in service for their full 40-year useful life, including a midlife overhaul. The 4000-Series and 5000-Series railcars were retired in lieu of midlife overhauls due to cost and reliability considerations. Following mid-life overhauls between 2003 and 2005, the 2000-Series and 3000-Series railcars are projected to have a 40-year average useful lifespan.

FIGURE 3-1: METRO VEHICLE SERIES COMPARISON[24]



Series	1000	2000 & 3000	4000	5000	6000	7000
# Purchased	300	76; 290	100	192	184	748
Entered Service	1976-1981	1984-1985; 1985-1989	1992-1994	2002-2005	2007-2009	2015-2020
Status	Retired (2016-2018)	74 in service; 276 in service	Retired (2017-2018)	Retired (2019-2020)	180 in service	748 in service
Builder	Rohr	Breda-Alstom	Breda	CAF	Alstom	Kawasaki
Dimensions: Length	75’ 0”	75’ 0”	75’ 0”	75’ 0”	75’ 0”	75’ 0”
Dimensions: Width	10’ 1.75”	10’ 1.75”	10’ 1.75”	10’ 1.75”	10’ 1.75”	10’ 1.75”
Dimensions: Height	10’ 10”	10’ 10”	10’ 10”	10’ 10”	10’ 10”	10’ 10”
Seats	80	68	68	68	A Car 64; B Car 66	A Car 62; B Car 68

FIGURE 3-2: ACTIVE VEHICLE SERIES SEATING CHARTS

2000-Series
3000-Series

6000-Series
(A Car)

7000-Series
(A Car)

[24] 8000-Series in active procurement.

3.1. Current Revenue Vehicle Fleet

Metro's fleet of revenue vehicles consists of 1,278 railcars. These cars were acquired through a series of procurements and entered service from 1976 through 2020.

3.1.1 2000/3000-Series

Seventy-six 2000-Series and 290 3000-Series railcars entered service from 1983 to 1988 after being received from Breda Construzioni Ferroviarie (Breda). The 2000/3000-Series have 68 seats per car. The series were rehabilitated by Alstom between 2003 and 2005. During the mid-life overhaul the vehicles were stripped to the bare shell and underwent comprehensive structural and mechanical inspections and evaluation. The car braking, communications, truck, and Automatic Train Operation (ATO) systems underwent mid-life overhauls. The interior liners, train-line wiring and HVAC systems were replaced, the propulsion system was converted to AC drive, and upgrades were made to the draw, couplers, auxiliary power, and air supply systems.

The 2000/3000-Series is expected to have a useful life of 40 years, with replacement anticipated to be completed by the end of FY2028. Reliability of the 2000/3000-Series improved following their 20-year mid-life rehabilitation, and Metro plans to keep them in service for their full-rehabilitated lifespan.

3.1.2 6000-Series

The 6000-Series vehicles were manufactured by Alstom. A total of 184 6000-Series railcars entered service from 2006 to 2008. The 6000-Series incorporate substantial structural and mechanical improvements when compared to previous series, informed by Metro's accumulated experience with the performance of each of these vehicle sub-systems. 6000-Series includes an advanced Vehicle Monitoring System (VMS) that is compatible with those in the 2000-, 3000-, and 5000-Series. As of 2020, the 6000-Series continues to have a strong reliability record.

The 6000-Series vehicles were designed with a 40-year lifespan and initiated heavy maintenance through the Scheduled Maintenance Program in FY2020, which will be repeated on a six-year cycle.

3.1.3 7000-Series

The 7000-Series was manufactured by Kawasaki. A total of 748 7000-series railcars entered service between 2015 and 2020. The production schedule for the 7000-Series was delayed by supply chain issues primarily associated with the 2011 Tōhoku earthquake and tsunami in Japan, resulting in vehicles not arriving in time to support Silver Line Phase 1 opening as planned. The 7000-Series cars were received in 6 phases to meet varying demands:

- Silver Line Phase 1: 64 cars
- Replacements for the 1000-Series: 300 cars
- Replacements for the 4000-Series: 100 cars
- Replacements for the 5000-Series (1): 130 cars
- Replacements for the 5000-Series (2) + Growth for eight-car trains: 90 cars
- Silver Line Phase 2: 64 cars

The new 7000-Series cars are maintained as married pairs and operated in sets of two married pairs (quads).

Only A-cars of the 7000-Series contain full operating cabs, which enables greater total passenger capacity. “Quads” are arranged in an A-B-B-A orientation, and two quads can be combined to form an eight-car train consist. The 7000-Series vehicles incorporate state-of-the-art crash energy management design features, and shift to roof-mounted HVAC modules (in lieu of the split system in use on older car series) to ease maintenance.

The 7000-Series cannot be fully electrically coupled for interoperability with earlier car series (rather, they can only be mechanically coupled to facilitate emergency train movements if needed). This limitation allows Metro to take advantage of modern, state-of-the-art trainline technology, rather than mandating compatibility with the 1970s-1980s standard in use on the older car series. This new technology offers dramatically enhanced communications capabilities, includes improved car mechanical diagnostics, and wireless car health data transfer.

3.2. Retired Revenue Vehicle Fleet

Starting in 2016, Metro began to retire several vehicles from its revenue fleet in order to improve reliability and operations. As the 7000-Series units were delivered, commissioned, and proved reliable Metro retired the 1000-Series, 4000-Series, and 5000-Series. The 1000-Series had reached and exceeded their useful life benchmark of 40 years while the 4000-Series and 5000-Series vehicles were retired early due to excessive reliability issues. Metro retained the first two cars of each series for historical and educational purposes.

3.2.1 1000-Series

The Rohr cars (1000-Series) were the first revenue rail fleet vehicles acquired by Metro, and were first put into operation with the opening of the Red Line in 1976. Each car had 80 seats. The 1000-Series vehicles underwent a major overhaul between 1994 and 1997, which was designed to improve their reliability and modernize key car components. The 1000-Series were projected to have a useful life of approximately 40 years. Metro began the retirement of the 1000-Series in 2016 and completed their retirement in 2018.

1000-Series vehicles were involved in incidents in which their passenger compartments suffered significant damage as a result of the railcars “telescoping” when impacted. Following the Ft. Totten accident in 2009, Metro instituted a policy to only operate the 1000-Series vehicles within the middle of train consists (otherwise known as the “belly” position) until their eventual replacement in 2016. These vehicles were decommissioned as the 7000-Series cars were received and commissioned for service. Of the 300 purchased, 298 have been decommissioned to date, and the remaining two are maintained for historical significance.

3.2.2 4000-Series

Breda was also the supplier for the 100 4000-Series vehicles which entered service between 1992 and 1993. The 4000-Series were originally intended to have a lifespan of 35 years. As such, they would normally have been expected to receive a mid-life overhaul around 2012. However, Metro retired these cars in 2017 and 2018, replacing them with new 7000-Series cars in lieu of a mid-life overhaul.

This car series experienced the lowest reliability performance in the Metro fleet. Because of the relatively small size of the fleet (100 cars), the cost-per-car to perform a major mid-life rehabilitation would have been relatively high, while the marginal cost of purchasing an additional 100 railcars on the 7000-Series contract was comparatively low, due to the amortization of startup and engineering costs.

The 7000-Series cars have a projected lifespan of 40 years, whereas overhauled 4000-Series cars would only have an expected remaining lifespan of perhaps 15 years. For these reasons, the 4000-Series cars were decommissioned. Two of these cars remain as part of the non-revenue fleet for historic preservation purposes.

3.2.3 5000-Series

The 5000-Series was constructed by Construcciones y Auxiliar de Ferrocarriles S.A. (CAF) and entered service between 2001 and 2004. A total of 192 5000-Series vehicles were constructed. This series was delivered with several unique design features such as an all-aluminum structure and the first on-board diagnostic system (though the 2000/3000-Series received such a system as part of their mid-life overhaul). The addition of these vehicles to the fleet coincided with the opening of the central portion of the Green Line and the extension of the Green Line to Branch Avenue.

In subsequent years, the 5000-Series displayed below average reliability and required greater than expected engineering and maintenance effort to maintain acceptable performance. Metro undertook an analysis in 2014-2015 to evaluate the expected costs and benefits of performing a major mid-life rehabilitation of the 5000-Series cars, which would have been due by approximately 2020. The costs and benefits of multiple overhaul approaches were compared against two avenues of replacing the 5000-Series in lieu of rehabilitation: exercising two contract options on the ongoing 7000-Series procurement of new cars, or initiating a new railcar procurement for a base order of 192 cars.

This analysis indicated that the optimal choice on the basis of capital cost per car, expected operating costs, and expected service reliability was to replace the 5000-Series by exercising the final two contract options for new 7000-Series cars. In spring 2015, Metro reached agreement with its member jurisdictions and the Federal Transit Administration to adopt this strategy. Delivery and acceptance of the replacement cars took place in 2019 which allowed the retirement of all 5000-Series cars. Two cars remain in Metro's non-revenue fleet for historic preservation purposes.

3.3. Adjustments to Vehicle Supply

From 1974 to the present, Metro has purchased 1,890 railcars. Through FY2020, 600 of these cars have been decommissioned, generally as part of the fleet replacement strategy outlined previously in Section 3.2. All 1000-Series, 4000-Series and 5000-Series railcars have been decommissioned through this approach, totaling 592 total vehicles no longer in service. A small number of vehicles have been decommissioned outside of these series-wide retirements, typically as a result of irreparable damage. Most of these 600 decommissioned vehicles were disposed of, although a handful now serve other functions (such as first-responder training). At the completion of the 7000-Series delivery, the Metrorail fleet is comprised of 1,278 railcars. Vehicles not available for service are subtracted from the fleet size before calculating the fleet spare ratio. Vehicles decommissioned, converted to another purpose, or not available for service use fall into the following categories:

3.3.1 Damaged and Disposition-Pending Vehicles

Eight 3000-Series vehicles have sustained irreparable damage and have been decommissioned[25]. These vehicles were decommissioned following the conclusion of investigations by the National Transportation Safety Board (NTSB) and Metro's insurance carrier.

Of these eight vehicles, six have been decommissioned and disposed of, and two are used for safety training purposes at Metro's Carmen Turner Facility.[26] Six other 3000-Series vehicles were involved in a collision on October 7, 2019 and are likely to be decommissioned due to the age of the cars and the prohibitive cost of potential repairs.[27] Two 6000-Series vehicles sustained major damage after a derailment in a storage yard, but are currently undergoing repairs and are expected to return to revenue service.[28]

3.3.2 Revenue Collection Vehicles

The Metrorail system is designed such that transporting money and fare media between passenger stations and the Treasury facilities is best accomplished by train. The Treasury facilities are directly accessible by train, and the money carts (wheeled vaults) in each station are stored in lockers at the platform level for easy access by money collection trains. Because money distribution and collection are performed during off-peak revenue hours when passenger trains are still in service, safety and operating considerations dictate that the money trains must have the same operating characteristics as the passenger trains among which they must run.

Revenue collection vehicles are modified so that seats, carpets, windscreens, and stanchion bars are removed; steel plates with tie-down rings are fitted over the floors. Bump rails are also installed to keep carts away from interior liners, and shotgun racks are installed for the use of security personnel.

As of the conclusion of FY2020, Metro has a total of four vehicles designated for revenue collection: two such vehicles converted from 2000-Series trains, and two such vehicles converted from 6000-Series trains. As the time approaches, if more revenue collection vehicles are required, Metro will review the matter and conduct another cost-benefit analysis of all options, including purpose-built vehicles and modifying existing passenger railcars for revenue collection purposes.

3.3.3 Overhaul Float

In the past, Metro would have to plan vehicle supply schedules to accommodate a "float" of vehicles out of service for midlife overhauls. The new Scheduled Maintenance Program has replaced midlife overhauls, rehabilitating vehicles on an ongoing basis and eliminating the need for one-time adjustments to accommodate these activities.

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[25] The eight decommissioned 3000-Series vehicles are railcars 3191, 3216, 3217, 3252, 3256, 3257, 3036 and 3037. Railcars 3191 and 3252 were involved in a collision on January 6, 1996. Railcars 3256, 3257, 3036 and 3037 were involved in a collision on June 22, 2009. Railcars 3216 and 3217 were involved in a collision on November 29, 2009.

[26] Railcars 3191 and 3252.

[27] Railcars 3008-3009, 3206-3207, and 3120-3121.

[28] Railcars 6050-6051.

3.3.4 Not Ready for Service

As new railcars are received, the cars undergo a series of tests and procedures to determine if the car is fit for service or requires minor issues to be addressed before going into service. In rare instances, vehicles may be returned to the manufacturer for major defects or significant damage during shipping and delivery. As these cars move through evaluation, they are deemed "not ready for service", but are counted in the overall fleet allotment.

3.3.5 Historical Significance

Metro maintains ownership of the first two cars of each series for historical significance and reference. Metro intends to continue this practice for each series as they are retired. Other decommissioned vehicles are used by public and private organizations for historical purposes or adaptive uses.

3.4. Existing and Planned Procurements

The projection of Metrorail vehicle supply considers the projected revenue vehicle demand and vehicle retirement plan. During the 2020 to 2040 Plan horizon, Metro will initiate one new rail vehicle procurement (referred to here as the 8000-Series) and begin preparation for additional replacements and expansions (referred to here as the 9000-Series).

3.4.1 8000-Series Railcar Procurement Program

Metro is in the process of procuring its next series of vehicles, known as the 8000-Series. The procurement will enable the replacement of the 366 originally purchased 2000-Series and 3000-Series railcars and the acquisition of additional railcars to accommodate fleet growth due to increased service requirements. Although not currently planned, the acquisition could also enable the early retirement of 6000-Series vehicles, which would most likely be undertaken to acquire vehicles compatible with a next generation train control system in lieu of retrofitting the 6000-Series vehicles. The procurement is structured with a base level and four options, with the potential to adjust option quantities prior to execution, to provide flexibility to meet Metro's needs.

The 8000-Series base order and initial option quantities will comprise up to 800 railcars:

- Base (256 cars)
- Option 1 (104)
- Option 2 (104)
- Option 3 (120)
- Option 4 (216)

The current long-term operating plan could be accommodated as follows with slight adjustments to the quantities of the option levels. Metro will need to exercise the base and Option 1 as planned to replace the 2000-Series and 3000-Series railcars (366). Options 2 and 3 would be exercised to achieve the capability for 7-minute headways (234). Option 4 would provide enough railcars for 6-minute headway operations or replacement of the 6000-Series railcars (184). The maximum order of 800 could also accommodate acquisition of 16 contingency railcars in addition to the other categories.

3.4.2 9000-Series Railcar Procurement Program

After the 8000-Series procurement, the next potential railcar procurement in the 20-year time horizon of the fleet plan is the 9000-Series. The 9000-Series procurement could be timed to replace the 6000-Series at the end of their 40-year lifespan between 2046 and 2048 and provide additional fleet expansion capabilities beyond 2040, if warranted. Alternatively, an accelerated schedule could be considered in the 2030s for a combination of fleet expansion, early retirement of existing vehicles, or replacement for compatibility with a potential next generation train control system.

3.4.3 Contingency Fleets, Retirements, and Procurement

Metro recognizes that newly-procured vehicles may require up to two years after their acceptance and entry into regular service to be "burned in", allowing maintenance staff and operators to identify and react to vehicle performance issues that may arise during revenue operations. Because of this, Metro phases its car replacement programs such that the older cars being replaced are not immediately retired on a one-to-one basis with the arrival of new cars; rather, the one-for-one retirement of older cars commences once the replacement cars have been in service long enough to establish their reliability. In some cases, this approach may result in apparent short-term increases in the size of the total fleet above the level needed to meet peak vehicle demand or impact the target operating spares ratio. However, beyond delaying retirement of old cars during a new car delivery, Metro does not plan to maintain any long-term "contingency fleets" of older vehicles beyond their useful life benchmark.

3.5. Summary of Vehicle Supply Plan

Table 3-1 presents a summary of the expected service lifespan of each vehicle series, including a summary of whether and when a series had or will receive a major mid-life rehabilitation. Table 3-2 presents a summary schedule of the proposed vehicle acquisitions, fleet adjustments, and retirements by year for FY2015-FY2040.

TABLE 3-1: VEHICLE LIFE EXPECTANCY BY FISCAL YEAR

Vehicle Series	Vehicle manufacturer	Number of vehicles	Fiscal Year Entered Service	Approx. Mid-life Overhaul Year	Useful Life Benchmark (years)	Expected End of Useful Life[29]
2000	Breda	70	1984	2004	40	2024
2000	Breda	6	1985	2005	40	2025
3000	Breda	84	1985	2005	40	2025
3000	Breda	90	1986	2006	40	2026
3000	Breda	48	1987	2007	40	2027
3000	Breda	62	1988	2008	40	2028
3000	Breda	6	1989	2009	40	2029
6000	Alstom	82	2007	-	40	2047
6000	Alstom	98	2008	-	40	2048
6000	Alstom	4	2009	-	40	2049
7000	Kawasaki	24	2015	-	40	2055
7000	Kawasaki	116	2016	-	40	2056
7000	Kawasaki	216	2017	-	40	2057
7000	Kawasaki	192	2018	-	40	2058
7000	Kawasaki	128	2019	-	40	2059
7000	Kawasaki	72	2020	-	40	2060
8000	Hitachi	256-800	2025-	-	40	2065-

[29] Actual year of retirement may vary from the useful life benchmark depending on fleet demands, lags between delivery and entrance to service, and other factors. In some cases, there may be a year or more gap between the delivery of a vehicle and its entrance into revenue service.

TABLE 3-2: SUMMARY OF PROPOSED RAILCAR ACQUISITIONS, ADJUSTMENTS, AND RETIREMENTS BY FISCAL YEAR [30, 31]

Car Series		FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032	FY2033	FY2034	FY2035	FY2036	FY2037	FY2038	FY2039	FY2040
1000-Series	1000-series fleet owned by WMATA (start of year)	288	285	242	65	6	6	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	1000-series adjustments for revenue collection	-4	-4	-6	-6	-4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1000-series adjustments for historical preservation	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	1000-series revenue vehicles (start of year)	284	281	234	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1000-series retirements	3	43	177	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1000-series retirements (vehicles not in revenue service)	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1000-series revenue vehicles on-site (end of year)	281	238	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000-Series	2000-series fleet owned by WMATA (start of year)	76	76	76	76	76	76	76	76	76	76	76	76	4	4	4	2	2	2	2	2	2	2	2	2	2	2
	2000-series adjustments for revenue collection	0	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	0	0	0	0	0	0	0	0	0	0
	2000-series adjustments for historical preservation	0	0	0	0	0	0	0	0	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	2000-series revenue vehicles (start of year)	76	76	76	74	74	74	74	74	74	74	72	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2000-series retirements	0	0	0	0	0	0	0	0	0	0	0	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2000-series retirements (vehicles not in revenue service)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	2000-series revenue vehicles on-site (end of year)	76	76	76	74	74	74	74	74	74	74	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3000-Series	3000-series fleet owned by WMATA (start of year)	288	282	282	282	282	282	282	276	276	276	276	276	204	60	2	2	2	2	2	2	2	2	2	2	2	2
	3000-series adjustments for revenue collection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3000-series adjustments for historical preservation	0	0	0	0	0	0	0	0	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	3000-series adjustments for disposition-pending vehicles	0	0	0	0	0	-6	-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3000-series revenue vehicles (start of year)	288	282	282	282	282	276	276	276	276	276	274	274	202	58	0	0	0	0	0	0	0	0	0	0	0	0
	3000-series retirements	6	0	0	0	0	0	0	0	0	0	0	72	144	58	0	0	0	0	0	0	0	0	0	0	0	0
	3000-series retirements (vehicles not in revenue service)	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3000-series revenue vehicles on-site (end of year)	282	282	282	282	282	276	276	276	276	276	274	202	58	0	0	0	0	0	0	0	0	0	0	0	0	0
4000-Series	4000-series fleet owned by WMATA (start of year)	100	100	100	74	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	4000-series adjustments for revenue collection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4000-series adjustments for historical preservation	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	4000-series revenue vehicles (start of year)	100	100	98	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4000-series retirements	0	0	26	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4000-series revenue vehicles on-site (end of year)	100	100	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5000-Series	5000-series fleet owned by WMATA (start of year)	192	192	192	192	192	10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	5000-series adjustments for revenue collection	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5000-series adjustments for historical preservation	0	0	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	5000-series revenue vehicles (start of year)	192	192	192	192	190	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5000-series retirements	0	0	0	0	182	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5000-series revenue vehicles on-site (end of year)	192	192	192	192	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6000-Series	6000-series fleet owned by WMATA (start of year)	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184
	6000-series adjustments for revenue collection	0	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4
	6000-series temporary adjustments for damaged vehicles	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	0	0	0	0	0	0	0	0	0	0	0
	6000-series revenue vehicles (start of year)	182	182	182	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
	6000-series retirements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6000-series revenue vehicles on-site (end of year)	182	182	182	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
7000-Series	7000-series fleet owned by WMATA (start of year)	0	24	140	356	548	676	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748
	7000-series revenue vehicles (start of year)	0	24	140	356	548	676	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748
	7000-series deliveries	24	116	216	192	128	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7000-series revenue vehicles on-site (end of year)	24	140	356	548	676	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748
8000-Series	8000-series fleet owned by WMATA (start of year)	0	0	0	0	0	0	0	0	0	0	0	144	288	432	576	600	600	600	600	600	600	600	600	600	600	600
	8000-series revenue vehicles (start of year)	0	0	0	0	0	0	0	0	0	0	0	144	288	432	576	600	600	600	600	600	600	600	600	600	600	600
	8000-series deliveries	0	0	0	0	0	0	0	0	0	0	144	144	144	144	24	0	0	0	0	0	0	0	0	0	0	0
	8000-series revenue vehicles on-site (end of year)	0	0	0	0	0	0	0	0	0	0	144	288	432	576	600	600	600	600	600	600	600	600	600	600	600	600
Total Fleet All Series	Fleet owned by WMATA (start of year)	1128	1143	1216	1229	1290	1236	1296	1290	1290	1290	1290	1434	1434	1434	1520	1542	1542	1542	1542	1542	1542	1542	1542	1542	1542	1542
	Est. annual adjustments	-6	-6	-12	-16	-16	-22	-18	-12	-12	-12	-16	-16	-16	-16	-16	-14	-14	-14	-14	-14	-14	-14	-14	-14	-14	-14
	Revenue vehicles (start of year)	1122	1137	1204	1213	1274	1214	1278	1278	1278	1278	1274	1418	1418	1418	1504	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528	1528
	Deliveries	24	116	216	192	128	72	0	0	0	0	144	144	144	144	24	0	0	0	0	0	0	0	0	0	0	0
	Retirements	9	43	203	129	182	8	0	0	0	0	0	144	144	58	0	0	0	0	0	0	0	0	0	0	0	0
	Retirements (vehicles not in revenue service)	0	0	0	2	0	4	6	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Revenue vehicles (end of year)	**1137**	**1210**	**1217**	**1276**	**1220**	**1278**	**1278**	**1278**	**1278**	**1278**	**1418**	**1418**	**1418**	**1504**	**1528**	**1528**	**1528**	**1528**	**1528**	**1528**	**1528**	**1528**	**1528**	**1528**	**1528**	**1528**
	% of revenue vehicles past useful life (end of year)	**0.0%**	**1.7%**	**2.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**5.3%**	**10.4%**	**6.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
	Average revenue fleet age (end of year)	23.6	21.7	16.2	13.1	12.3	12.5	13.4	14.3	15.3	16.2	15.3	12.1	8.9	7.8	8.6	9.5	10.5	11.4	12.4	13.4	14.3	15.3	16.2	17.2	18.1	19.1

[30] Based on delivery schedules for 8000-Series, retirement of 2000-Series and 3000-Series vehicles, and completion of 7000-Series delivery in FY2020. Forecast assumes retirement of older vehicles in coordination with delivery of new vehicles, while growing fleet to meet ridership demand. Deliveries reflect the fiscal year vehicles entered revenue service.

[31] In FY2020, four 1000-Series railcars were retired and removed from the fleet inventory after having served as revenue collection vehicles. Those vehicles were cars 8002, 8003, 8004 and 8005 and were removed as of May 20, 2020.

4 Maintenance and Reliability

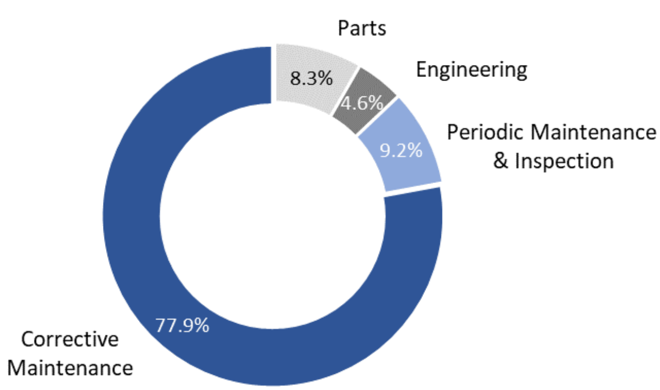
This section provides greater detail regarding the approach to railcar maintenance and rehabilitation to sustain a reliable fleet that underpins the target spare ratio.

Each day, in the same manner that a given number of vehicles is required to provide service to passengers, a given number of vehicles is required by Metro's railcar maintenance staff to maintain a reliable fleet. Metro car maintenance staff track vehicles out of service in real-time according to the following high-level categories:

- Vehicles out of service for rehabilitation under the Scheduled Maintenance Program (SMP)
- Vehicles out of service for corrective maintenance
- Vehicles out of service undergoing Periodic Maintenance & Inspections
- Vehicles out of service for engineering analysis or campaign-based modifications
- Vehicles out of service awaiting the delivery of parts

While Metro car maintenance works around the clock, the most critical aspect of car availability for the purposes of the fleet management plan is the extent to which vehicles are not available to operate during peak periods. On a typical weekday at 07:00 AM, the reasons for vehicles out of service break out as follows:

FIGURE 4-1: TYPICAL WEEKDAY PEAK OUT OF SERVICE REQUIREMENT[32]



[32] Source: 7AM non-holiday weekday "RCAR" Maximo Report, May 2016-September 2019. Overall non-holiday weekday percent out-of-service average is 18.51% for the same timeframe. Corrective Maintenance otherwise referred to as "repairs." Vehicles undergoing SMP are included within total for vehicles out of service for Periodic Maintenance & Inspection.

The following subsections describe Metro's Preventive Maintenance & Inspection (PMI) program, the Scheduled Maintenance Program, its approach to Corrective Maintenance, its engineering campaign strategy, and other reliability-centered initiatives.

4.1. Preventive Maintenance

The Preventive Maintenance and Inspection (PMI) Program constitutes the core strategy in maximizing the reliability of vehicles in revenue service and reducing the maintenance spares requirement. The PMI Program comprises all periodic (scheduled) progressive inspection, servicing and cleaning activities needed to meet the inspection requirements defined by the vehicle manufacturer.

4.1.1 Inspections

Scheduled inspections are the basis of Metro's PMI Program. An inspection of the vehicle includes a visual and mechanical inspection, system tests and servicing of mechanical components. Inspections also include replacement of components based on the recommendations of respective manufacturers. Defects identified during this inspection are corrected prior to the release of the vehicle from maintenance.

The Metro PMI Program contains four inspection types performed on each car at varying intervals, as summarized in the table below.

TABLE 4-1: OVERVIEW OF PREVENTIVE MAINTENANCE INSPECTIONS[33]

Inspection Type	Scheduled Inspection Interval	Average Interval (Mileage)	Standard Inspection Time (Hours)	Standard Inspection Labor Time (Hours)
Daily	24 hours	166	0.5	0.5
A	60 days / 90 days*	10,000 / 15,000*	24	30
B	Semi-Annual	30,000	24	46
C	Annual	60,000	36	60

** - 7000-Series trains*

In past inspection schedules, vehicles were scheduled for inspections to occur at various intervals: every 24 hours (daily); every 30 days (intermediate); every 90 days (type A inspection); semi-annually (type B inspection); and annually (type C inspection). In an update to the Metro PMI Program, the intermediate inspection has been eliminated and the type A inspection – which previously occurred every 90 days – now occurs every 60 days for 2000-Series, 3000-Series, and 6000-Series vehicles. Type A inspections continue to occur every 90 days for 7000-Series trains.

Daily inspections occur each day on vehicles released for service. These inspections are typically performed after PM peak service concludes and prior to the time the system begins revenue operations again the

[33] Some variability exists in the exact tasks and requirements related to inspections of each different car series.

next morning. Given the scope and time requirements of the Type A, B and C inspections, vehicles undergoing these preventive maintenance tasks are withheld from peak service for one to two days. These inspections typically occur Monday through Friday over the course of four working shifts.

A brief summary of periodic maintenance activities follows:

> Daily Inspection: The Daily inspection consists of a safety test of the car-borne automatic train control equipment, visual inspection of the interior and exterior of the car, and a functional test of safety-critical and passenger convenience-related components such as lighting, the public address system and emergency evacuation equipment. Defects are addressed prior to releasing the car for service. Graffiti removal is a top priority: Metro aims to never release a car for service with graffiti or vandalize equipment. Daily inspections are typically performed in the yard as opposed to inside the shop facility.
>
> Type A Inspection: Prior to technical inspection, under-car equipment is cleaned to enhance the quality of the inspection. Blow pits with compressed air hoses are provided at each service and inspection facility to blow carbon dust out of traction motors and generators. Blow pits also have hot water wash equipment to remove grease and dirt from mechanical components such as air conditioning condenser coils, couplers and wheel trucks. Following the cleaning process, designated system components are inspected for serviceability and are functionally tested.
>
> Type B Inspection: This includes all the requirements of the Type A inspection. Additional tasks include but are not limited to: a detailed door inspection and adjustment check, a detailed coupler and draft gear inspection, and other servicing and adjustments not required as frequently as in the previous inspections.
>
> Type C Inspection: This encompasses all the requirements of previous inspections and adds routine overhaul of selected electrical and mechanical components. The equipment to be overhauled is removed and replaced in compliance with the inspection procedure published by the Office of Chief Engineer, Vehicles (CENV). Removed components are sent to the appropriate overhaul shop (either Greenbelt or Brentwood).

The specific inspection and preventive maintenance requirements differ somewhat by car series, which results in each car series having unique PMI mechanic training, equipment, and materials requirements. In the interest of efficiency and to minimize duplicative resources not to duplicate vehicle specific resources, Metro assigns each car series to a specific “home” Service & Inspection (S&I) shop for A, B, and C inspections, as shown in Table 4-2:

TABLE 4-2: PERIODIC INSPECTION BLOCK ASSIGNMENT BY S&I SHOP [34]

S&I Shop	2000-Series	3000-Series	6000-Series	7000-Series	Total
Shady Grove	30	-	182	174	386
Alexandria	12	98	2	68	180
West Falls Church	14	120	-	56	190
New Carrollton	10	64	-	116	190
Greenbelt	10	-	-	334	344
Total	**76**	**282**	**184**	**748**	**1,290** [35]

In this context, the "home" shop does not describe a physical location the vehicle returns to each night, but instead describes the locations for periodic inspections to be performed on a given vehicle series. Each shop typically performs from one to three periodic inspections a day.

4.1.2 Cleaning

Most cleaning is performed during off-peak and non-revenue hours, although some is done while the vehicle is out of service for other inspections.

There are three levels of interior cleaning, as well as an exterior cleaning. When possible given schedule constraints and train wash availability, exterior washing is accomplished by train operators taking their trains through the automatic train wash as they return to the yard following passenger service. Cars with serious graffiti or other vandalism are removed from service immediately. Metro has experienced only a few incidents of major graffiti on railcars in service, and its removal requires a major effort that is outside the scope of this routine cleaning program. Additionally, Metro performs a monthly disinfection of railcars which includes the wiping down of all frequently touched surfaces[36].

The three types of interior cleaning are performed as follows:

Terminal cleaning: Basic cleaning performed on a train when it reaches a terminal, before re-entering service. This cleaning includes the removal of trash and newspaper. Train cleaning personnel are assigned to terminal stations to perform this task. They also provide emergency spot cleaning and alert the Terminal Supervisor to more extensive cleaning requirements that may warrant removing the train from service temporarily. This cleaning occurs from 7:00am to 11:00pm, Monday through Friday.

[34] Figures shown reflect point-in-time information from Reliability Centered Maintenance Planning (RCMP) as of May 29, 2020. Periodic inspection block assignments change over time with operational requirements and fleet size.

[35] Metro's active revenue fleet consists of 1,278 railcars. Two 2000-Series vehicles and two 6000-Series vehicles are currently designated for revenue collection purposes, and are assigned to Alexandria. Two 6000-Series vehicles are out for long-term repair and will be assigned to track inspection. Six 3000-Series railcars are pending decommission.

[36] At the time of this document's publication, Metro's disinfection techniques and schedules have been adapted to respond to the ongoing COVID-19 pandemic. Every railcar is disinfected daily before entering revenue service, and electrostatic sprayers are used to disburse the approved disinfectant. The operator's cab is also disinfected in the course of this cleaning.

Midday Layover Cleaning: This cleaning includes sweeping, the wiping of surfaces and the mopping of 192 railcars during weekday mid-day layovers.

Heavy Duty Cleaning: This task is performed in conjunction with the Type A inspection, every 60 days for 2000-Series, 3000-Series and 6000-Series vehicles and every 90 days for 7000-Series vehicles. The interior of the car is thoroughly cleaned. The walls, ceiling, windows, light fixtures, and seats are hand washed with detergent, and the carpet is shampooed.

4.2. Railcar Rehabilitation

Metro utilizes a Scheduled Maintenance Program (SMP) for railcar rehabilitation, wherein railcars are rehabilitated on a recurring six-year cycle. In previous maintenance practices, specific sub-systems and components were replaced during periodic inspections or in accordance with manufacturer recommendations. As a result, railcars underwent this type of maintenance over the course of multiple separate occasions. By consolidating all major sub-system replacement under a single scheduled maintenance operation, Metro achieves gains in efficiency and ensures that all sub-systems are maintained in a state of good repair.

Previously, railcars were not comprehensively overhauled until their estimated mid-life point of 20 years. Through the SMP, railcars will be maintained in a state of good repair throughout their anticipated useful life benchmark. Additionally, Metro will utilize the SMP to introduce targeted improvements to achieve enhanced reliability, maintainability and a positive customer experience. For example, 6000-Series vehicles will undergo seat replacement and the introduction of LED interior lighting, while 7000-Series vehicles will undergo the installation of improved video camera systems.

In the past, 20-year mid-life railcar overhauls cost approximately 70% of the cost of an entirely new railcar. With newly instituted six-year SMP cycles, railcar rehabilitation will become more frequent, improving reliability and reducing rehabilitation costs. With the installation of more energy efficient sub-systems and components, energy consumption will also be reduced. The planned opening of the HR&O facility will expand Metro's capacity to perform the railcar rehabilitation activities associated with the SMP. Other periodic inspections and repairs will continue as outlined in Section 4.1.1.

With an established and coordinated railcar rehabilitation process, Metro is able to drive process improvements and better maintain the overall appearance of cars in service. It is anticipated that this approach will also allow for increased railcar rehabilitation throughput and efficiency gains by creating predictability in material acquisition. The SMP also utilizes railcar-specific performance measures to support a process of continued improvement.

4.2.1 Current Scheduled Maintenance Program (SMP) Rehabilitation Status by Series

As Metro transitions its overhaul process to the approach outlined above, rehabilitation schedules and scope within the SMP vary by vehicle series. Older vehicles within Metro's fleet are currently in the process of being rehabilitated, and this work will recur within six-year cycles.

- 2000/3000-Series

Vehicles in the 2000-Series and 3000-Series began to undergo rehabilitation within the SMP starting in FY2018. Specific efforts include overhauling air compressors, HVAC systems and truck assemblies.

- 6000-Series

  From FY2019 to FY2021, all 6000-Series railcars are planned to be rehabilitated as part of the SMP. Vehicles that have undergone SMP have seen notably improved performance as measured by MDBF.

- 7000-Series

  As they are the newest vehicles in the fleet, 7000-Series railcars have not yet undergone rehabilitation within the SMP. Metro forecasts 7000-Series railcars to begin rehabilitation in FY2022. Due to the size of the 7000-Series fleet, these rehabilitation efforts are anticipated to take six years to complete. The first round of 7000-Series rehabilitations will conclude in FY2026, and the SMP will run continuously for the life of this series of vehicles. Material and equipment requirements will be defined in advance, and planning efforts for this round of rehabilitation are currently underway.

4.3. Corrective Maintenance and Fleet Reliability

Metro's preventive maintenance and railcar rehabilitation programs aim to reduce failures and minimize the impact of unscheduled corrective maintenance on vehicle availability. Unscheduled maintenance is triggered by failures identified on out of service vehicles, such as during daily safety inspections, as well as vehicles that are removed from service due to an in-service failure. Unscheduled maintenance activity accounts for roughly three quarters of the railcars out of service at any given time. Significant improvements in Mean Distance Between Delays (MDBD) and fleet availability are further detailed below.

When failures occur, Metro's goals are: 1) to make sure no unsafe vehicle is deployed for service; 2) to return a repaired vehicle to service as quickly as possible; and 3) to identify the root cause of the failure and properly address it to avoid recurrence. Most corrective maintenance activities are performed in maintenance shops. Metro also positions Road Mechanics in the system to intercept problem trains in service to minimize the impact of a failure on service. Road Mechanics work to quickly assess the reported failure, perform any appropriate minor mechanical repairs, and determine whether it is safe for the railcar to remain in service.

4.3.1 Fleet Reliability

It is the responsibility of Metro's Office of Reliability Engineering and Performance Analysis (REPA) to track service delays and mechanical failures that cause unscheduled maintenance. Through careful record keeping, Metro can identify trends that can either be addressed through engineering campaigns or incorporated into scheduled maintenance routines, thereby increasing vehicle availability and performance over the long run.

Mean Distance Between Delays (MDBD) is Metro's primary reported fleet reliability measure. MDBD includes failures during revenue service resulting in delays of four or more minutes. Metro also tracks Mean Distance Between Failures (MDBF), including all mechanical failures, monthly by car series to facilitate performance management and trend analysis. Table 4-3 summarizes in-service reliability trends at the car series and fleet-wide level from FY2015 through FY2019:

TABLE 4-3: ANNUAL MEAN DISTANCE BETWEEN DELAYS BY CAR SERIES, FY2015-FY2019 [37, 38]

Fiscal Year	1000-Series	2000-Series	3000-Series	4000-Series	5000-Series	6000-Series	7000-Series	Fleet Avg
2015	60,441	89,242		24,689	48,802	100,683	46,294	**63,015**
2016	64,583	76,227		24,082	41,301	115,969	60,932	**60,105**
2017	69,708	81,472		43,372	54,140	100,407	126,241	**79,656**
2018	-	94,070	70,988	-	50,589	85,312	141,914	**92,657**
2019	-	137,469	92,242	-	46,621	116,166	268,899	**160,985**

The rail fleet MDBD performance has increased in recent years, reaching over 160,000 miles between delays in FY2019. These trends illustrate the reliability challenges that were presented by the 1000-Series, 4000-Series, and 5000-Series cars which performed below the fleet-wide average for in-service reliability. The 1000-Series and 4000-Series railcars were retired from the fleet in FY2017; the 5000-Series railcars were retired in FY2019. In contrast, the latest additions to the railcar fleet, the 6000-Series and 7000-Series railcars, have been consistent high-performers in recent years.

The reduction in the frequency of vehicle-related delays correlates with an improvement in the percentage of the fleet that is out of service for unscheduled maintenance. This reduction in vehicles out of service for maintenance allows for a lower total operating spare ratio (OSR), with typical weekdays now showing a roughly 12.5% fleet requirement for unscheduled maintenance with only outlying days upwards of 20% (in contrast to a typical day of 20% as in 2010). These prior improvements, combined with replacement of the oldest and least reliable cars in the fleet, allow Metro to plan for a minimized OSR.

4.3.1.1 Sub-System Delays

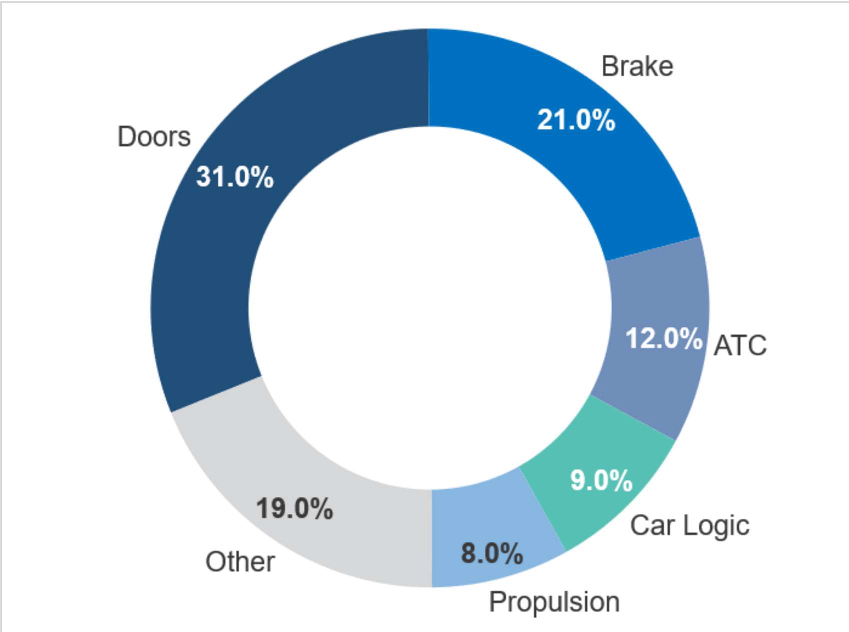
Metro also keeps significant statistics on the sub-systems that fail, a practice which helps to identify trends in failures by component and supplier at the fleet-wide or car series level, as needed.

Figure 4-2 shows the rate of delays caused by each of the major individual car-borne sub-systems per million miles across all cars in the fleet during the period from July 2018 through June 2019. The data indicate that Doors, Brake, Automatic Train Control, Car Logic and Propulsion are the top five sub-systems responsible for in-service delays.

[37] From Metro Office of Transit Performance Management.

[38] Mean Distance Between Delay values for 2000-Series and 3000-Series trains were measured as a combined measure until FY2018.

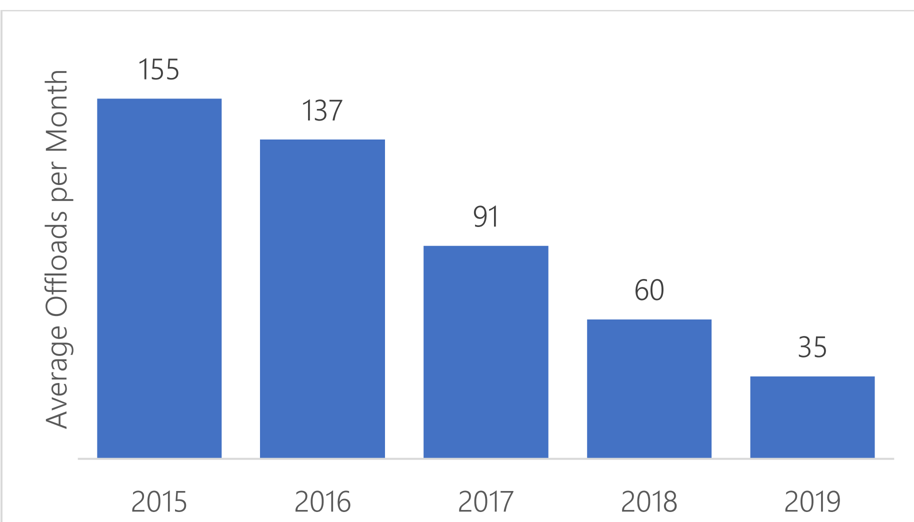
FIGURE 4-2: SUB-SYSTEM DELAYS (4 OR MORE MINUTES) PER MILLION MILES[39]



4.3.1.2 Railcar Offloads[40]

Metro measures and reports the offload metric so that management is able to prioritize critical failures that impact customers. Over the last five fiscal years, there has been a drastic decline in the number of railcar offloads experienced, as shown in Figure 4-3 The improved offload performance is due in large part to the retirement of older fleets as well as a concentrated effort in reducing failures that cause offloads.

FIGURE 4-3: AVERAGE OFFLOADS PER MONTH (2015-2019) [41]



[39] From Office of Reliability Centered Maintenance Planning (RCMP) sub-system delay rolling 12-month report, October 2019.
[40] A railcar offload is a significant consequence of a railcar failure that requires passengers to be removed from an affected railcar. These figures do not include offloads caused by other purposes, such as a track fire.
[41] From Metro Office of Transit Performance Management.

4.4. Engineering Campaigns

When a recurring defect on a particular car series is identified, one or more cars may be held out of service for detailed engineering evaluation. If a defect is identified as presenting an on-going issue throughout a subset of cars in the fleet, the Office of the Chief Engineer-Vehicles (CENV) will prepare an Engineering Test Plan (ETP), with potential components and requirements to correct or prevent the identified problem. An ETP is followed up by an Engineering Test Report (ETR) to validate a technical solution, and subsequently an engineering campaign is initiated to apply the solution to all vehicles affected by the issue.

The engineering campaign process is important for maximizing in-service reliability and vehicle availability. However, performing engineering campaign work requires the availability of cars on which to perform the modifications, and as such if the OSR is too low, campaigns will take longer to complete and the performance benefits will be deferred or delayed. Metro has been working to instill industry best practices in scheduled maintenance and rehabilitation programs and coordinating engineering activities with scheduled maintenance to reduce the number of cars unavailable for peak service at any one time due to engineering requirements.

4.5. Reliability Initiatives

Metro has employed several ongoing efforts to improve fleet availability and reliability.

4.5.1 Dedicated Consists and Dedicated Yards

Metro has implemented a practice of running trains in dedicated single-series consists and scheduling trains to return to dedicated yards. Starting in fiscal year 2018 following the retirement of 1000-Series railcars, Metro has operated trains in dedicated consists of a single railcar series. It previously operated 1000-Series railcars only in the "belly" position of train consists between other series vehicles following the 2009 Fort Totten collision. Although designed for interoperability, the railcars perform best when operated as trains within a single series.

Starting in fiscal year 2019, railcars are scheduled to return to dedicated yards each night allowing most scheduled and unscheduled maintenance on vehicles to be performed in the same shops. This practice enables maintenance teams to develop familiarity and greater pride of ownership with specific assets. As railcar mechanics must be specifically trained in each series, it also improves the efficiency of maintenance by allowing staff assignments to be better aligned with the specific car series serviced in each shop.

4.5.2 Reliability Centered Maintenance and Performance Management

Metro uses asset performance, condition, and failure data, enabled by information technology systems, to adjust maintenance programs and inform performance management. Metro is implementing a reliability centered maintenance approach to developing maintenance programs for assets based on a data-driven understanding of the characteristics of each asset, accounting for the operating context and risk profile. As a part of this approach, Metro works to ensure that every asset is maintained properly through an effective maintenance program. Metro also uses data to investigate root causes of failures and design appropriate maintenance and engineering solutions.

Reliability centered maintenance is a key element in how Metro develops its asset management strategy, encompassing inspections and maintenance (both preventive and corrective) as well as planned capital renewal. In this way, Metro is able to examine the effectiveness of its asset management strategies. Metro regularly monitors and sets targets for a range of performance measures, tracked on a monthly basis for internal management and published quarterly in the *Metro Performance Report*.

4.5.3 Quality Assurance

As a part of its quality assurance processes, Metro's Office of Quality Assurance, Internal Compliance & Oversight (QICO) monitors and assesses compliance with quality requirements for rolling stock maintenance, operations and engineering. QICO also monitors the performance of new fleet vehicles and the quality of maintenance work performed on all vehicles to ensure that practices and procedures are effectively supporting the goal to provide the best in safe, reliable, cost effective and attractive rail transit services.

The Office of the Chief Mechanical Officer, Rail (CMOR) also monitor failures and documents trends for quality assurance purposes. Daily audits are performed within the various maintenance shops and on revenue lines to measure the quality of maintenance performed. The results of the audits are reported to the respective maintenance managers. Procedural problems and failure trends are reported to the Office of Chief Engineering Vehicles for further evaluation and corrective action.

4.5.4 Parts Availability

Metro's Office of Supply Chain Management (SCM) was established in fiscal year 2018 to modernize management of the supply and distribution of parts and materials. The office is responsible for inventory planning and operations of a central supply warehouse and on-site storerooms at major operations facilities including rail yards. SCM is working to centralize and improve inventory planning, standardize data, and reduce inefficient spending on parts and materials. Through its supply chain management efforts, Metro expects to order and receive parts faster, increase asset availability, and improve operational cost efficiency.

As a part of this effort, Metro established the Office of Supply Chain Planning and Analytics (SCPA) within SCM. This office works to improve forecasting accuracy, coordinate planning and analytics, and increase planning effectiveness through data-driven decisions. Metro is also planning to implement a Vendor Managed Inventory program (VMI), a collaborative approach between Metro and a vendor which is expected to reduce wait time for parts from suppliers and allow those parts to be purchased at a lower cost.

4.6. Test Track and Commissioning Facility

Extensive testing is necessary on each train delivered to Metro before it is accepted and placed into service. The testing and commissioning period for a pair of railcars is typically sixty days. All on-board systems are tested, including the car's interface with the Automatic Train Control system. The tests are performed under a variety of operating conditions that examine performance both within the normal operating range and at the limits of that range, including tests on acceleration and braking performance, communications, heating and cooling systems, lighting, signage and door controls.

Prior to 2015, the acceptance testing process was conducted primarily during the brief overnight periods, during which time track usage would also have to be coordinated with maintenance crews, contractors, and non-revenue train movements. This significantly limited the number of cars per month that Metro could test and commission. As part of the 7000-Series Program, Metro constructed a test track and commissioning facility at the Greenbelt rail yard, both fully complete by 2016. This facility accommodates the testing and commissioning of up to 20 railcars per month. The facility also houses office space for Rail Engineering personnel and will be used for ongoing engineering analysis of the entire rail fleet.

4.7. Heavy Repair and Overhaul Facility

Metro is constructing a consolidated Heavy Repair and Overhaul (HR&O) facility to meet the needs of the current fleet and accommodate future growth. This facility will be dedicated to railcar rehabilitation work, component overhaul and extensive repair projects. The facility will have space for 40 railcars in the shop space and serve as the central hub for the railcar rehabilitation program. Additionally, shop space will be reserved for unscheduled heavy maintenance. The opening of the HR&O facility will replace most heavy repair and overhaul functions at the Brentwood Shop. Brentwood's 42 car-bays will be reallocated to service and inspection and car track equipment maintenance (CTEM) while retaining capacity to perform overflow heavy repair work.

5 System and Facilities Capacity

5.1. Gaps in Current System

To properly and accurately assess Metro's capability to meet future demand, Metro combines ridership forecasts and with assessments of the system's infrastructure. Beyond the railcar fleet itself, system gaps are driven by storage and maintenance capacity, core and terminal throughput, traction power, and station capacity. Understanding the constraints of the current system allows Metro to identify what areas of the system will need improvement to meet 8, 7, and ultimately 6-minute headways. This allows Metro to plan and prioritize improvements needed for the system to reliably deliver higher service levels.

In addition to projects already underway, including Dulles Yard, the Heavy Repair & Overhaul Facility, and traction power upgrades, Metro needs to plan for and begin execution of several projects to deliver 100% eight-car train service at 7-minute headways by 2030. These include addressing storage capacity constraints on the Blue, Orange, and Silver Lines and the Red Line and maintenance shop capacity constraints on the Green Line and corresponding with storage expansion on the Blue, Orange, and Silver Lines. In addition, terminal capacity is a constraint under Metro's current operational standard of 15 trains per hour. More frequent service requires reducing scheduled recovery time at terminals and may require operational changes, such as increased use of drop-back operators.

Long-term planning and investments require decisions made years in advance in order to ensure system capacity and infrastructure are sufficient to meet demand in the future. Table 5-1 summarizes the approximate lead time required for major capital investment decisions.

TABLE 5-1: RAIL SYSTEM CAPITAL INVESTMENT DECISION LEAD TIME REQUIREMENTS

Category	Capital Investment	Approximate Lead Time Required
Railcars	Initiating new railcar procurement	5 to 8 years
Railcars	Exercising railcar procurement option	1 or more years
Yards & Shops	Expanding rail yard or shop capacity	2 to 6 years
Yards & Shops	Building new rail yard or shop facility	5 to 10 years
System Expansion	Opening new rail line	20 or more years

5.2. Railcar Storage

5.2.1 Current Railcar Storage

Revenue vehicles are currently stored at nine locations throughout the Metrorail system and will expand to ten with the opening of Dulles Yard. As summarized in Table 5-2, the total capacity will be 1552 spaces for revenue vehicle storage.[42] One space is equivalent to one revenue vehicle or approximately 75 feet of electrified track. Non-revenue storage track is predominately non-electrified track allocated to diesel operated Maintenance of Way (MoW) operations and storage. Electrified non-revenue storage track is also allocated to treasury trains and specialized testing and maintenance equipment.

Metro's current yard footprint has two primary challenges as Metro implements 100% eight-car trains and more frequent service, including internal yard configurations not optimized for full length train consists, requiring a greater number of yard movements to fully utilize available storage, and a structural imbalance between western and eastern yards on the Blue, Orange, and Silver Lines, which constrains capacity and drives operational inefficiency due to the need to operate non-revenue trips to stage trains for service and return trains to yards afterwards, adding operating cost and encroaching on the overnight track maintenance window.

Table 5-2 summarizes the storage and maintenance capacity of each yard as well as the share of storage capacity that can be used by eight-car trains.

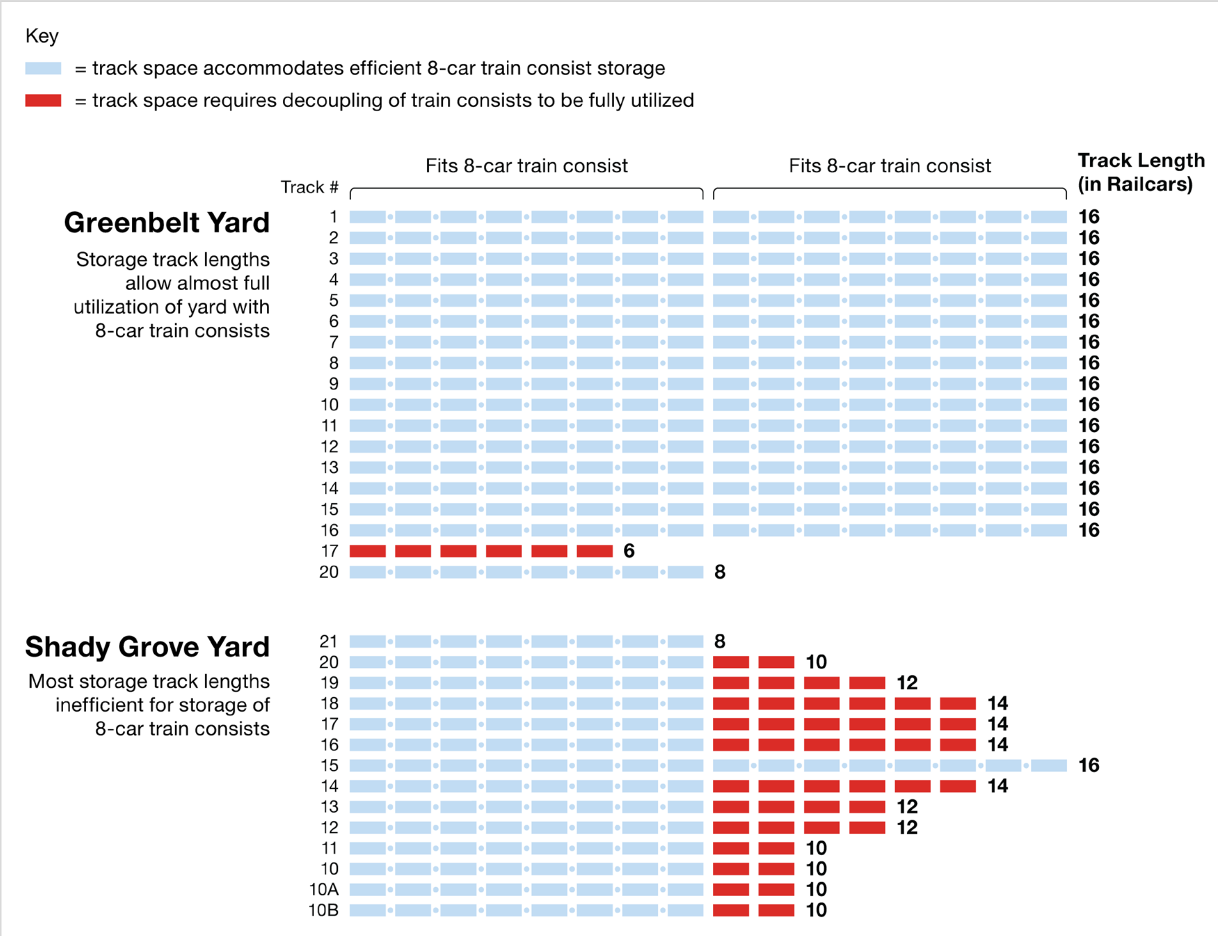
TABLE 5-2: RAILCAR STORAGE LOCATIONS

Yard	Location	Revenue Storage Track Spaces	Railcars Storable as 8-Car Trains	Percent Stored as 8-Car Trains	Non-Revenue Storage Track	Maintenance Bays
A99	Shady Grove	166	120	72%	28	36
B98	Glenmont	132	88	67%	20	0
B99	Brentwood	90	72	80%	0	42
C99	Alexandria	176	136	77%	50	20
D99	New Carrollton	120	88	73%	54	16
E99	Greenbelt	270	264	98%	38	20
F99	Branch Avenue	174	120	69%	16	8
G05	Largo	38	32	84%	0	0
K99	West Falls Church	188	144	77%	24	28
N99	Dulles [43]	168	128	76%	16	20
Total		**1522**	**1192**	**78%**	**246**	**190**

Metro can only utilize 78% of its total storage capacity with eight-car trains as many storage tracks lengths do not translate to multiples of eight. For example, a revenue vehicle track segment may store 14 revenue cars and therefore may only store one complete eight-car train. As a result, either six spaces must be left vacant or a train must be separated and redistributed in reduced consists to vacant track segments. This does not make the space unusable but increases the cost in time and resources required to make use of the space. Figure 5-1 compares the revenue storage layout of Greenbelt Yard to that of Shady Grove Yard.

[42] This total includes the completion of the Dulles Yard, which adds 168 revenue vehicle storage spaces.
[43] Dulles Yard is scheduled to open with Silver Line Phase 2.

FIGURE 5-1: REVENUE VEHICLE STORAGE TRACK EFFICIENCY COMPARISON, 8-CAR TRAIN CONSISTS



While Greenbelt is optimally designed to accommodate eight-car train consists, many of Shady Grove's storage tracks are of lengths which require decoupling of train consists if they are to be fully utilized. As a result of the layout implications shown in Figure 5-1, 98% of Greenbelt's storage spaces can accommodate eight-car trains, while only 72% of Shady Grove's may be utilized before decoupling of consists is required.

The revenue vehicle storage track is configured to store trains as married pairs, the base unit for Metrorail's legacy fleet. The base unit of two was the determinate for revenue storage track segment length. However, the 7000-Series fleet operates a base consist of four cars (a "quad"), and trains for service at eight-cars. Greenbelt is the only yard designed to store eight-car trains with almost all storage tracks 16-cars in length.

The distribution of yard revenue vehicle storage capacity across the east-west axis of the Metrorail system is as follows (see Table 5-2):

1. Red Line: 388 revenue storage spaces dedicated to the Red Line. Red Line operations are physically separated from other lines. The Red Line's three dedicated yards are Shady Grove, Brentwood, and Glenmont.

2. **Blue, Orange, and Silver Lines (Western axis):** 444 spaces in yards at or near the western termini of the Blue, Orange, and Silver lines. These yards are Alexandria,[44] West Falls Church, and Dulles.
3. **Blue, Orange, and Silver Lines (Eastern axis):** 158 revenue storage spaces in yards at the eastern termini of the Blue, Orange and Silver Lines. These yards are New Carrollton and Largo.
4. **Green and Yellow Lines**: 532 revenue storage spaces in yards on the Green and Yellow Lines. These yards are Greenbelt, Branch Avenue, and Alexandria.[45]

FIGURE 5-2: YARD AND SHOP CAPACITY SYSTEM MAP

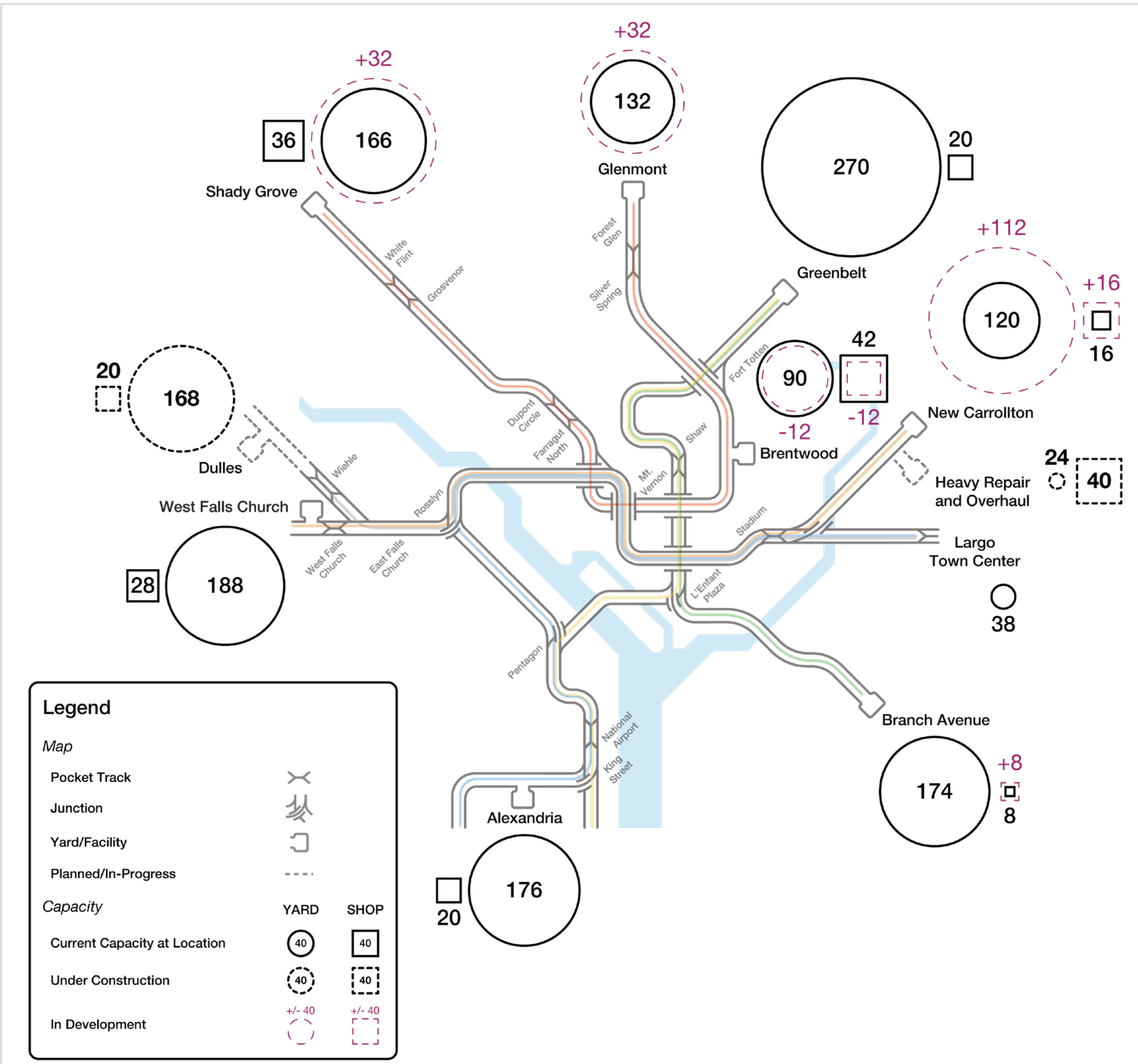


Figure 5-2 displays the distribution of storage capacity across the system. Storage imbalances along the Blue, Silver, and Orange lines generate operations and maintenance challenges on those lines which impact the entire system. For example, the storage of Blue line trains at Alexandria may compel the reallocation

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[44] Assumes 50% of Alexandria storage is allocated to Blue and 50% allocated to Yellow Line.

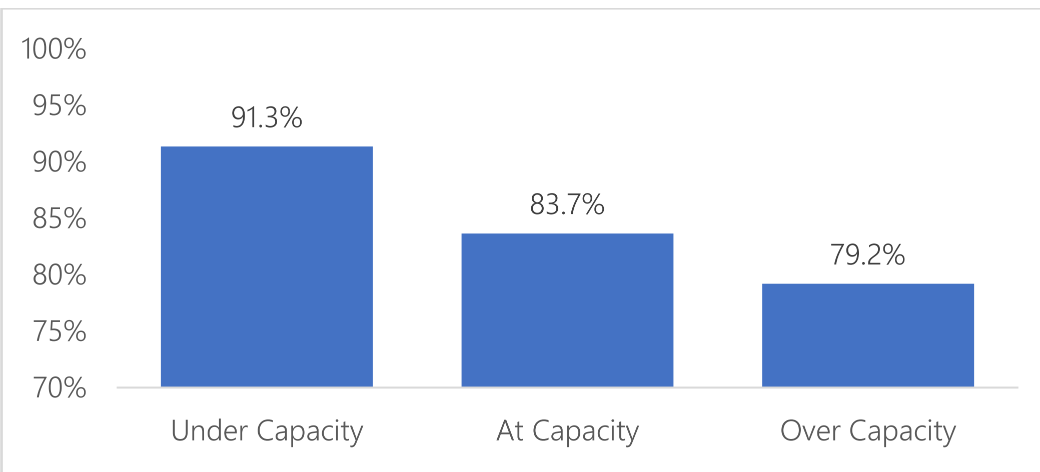
[45] Assumes 50% of Alexandria storage is allocated to Blue and 50% allocated to Yellow Line.

of Yellow Line trains to Greenbelt. The result is an increase in revenue vehicles operating non-revenue trips ("deadhead") at the beginning or end of revenue service. Deadhead trips add operating costs to provide service and may impact the time available to perform overnight maintenance.

Loop tracks are track segments that circumvent a given yard or storage area and connect yard operations to the main service line. They allow for greater freedom of movement for trains and consists within yards. Loop tracks provide a means for service dispatch and staging, assembly, disassembly, storage, and maintenance. Revenue vehicles operating in a yard without a loop track will require more yard movements for assembly and disassembly. Glenmont, Branch Avenue, and Largo are the only yards that are not serviced by a loop track.

Yard capacity and utilization levels also affect service reliability with less capacity-constrained yards generally performing better. As shown in Figure 5-3, rail yards with a higher capacity utilization generally meet service requirements less frequently. Storage imbalances between lines, inconsistent revenue storage track length and yard configurations also present risks to timely service and increased instances of coupling and uncoupling of trains.

FIGURE 5-3: PERCENT OF DAYS MEETING SERVICE REQUIREMENTS BY YARD CAPACITY UTILIZATION, 2019[46]



5.2.2 Additional Yard Infrastructure

In addition to revenue vehicle storage, maintenance of way vehicle storage, and maintenance facilities, yards contain facilities dedicated to supporting Metro's operations. These facilities include train washes, police stations, communications equipment, office space, and revenue collection operations.

Metro currently operates five train washes, located at the Shady Grove, Glenmont, Alexandria, Greenbelt and West Falls Church yards. There are three train washes currently not in use at Branch Avenue,

[46] Yards under capacity in 2019 were Greenbelt and Branch Avenue. Yards at capacity were Shady Grove and Glenmont. Yards over capacity were Alexandria, New Carrollton, and West Falls Church. Figure excludes Brentwood and Largo, rail storage facilities with unique functions.

Brentwood and New Carrollton,[47] while others need improvements. A train wash improvement program is in development to assess and address train wash needs throughout the system.

5.2.3 Future Railcar Storage

Metro plans to grow its yard storage with a planned expansion at New Carrollton Yard and is developing options to expand storage at other yards. To accommodate anticipated future railcar storage needs, Table 5-3 shows the locations of needed storage increases in the rail yards within the system.

TABLE 5-3: FUTURE YARD STORAGE CAPACITY AND SHOP CAPACITY NEEDS TO ACHIEVE ALL 8-CAR TRAINS AT 7-MINUTE HEADWAYS

		Revenue Storage Capacity			Shop Capacity		
Yard	Location	Existing/Under Construction Spaces	Additional Spaces Needed	New Total	Existing/Under Construction Spaces	Additional Spaces Needed	New Total
A99	Shady Grove	166	52 [48]	218	36	-	36
B98	Glenmont	132	-	132	-	-	0
B99	Brentwood	90	-	90	42	-	42
C99	Alexandria	176	-	176	20	-	20
D99	New Carrollton	120	112 [49]	232	16	16 [50]	32
E99	Greenbelt	270	-	270	20	-	20
F99	Branch Avenue	174	-	174	8	8 [51]	16
G05	Largo	38	-	38	-	-	0
K99	West Falls Church	188	-	188	28	-	28
N99	Dulles [52]	168	-	168	20	-	20
	Heavy Repair & Overhaul [53]	-	-	--	40	-	40
Total		**1522**	**164**	**1,686**	**230**	**24**	**254**

[47] The train wash facilities at Brentwood and New Carrollton are inoperable for environmental reasons. The Brentwood train wash facility has been inoperative for many years and consists of some track-level equipment.
[48] Need for 52 spaces listed at Shady Grove, but need could be met at other rail yards on the Red Line: Glenmont and Brentwood.
[49] For purposes of system balancing, most operationally ideal outcome is expansion of New Carrollton by 112 revenue storage spaces. If full expansion at New Carrollton is not possible, expansion at Dulles yard may be potential alternative outcome.
[50] At New Carrollton, 16 additional shop spaces are needed to accommodate a 112-car revenue storage space expansion. If only 56 revenue storage spaces are added at New Carrollton, only 8 additional shop spaces will be required. If all 16 shop spaces cannot be added at New Carrollton, half could be added to another shop serving the Blue, Orange, or Silver Lines – Alexandria, West Falls Church, or Dulles.
[51] The shop expansion is needed on the Green Line between Branch Avenue and Greenbelt and assigned here at Branch Avenue.
[52] Assumes completion of Dulles Yard and Silver Line Phase 2.
[53] The Heavy Repair and Overhaul facility will include three eight-car storage racks to accommodate trains awaiting repair and overhaul and will not be available for regular storage of trains for revenue service.

Table 5-3 shows the additional revenue storage spaces and shop capacity that will be needed to accommodate the forecasted fleet size associated with operation of all eight-car trains running at 7-minute headways. This table does not show the planned expansion of New Carrollton's revenue storage by 56 spaces, which would reduce the additional spaces needed to 56.

Planned expansion projects:

1. **Heavy Repair & Overhaul Facility:** The HR&O facility will largely consolidate Metro's heavy repair operations into one facility (Greenbelt will retain four HR&O slots for truck repair) with 40 dedicated slots. Half of the slots will be dedicated to major rehabilitative repairs, which require separation of the vehicle chassis from trucks and movement by crane, and the other half to heavy repairs of shorter durations. The HR&O facility will also hold 24 storage spaces for revenue cars. Plans include capacity for expansion to include twelve maintenance bays for Maintenance of Way (MoW) repair and seven track segments for MoW storage. The MoW storage and maintenance bay would be located in a self-contained area of the HR&O Facility grounds and include a non-electrified loop track, which allows for greater efficiency in vehicle yard movements.

2. **New Carrollton Northwest:** The planned expansion of the northwest of the New Carrollton yard will add 56 revenue storage spaces to the existing capacity of 120 revenue storage spaces, for a total of 176 revenue storage spaces.

Metro is developing plans to achieve 100% eight-car trains at 7-minute headways by 2030, with exploration of future potential 6-minute headways. However, yard space becomes constrained as service requirements increase, Table 5-4 reflects the relationship between the minimum fleet size needed to meet planned headways, the projected Peak Vehicle Requirement (PVR), and the currently planned storage capacity.

TABLE 5-4: PEAK VEHICLE REQUIREMENT, MINIMUM REQUIRED FLEET AND STORAGE CAPACITY COMPARISON[54]

Anticipated Year	Headway	PVR	Fleet Size Needed to Meet HW	Storage Capacity	Storage Capacity Utilization
2020	Current	966	1166	1522	77%
2025	8-Min HW, 100% 8-car	1136	1364	1602	85%
2030	7-Min HW, 100% 8-car	1272	1528	1602	95%
2040	7-Min HW, 100% 8-car	1272	1528	1602	95%
Future year	6-Min HW, 100% 8-car	1424	1712	1602	107%

Storage capacity along lines that span the east-west axis of the system become increasingly constrained as service demand increases. Notably, New Carrollton and Dulles reach or exceed capacity thresholds at increased headways. Additionally, revenue vehicle storage requirements within the Red Line yards at Shady

[54] Includes rounding up to account for married pair requirements. Operations and fleet size in 2020 are not in line with 20% Operating Spare Ratio due to higher levels of corrective maintenance.

Grove, Brentwood, and Glenmont, reach full utilization at the 8-minute headway level and require expansion for 7-minute and 6-minute headway operations.

Metro is developing options to meet the remaining identified railyard storage and maintenance capacity needs.

5.2.4 Maintenance of Way Fleet Storage

The MoW fleet performs maintenance primarily on Metro's track and facilities. The vehicles are diesel-powered and stored primarily on non-electrified track at each yard. Largo is the only storage facility without dedicated MoW storage. A small allocation of electrified track is dedicated to revenue collection vehicle storage. Treasury trains are former revenue vehicles converted for the collection and transport of fares (alternatively referred to as "money trains" or "revenue collection vehicles").

The maintenance of way fleet consists of 186 vehicles across many distinct functions. For the purposes of this document, those functions are organized into five categories: prime movers, work cars, tie replacement and surfacing equipment, heavy construction equipment, and miscellaneous equipment.

TABLE 5-5: MAINTENANCE OF WAY FLEET COMPOSITION [55]

Vehicle Type	Count
Work Cars	**71**
Flat Cars	66
Ballast Cars	5
Tie Replacement and Surfacing Equipment	**45**
Swing Loaders	12
Tie Remover/Inserter Machines	4
Tie Cranes	4
Spike Drivers	4
Ballast Regulators	4
Spot Tampers	4
Tampers	3
Quad Drill Equipment	2
Spike Pullers	2
Rotary Scarifiers	2
On/Off-Track Cranes	2
Tie Shears	1
Track Stabilizers	1
Prime Movers	**42**
Utility Vehicles	34
Locomotives	3
Aerial Lifts	2
Jet Rodders	2
Welders	1
Miscellaneous Equipment	**28**
Rail Tie Carts	6
Vacuum Trucks	4
Scissor Lift Trucks	3
High Rail Flatbeds	2
Bridge Inspection Equipment	2
CTEM Track Geometry Vehicles	1
Ballast Vacuum Excavators	1
Pick-Up, Crew Cabs	1
Switch Maintenance Trucks	1
Rail Trains	1
Crane Trucks	1
High Rail Excavators	1
High Rail Crane Trucks	1
Mobile Maintenance Units	1
Locomotives [56]	1
Lube Trucks	1
Total	**186**

[55] For purposes of this document, Metro's Maintenance of Way fleet of 186 vehicles includes vehicles which are not included in the list of 78 vehicles Metro reports to the National Transit Database (NTD). The NTD reporting requirement calls for the exclusion of vehicles which have rubber tires or which are not self-propelled. Of the 186 MoW vehicles included in this report, 108 either have rubber tires or are not self-propelled.

[56] This vehicle is distinct from the Prime Mover Locomotive listed above as it does not serve a prime mover function. It is used exclusively for the purpose of moving other maintenance vehicles, and cannot be equipped with other specialized equipment.

The MoW fleet includes vehicles with various purposes and specialties. Most vehicles categorized as work cars are flat cars, which are towable units used for the transport of materials and equipment. Tie replacement and surfacing equipment vehicles are used to replace railroad ties (or cross ties) and perform other maintenance activities affecting tracks and surfaces. Prime movers serve as the primary source of propulsion for MoW trains and may be equipped with cranes and other specialized equipment. Heavy construction equipment vehicles are generally used for excavation and loading functions. The miscellaneous equipment category includes vehicles serving other distinct functions.

TABLE 5-6: MAINTENANCE EQUIPMENT STORAGE TRACK CAPACITY [57]

Yard	Location	Unelectrified Storage Track (50' Vehicle Spaces)
A99	Shady Grove	30
B98	Glenmont	12
B99	Brentwood	6
C99	Alexandria	33
D99	New Carrollton	28
E99	Greenbelt	62
F99	Branch Avenue	22
G05	Largo	0
K99	West Falls Church	16
N99	Dulles	18
Total		**227**

For the purposes of determining MoW storage requirements in this document, one space of MoW storage is equivalent to 50 feet of track, the average length of a MoW vehicle. Due to the diversity of equipment within of the MoW fleet, a standard vehicle length does not exist. Contractor-owned vehicles also occupy space in yards to support system renewal programs.

The design and placement of non-electrified track may complicate yard movements. For example, fuel pumps for MoW vehicles are often placed along dead-end siding track as opposed to loops. The design requires vehicles pull in and reverse out, which increases yard movements.

Track maintenance often requires vehicles to concentrate on specific points within the system in need of repairs. Maintenance of way vehicles, including specialized equipment, are often staged at yards near planned work zones away from home yards, requiring all yards to have capacity to accommodate an increased number of vehicles.

[57] Analysis performed July 1, 2019 – October 31, 2019, reconciled with Metro's yard management software (RPM) and Car Track Equipment Maintenance (CTEM) data, provided August 13, 2019 and October 31, 2019. Dulles Yard totals are approximate for three MoW tracks in the assembly area.

5.2.5 Future Maintenance of Way Storage

The construction of the HR&O facility will include future capacity to add storage space for 38 vehicles to the existing 247 spaces of MoW storage enclosed within a dedicated yard, complete with a non-electrified loop track. The "yard within a yard" design—to include a loop track, the only non-electrified loop track in the Metrorail system—allows for ease of yard operations, fueling, and throughput.

5.3. Railcar Maintenance Shops

Revenue vehicles are maintained at shops located at seven of the nine yards in the Metrorail system, increasing to eight of ten with a total of 190 maintenance shop spaces once Dulles Yard opens. One maintenance shop space is equivalent to one 75-foot railcar and spaces are configured to support maintenance of married-pairs. All shop spaces are non-electrified track, covered and enclosed within a maintenance facility.

Metro maintains a shop capacity standard of 15%, meaning enough shop spaces must be available to accommodate 15% of the revenue fleet. This standard includes decentralized service and inspection and running repair and centralized heavy repair and overhaul at a three to one ratio (11.25% to 3.75%). The need for service and inspection and running repair capacity is localized to individual yards or lines as capacity is necessary to meet ongoing daily needs for scheduled preventive maintenance and inspection and corrective maintenance. Heavy repair and overhaul needs are best met at specialized central facilities serving the whole fleet. Metro's shop capacity standard is somewhat less than the total share of maintenance spares in the fleet as some out of service vehicles, including those awaiting parts, do not need to occupy shop space, and some corrective maintenance activities can be completed in less than a day, allowing shop bays to turnover.

TABLE 5-7: RAIL MAINTENANCE SHOP CAPACITY

		Maintenance Bays					
Yard	**Location**	**Lifts**	**Posted Rail**	**Flat Track**	**Total**	**Blow Pits**	**Wheel Lathes**
A99	Shady Grove	14	20	2	36	4	1
B98	Glenmont	0	0	0	0	0	0
B99	Brentwood	34	6	2	42	0	1
C99	Alexandria	6	10	4	20	2	1
D99	New Carrollton	8	6	2	16	4	1
E99	Greenbelt	16	2	2	20	4	1
F99	Branch Avenue	8	0	0	8	0	0
G05	Largo	0	0	0	0	0	0
K99	West Falls Church	10	10	8	28	2	1
N99	Dulles	18	0	2	20	2	2
Total		**114**	**54**	**22**	**190**	**18**	**8**

Maintenance shop spaces are distributed into three categories: Lifts, posted rail, and flat track.

1. **Lifts:** A hydraulic system that elevates train cars to allow for undercarriage and truck maintenance work. Some lifts are equipped with body jacks, a function that allows for the removal of trucks from the train undercarriage.
2. **Posted rail:** Posted rail is a shop track segment fixed on posts spanning the length of a dugout, this allows for rapid undercarriage maintenance work without the need to elevate the train.
3. **Flat track:** Shop track not on posted rail or equipped with a lift. Flat track is often positioned near wheel lathes.

Furthermore, Wheel lathes, blow pits, and cleaning tanks are critical track spaces and functions within maintenance bays, but not considered as dedicated maintenance space.

1. **Wheel lathe**: a deep pit dedicated to wheel maintenance with dimensions adequate for two standing workers.
2. **Blow pit:** a track segment leading into a maintenance bay where the undercarriage of a revenue vehicle is pressure washed with compressed air and hot water to remove debris prior to inspection. Blow pits are critical to the conduct of timely periodic inspections.
3. **Cleaning tank:** An electrified track segment in an enclosed bay dedicated to the deep cleaning of trains following an inspection. Due to the electrified track, no undercarriage work may be performed on a train inside of a cleaning tank. Cleaning Tanks are occasionally used for internal car repairs.

Maintenance work is distributed into two categories: Service and Inspections and Heavy Repair and Overhaul.

1. **Service and Inspection and running repair (S&I);** servicing and periodic inspections as part of the planned maintenance and upkeep of the revenue vehicle fleet as well as unplanned maintenance.

2. **Heavy Repair & Overhaul (HR&O):** Major and lengthy repairs to vehicles, often requiring substantial assembly and disassembly.

S&I is the predominate use of shop space. Of Metro's 190 shop spaces,[58] 144 are dedicated to S&I and 46 are dedicated to HR&O. The latter is conducted at two facilities, Brentwood and Greenbelt, with Brentwood scheduled to revert to S&I and MoW maintenance after the HR&O facility opens. S&I is distributed by car block, with shops dedicated to servicing specific lines. For example, Shady Grove serves as the Red Line's dedicated S&I shop.

Shop throughput is critical to maintaining high service standards and effectiveness. Under current shop configurations, the maintenance of revenue vehicles requires hours of prepositioning, decoupling, and preparation. To achieve greater efficiency in operations, maximizing "wrench" time and increasing throughput, Metro seeks to develop the ability to conduct maintenance of full trainsets by constructing capacity expansions as eight-car posted rail maintenance track segments.

[58] Including the 20 maintenance bays added by the completion of Dulles Yard.

TABLE 5-8: EXAMPLE MAINTENANCE SCENARIO: CORRECTIVE MAINTENANCE (BRAKES)

Maintenance Scenario	Duration (Hours)				Daily Throughput (Cars)
	Yard Movements	Staging/Lifts*	Wrench Time**	Total	
Standard configuration: train decoupled, split into 4 pairs	8 (8 moves, 1 hour/move)	0.25	4	12.25	16
8-car posted rail: train coupled, intact	2 (2 moves, 1 hour/move)	0	4	6	32

**Raising and lowering cars on lifts*
***Direct work on railcars*

Posted rail track segments require only limited maintenance, whereas the hydraulic system on a lift track segment requires a dedicated maintenance program. Repairs must be contracted and lifts can be out of service for weeks or months, rendering the shop bays usable for only limited maintenance activities.

Metro operates one commissioning facility at Greenbelt yard, enclosed within a two-track maintenance bay, and equipped with six segments of flat track, two segments of posted rail, and 12 segments of lead track. The facility prepares new trains for service and serves as the primary facility for maintenance engineering campaigns.

TABLE 5-9: PROJECTED FLEET GROWTH AND SHOP CAPACITY

	2020	2025	2030	2040
Fleet Size	1278	1364	1528	1528
Shop Capacity	190	218	218	218
Percent	15%	16%	14%	14%

5.3.1 Future Railcar Maintenance Shops

The system-wide shop-to-revenue storage ratio is only a starting point and must be examined with respect to specific locations within the system. Shop space is constrained in present operations with deficiencies in space at the Green Line yards, Greenbelt and Branch Avenue. Projected fleet growth will further constrain shop capacity and poses a risk to future service reliability. Projects to increase shop capacity must accompany yard storage expansions or significant planned increases in yard storage utilization where it creates a deficiency in the shop capacity standard. Notably, shop capacity expansion needs to accompany storage expansion at New Carrollton to ensure reliable service delivery as the yard grows to meet increased demand.

The construction of the Dulles Yard maintenance shop and HR&O facility—along with the associated shop realignment at Brentwood—are the sole planned expansions of Metro's maintenance shop space. Other needs are under development and evaluation in a system-wide yard improvement study and will be considered for inclusion as projects in future capital planning cycles.

5.3.2 Car Track Equipment Maintenance (CTEM) Facilities

The Maintenance of Way vehicle fleet is assigned shop space and a maintained by Car Track Equipment Maintenance (CTEM). CTEM shop facilities are in four of the nine yards. Dedicated CTEM shop facilities are located at Alexandria, New Carrollton, Greenbelt, and Branch Avenue. Additional facilities at New Carrollton, Shady Grove, West Falls Church serve maintenance field base functions, supporting the operations of work equipment, which are distinct from the activities performed by CTEM. CTEM Shops are shops dedicated to the performance of maintenance on work equipment itself, whereas maintenance field bases serve other purposes and are run by maintenance departments including the Office of Track and Structures (TRST).[59]

TABLE 5-10: MAINTENANCE OF WAY FACILITY CAPACITY

Yard	Location	Function	Maintenance Bays			
			Lifts	Posted Rail	Flat Track	Total
A99	Shady Grove	Maintenance Field Base	0	0	1	1
C99	Alexandria	CTEM Shop / Maintenance Field Base	0	1	5	6
D99	New Carrollton	CTEM Shop / Maintenance Field Base	0	0	8 CTEM 4 Maint. Field Base	8 CTEM 4 Maint. Field Base
E99	Greenbelt	CTEM Shop / Maintenance Field Base	0	1	3	4
F99	Branch Avenue	CTEM Shop / Maintenance Field Base	0	1	3	4
K99	West Falls Church	Maintenance Field Base	0	0	1	1
N99	Dulles [60]	-	0	2	4	6
Total			**0**	**5**	**29**	**34**

The shop facilities are not equipped with lifts; however, shop facilities are frequently equipped with mobile lifts for undercarriage work, and future shop facility space at Brentwood may contain hydraulic lifts.

5.3.3 Future Car Track Equipment Maintenance (CTEM) Shops

Future shop expansions are planned at the HR&O facility and Brentwood Yard. The construction of the HR&O facility for railcars enables the realignment of three shop tracks, currently with capacity for 12 railcar spaces, at Brentwood to CTEM. Additionally, the planned HR&O facility includes a planned but currently unfunded Car Track Equipment Maintenance shop and a Maintenance of Way yard that would include one

[59] The Office of Track and Structures (TRST) is responsible for inspecting, maintaining and rehabilitating all revenue and yard tracks as well as all aerials, bridges, retaining walls and tunnels.
[60] Dulles Yard facilities to begin operations with opening of Silver Line Phase 2.

lift, two inspection pits, and one dedicated wash track (not included in the total shop space count).

TABLE 5-11: FUTURE CAR TRACK EQUIPMENT MAINTENANCE SHOP FACILITY CAPACITY

Shop Capacity	Yard	Location	Maintenance Bays			
			Lifts	Posted Rail	Flat Track	Total
Current	**Total**		**0**	**5**	**29**	**34**
Future	B99	Brentwood	8	0	4	12
	Z99	HR&O	1	2	9	12
	Total		**9**	**2**	**13**	**24**
Total			**9**	**7**	**42**	**58**

5.4. Train Throughput

5.4.1 Core Capacity

Train throughput is defined as the number of trains traversing a given point in the Metrorail System over a period of time, typically described as trains per hour. This is a critical factor in meeting demand at peak times, as it governs the number of trains available to passengers during the highest periods of service to meet requirements and operate safely. Metrorail's core throughput is constrained to a practical maximum of 26 trains per hour, while terminal throughput, the number of trains that can be turned around and redeployed at end-of-line stations, is 15 trains per hour under current operating conditions.

Maximum train throughput is defined as the maximum number of trains that can be reliably operated per hour, also expressed as the minimum sustainable headway. Maximum train throughput is driven by three components:

1. Minimum train separation: Train separation is determined primarily by a train’s ability to accelerate quickly up to its maximum speed and brake safely to a stop (managed by the Automatic Train Control system), the train’s length, and the configuration of stations and tracks.

2. Governing dwell time: The governing dwell time is the maximum time that a train is stopped at a station and is determined primarily by the number and width of railcar door openings and the passenger volumes at major stations on each line.

3. Operating margin: The operating margin is an amount of time between successive trains that is inserted into a timetable to accommodate minor delays to maintain schedule adherence without significantly impacting following trains.

As determined by prior Metro studies, these various infrastructure, fleet, and operational factors yield a minimum sustained headway of approximately 135 seconds (or 2.3 minutes) between trains, or a maximum of approximately 26 trains per hour. Metro’s train control system was designed to accommodate headways as short as 90 seconds. As a result, in certain instances, successive trains may travel past a given point fewer than 135 seconds apart. However, this typically occurs in certain core track segments during short periods of time and cannot be reliably sustained over an entire rush period on a regular basis.

The Blue-Orange-Silver trunk line has the highest core train throughput in the Metrorail System at 22.5 trains per hour, with each service operating at an 8-minute headway. If headways along the Blue-Orange-Silver lines were reduced to 7-minutes, the maximum throughput on that same section would increase to the system-wide throughput capacity limit of about 26 trains per hour. In order to achieve 6-minute headways on the Blue-Orange-Silver Line trunk line, substantial capital investments are required, to be determined by ongoing studies as shown in Table 5-13. Table 5-12 illustrates the progression of throughput needs and gaps (in red) at the milestone service levels (8-minute, 7-minute, and 6-minute headways).

TABLE 5-12: TRAINS PER HOUR CAPACITY STANDARDS AND MAXIMUM NEEDS AT VARIOUS HEADWAYS

		8-minute headways	7-minute headways	6-minute headways
System segment	Capacity standard	Maximum need		
Terminal	15 trains per hour	15	17.14	20
Core	26 trains per hour	22.5	25.71	30

5.4.2 Terminal Capacity

Metro's current capacity standard for turning around trains at terminals is 15 trains per hour, or every four minutes, based on current operational practices and infrastructure. Metrorail service changes in recent years have ended Red Line turnbacks at Grosvenor and Silver Spring, and Yellow line turnbacks at Mt. Vernon Square. As a result of this increase in service, Red Line terminals at Shady Grove and Glenmont, and the combined Green-Yellow Line terminal at Greenbelt must accommodate twice the frequency of trains compared to the period before the service changes, increasing throughput from 7.5 train per hour (8-minute headways) to 15 trains per hour (4-minute headways). The Blue-Silver Line terminal at Largo accommodates the same number of trains.

More frequent service at the Shady Grove, Glenmont, Greenbelt and Largo terminals – at a 7-minute system headway, or 3.5 minutes between trains (17.14 trains per hour) – requires reducing scheduled recovery time at terminals and may require operational changes, such as increased use of drop-back operators. In addition, potential infrastructure improvements, including construction of new pocket tracks, could further support reliable terminal operations.

5.4.2.1 Automatic Train Control (ATC)

The Automatic Train Control (ATC) system provides for the safe and efficient movement of trains through a series of track circuits and integrated logic for routing controls and speed controls. Metro is studying next generation train control to determine whether to modernize the existing system or transition to Communication-Based Train Control (CBTC) technology. CBTC systems can improve the accuracy of train positions by allowing trains to communicate to one another, allowing them to operate closer together. This newer technology provides enhanced Roadway Worker Protection, the potential for increased throughput capacity, and other benefits.

5.4.3 Future Rail System Service and Capacity Studies

Metro has studies underway to prepare for future service needs and develop solutions to identified operational and infrastructure challenges and core capacity constraints. Table 5-13 details these studies and their expected outcomes.

TABLE 5-13: FUTURE RAIL SYSTEM SERVICE AND CAPACITY STUDIES

Study	Scope	Est. Completion Date
Next Generation Automatic Train Control	This study considers options for making significant long-term investments to modernize or replace Metro's train control system.	2022
Blue/Orange/Silver	This study evaluates alternatives to identify the best solutions to address future ridership, service, and reliability needs on the Blue, Orange, and Silver lines.	2022

5.5. Traction Power

Metro has completed upgrades to its traction power system, including substations, tiebreaker stations, and cables, to enable operation of 100% eight-car trains at an 8-minute system headway. Ongoing work is underway to rehabilitate existing systems to a state of good repair and complete further upgrades to enable eight-car train operations with higher service frequencies. Planned traction power upgrades meet the needs at the 6-minute system headway level, supporting eight-car train operation at up to two-minute frequencies, by 2030. The line-by-line schedule for these upgrades is shown in Table 5-14. Blue, Orange, and Silver Line upgrades are fully funded in the current program. The schedule and completion of the remaining planned system segments is contingent on future funding availability.

TABLE 5-14: PLANNED SCHEDULE FOR TRACTION POWER UPGRADES

Line(s)	Year of Upgrade Completion
Red	FY2026
Yellow/Green	FY2030
Blue/Orange/Silver	FY2022

5.6. Stations

Station capacity drives system gaps in two ways:

1. **Platform length.** It restricts the number of cars per station to eight due to layout and vertical circulation (the movement of customers outside of trains while within the faregates). The layout of each station allows for a maximum of eight-car trains which makes the option of expanding service to 10-car trains at maintained scheduled headway infeasible due to capital requirements to modify each of the 91 stations.
2. **Limitations to station infrastructure.** As passenger volumes increase, station stairs, escalators, elevators, platforms and faregates can constrain the movement of riders moving through the rail system, thereby causing platform crowding and potentially unsafe conditions. Figure 5-4 below shows the volume-to-capacity ratio for each station's most crowded vertical circulation element in 2020 at the 5pm-5:30pm half hour time period.

FIGURE 5-4: VERTICAL CIRCULATION VOLUME-TO-CAPACITY UTILIZATION, PEAK HALF-HOUR

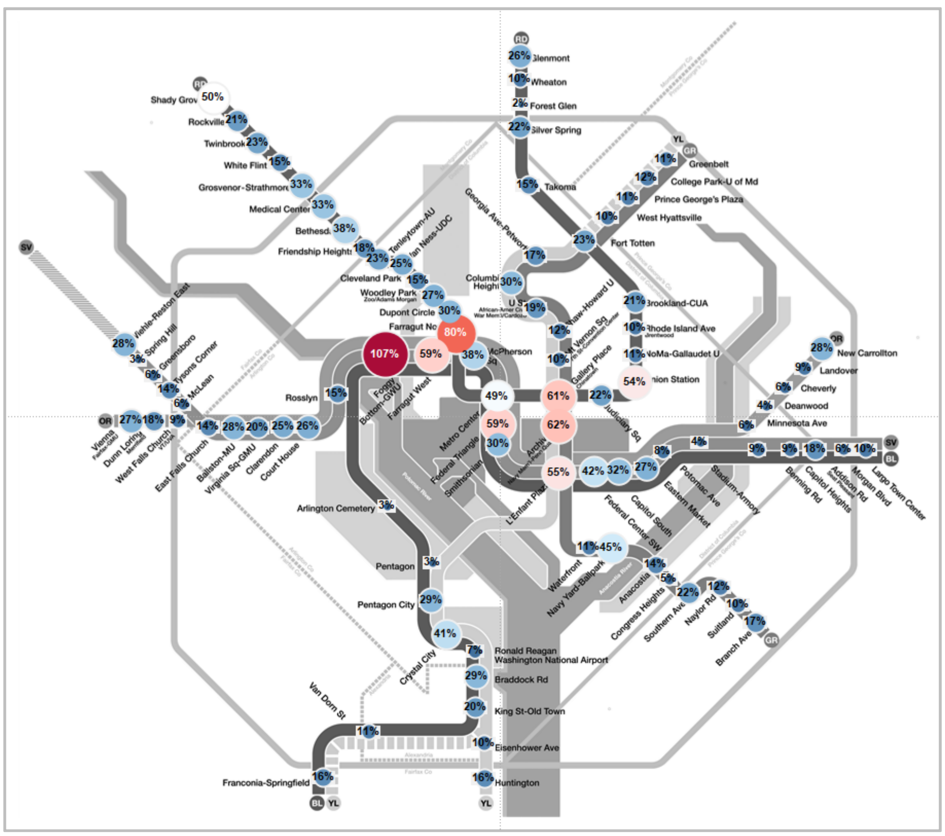


Table 5-15 shows the increase of vertical circulation crowding for each milestone service level by year for the ten most impacted stations.

TABLE 5-15: VERTICAL CIRCULATION USAGE BY YEAR [61]

Station	2020	2030	2040
Foggy Bottom	107%	116%	120%
Farragut North	80%	87%	90%
Archives-Navy Memorial	62%	68%	71%
Gallery Place-Chinatown	61%	67%	70%
Farragut West	59%	64%	66%
Federal Triangle	59%	65%	68%
L'Enfant Plaza	55%	60%	62%
Union Station	54%	63%	68%
Shady Grove	50%	57%	60%
Metro Center	49%	56%	60%

Metro is evaluating several projects to address vertical circulation constraints across the system which includes faregates, continued improvement on escalator and elevator reliability, and station operations generally. These projects are summarized in Table 5-16.

[61] Volume-to-capacity ratio shown for most crowded vertical circulation element. Metro's capacity standard is 50%, implying that a platform would clear in approximately half the time between train arrivals at that station platform.

TABLE 5-16: VERTICAL CIRCULATION IMPROVEMENT PROJECT LIST [62]

Station	New Asset	Status
Archives	Entrance, Mezzanine, Vertical Circulation Elements	Development & Evaluation Complete
Ballston*	Entrance	35% Design in Progress
Courthouse*	Street Elevators	Development & Evaluation Complete
Crystal City*	Entrance	Development & Evaluation Complete, Preliminary Engineering Pending
Bethesda	Entrance	Design
Farragut North and Farragut West	Station Improvements and New Passageway	Development & Evaluation Complete
Foggy Bottom	Mezzanine, Stairs, and Elevators	Development & Evaluation Complete
Huntington	Entrance	Design
L'Enfant Plaza	Elevator and Stairs	Design in Progress
McPherson Square	Elevators	Development & Evaluation Complete
Medical Center*	Entrance	Construction
Metro Center	Elevator and Stairs	Design In Progress
Pentagon City	Street Elevators	Design
Potomac Yard [63]	Entrance	Design
Shady Grove	Stairs	Design
Silver Spring	Entrance	Design
Smithsonian	Elevators	Development & Evaluation in Progress
Union Station	Entrance Relocation	Design

[62] * - Denotes project not being delivered by Metro.
[63] Potomac Yard Station to open in 2022.

Appendix

A.1. Definition of Acronyms and Terms

A.1.1 Acronyms

ADA	Americans with Disabilities Act
ATC	Automatic Train Control
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
ATO	Automatic Train Operation
CAF	Construcciones y Auxilar de Ferrocarriles, S.A., a Spanish railcar manufacturer
CBTC	Communication-Based Train Control
CM	Corrective Maintenance
CTEM	Car Track Equipment Maintenance
FTA	Federal Transit Administration, United States Department of Transportation
HR&O	Heavy Repair and Overhaul
HVAC	Heating, Ventilation and Air Conditioning
MDBD	Mean Distance between Delays
MDBF	Mean Distance between Failures
MoW	Maintenance of Way
MWAA	Metropolitan Washington Airports Authority
MWCOG	Metropolitan Washington Council of Governments
OSR	Operating Spares Ratio
PMI	Preventive Maintenance and Inspection
PMOC	Project Management Oversight Contractor
PPC	Passengers per Car
PVR	Peak Vehicle Requirement
S&I	Service and Inspection Shop
SMP	Scheduled Maintenance Program
STRF	Short-Term Ridership Forecast
TPB	National Capital Region Transportation Planning Board
TWC	Train-to-Wayside Communication
VDC	Volts Direct Current
VMS	Vehicle Monitoring System
WMATA	Washington Metropolitan Area Transit Authority

A.1.2 Terms

"A" CAR – The even-numbered car of a married pair that houses the Automatic Train Control apparatus.

AUTHORITY – The Washington Metropolitan Area Transit Authority.

AUTOMATIC TRAIN CONTROL – The system for automatically controlling train movement, enforcing train safety, and directing train operations.

BAY – Space in a shop where railcars maintenance may be performed.

"B" CAR – The odd-numbered car of a married pair.

BELLY CAR – A revenue vehicles used in the center position of a six- or eight-car train.

COMMUNICATION-BASED TRAIN CONTROL – A train control system that enables the continuous communication between trains and equipment, allowing trains to operate closer together.

CONSIST – The quantity and specific identity of vehicles that make up a train.

CONTACT RAILS – These rails (often referred to as Third Rails) provide electrical power to trains.

CROSSOVERS – Switches allowing trains to move from one track to another.

DEADHEAD – When revenue vehicles perform non-revenue trips to reposition before or after revenue service.

FAILURE RATE – The frequency of failure, expressed as failures per million miles.

FISCAL YEAR – The budget or financial year, beginning July 1 and ending June 30, denoted in the calendar year in which it ends (e.g., July 1, 2019 is part of the 2020 fiscal year).

GAP TRAIN – A ready train stored for immediate deployment in the event a train must be taken out of service.

HEADWAY – The time between consecutive trains operating on the same route.

INFILL STATION – A station that is constructed on an existing rail line, between existing stations.

INTERLOCKING – An arrangement of special track work and signals to prevent conflicting movements through a rail junction, crossover, or crossing.

JUNCTION – A point at which two rail lines merge into one. Junctions can be grade-separated at stations to allow passengers to transfer from one line to another.

MAINTENANCE OF WAY – Referring to assets involved in the repair and maintenance of the rail system.

MARRIED PAIR (Two-Car Unit) – The combination of an "A" car and a "B" car, semi-permanently coupled and sharing certain essential apparatus, and the smallest unit capable of independent operation.

MAXIMUM LOAD POINT – The segment of a line that carries the highest number of passengers using that line.

MEAN DISTANCE BETWEEN DELAYS – A measure that reports the number of miles between railcar failures resulting in delays of service of four or more minutes. The higher the mileage for the mean distance between delays, the more reliable the railcars.

MEAN DISTANCE BETWEEN FAILURES – A measure that reports the number of miles between railcar failures. The higher the mileage for the mean distance between failures, the more reliable the railcars.

OPERATING SPARES RATIO – The number of spare vehicles (as defined by subtracting the Peak Vehicle Requirement from the total available fleet) divided by the Peak Vehicle Requirement.

OPERATOR – The individual on board who is responsible for train operation in manual modes and overseeing train operation in any automatic mode.

OVERHAUL – Disassembly into component parts or subassemblies; replacement of worn and defective parts (with new or reconditioned parts as approved by Metro); and reassembly into complete functional assemblies, in accordance with the applicable instructions/procedures.

PEAK HOUR – The hour when passenger volume is greatest in the system.

PEAK VEHICLE REQUIREMENT (PVR) – The total number of revenue vehicles, inclusive of scheduled standby (gap) vehicles, required to operate schedule peak period service.

PERFORMANCE – The measure of output or results obtained by a component, system, etc.

POCKET TRACK – A third track between mainline tracks capable of storing a train, enabling mid-route turnbacks.

POWER SUBSTATIONS – Stations that convert electrical power into the necessary form needed to supply electricity to the contact third rails.

PREVENTIVE MAINTENANCE – A core Metro strategy of maximizing the reliability of vehicles in revenue service and reducing the maintenance spares requirement.

QUAD – The configuration of two married pairs of 7000-Series railcars to form a four-car unit.

RAILCAR OFFLOADS – When critical failures result in the offloading of customers from a train.

RECTIFIERS – Power converters that are part of traction power system.

RELIABILITY – The probability of performing a specified function, without failure and within design parameters, for the period of time intended under actual operating conditions.

REVENUE SERVICE – Service on routes established for train use by the public.

REVENUE VEHICLE – A heavy rail vehicle that is staffed and prepared to carry passengers.

RUNNING RAILS – Track rails that return the negative power to the substation.

SAFETRACK – A 13-month system-wide renewal initiative that required weekday service disruptions to accommodate multi-week surges of repair and renewal work.

SERVICE LIFE – The actual time during which any vehicle serves its intended purpose of safely and reliably transporting passengers. The end of service life occurs when degradation of the structural integrity of the vehicle requires that it be removed from service.

SCHEDULED MAINTENANCE PROGRAM (SMP) – an approach implemented in the Railcar Rehabilitation Program in which railcars are overhauled in stages on a recurring 6-year cycle

SHORT-LINING – When some scheduled trains terminate service and reverse directions prior to reaching the line's terminal.

SWITCHGEAR – Systems used to de-energize equipment to allow maintenance work.

TAIL TRACKS – Storage tracks beyond the terminus of a line.

TERMINAL – Where train lines originate, reverse direction, and end service.

THIRD RAIL – These rails (also referred to as Contact Rails) provide electrical power to trains.

TIE-BREAKER STATION – Stations that convert and supply power to the contact rail system.

TRACTION POWER SYSTEM – The system that provides the power source for vehicle propulsion.

TRAIN – A set of two, four, six, or eight rail vehicles coupled and operating together.

TRAIN THROUGHPUT – The number of trains traversing a given point in the Metrorail System over a period of time.

TRANSFORMERS – Devices that transfer Alternating Current (AC) to a Direct Current (DC) Substation.

TRIPPER TRAIN – An extra revenue vehicle scheduled to operate during peak hours of service to supplement the passenger capacity provided by trains operating on a regularly scheduled headway.

TURNBACK – A location where some scheduled trains terminate service and reverse directions prior to reaching the line's terminal.

YARD – A rail vehicle storage location that may also provide maintenance facilities.

A.2 Metrorail Service Planning Model

The Metrorail service planning model is a multi-step process used to develop fleet size requirements. Fleet size requirements are updated on a periodic basis prompted by events such as opening of new rail segments or the procurement of new railcars. The elements are as follows:

- Step One: Determine future peak hour passenger demand for Metrorail service.
  Develop peak hour passenger demand projections at the maximum load points of each Metrorail line.
- Step Two: Determine the service level requirements for each line.
  Apply Metro Board-adopted peak period service standards for maximum headways (i.e. minimum frequencies) and passenger loading to the maximum load points in the system. The frequency and train length requirements to meet target service levels determine the service level requirements of each line.
- Step Three: Determine number of cars needed for strategic gap trains.
  Determine the number of gap trains, and the resulting number of railcars, needed to maintain scheduled service levels and deliver reliable service.
- Step Four: Determine total operating Peak Vehicle Requirement (PVR).
  Apply vehicle running times (inclusive of recovery time) and operating constraints to the service level requirements to calculate the total scheduled vehicle requirements by route. The peak vehicle requirement is the sum of the scheduled peak car requirements of all lines in the system plus those of gap trains.
- Step Five: Determine Operating Spares Ratio (OSR).
  The operating spares ratio (OSR) is meant to accommodate vehicles being out of service during peak periods due to both scheduled and unscheduled maintenance.
- Step Six: Determine total fleet requirement.
  The total fleet requirement is the sum of the railcars required for peak service (including gap trains) and the railcars included in the operating spares ratio. The total fleet requirement is the basis for managing the supply of revenue vehicles through planning railcar procurements and retirements as well as developing needs for supporting systems and facilities.

A.3 Additional Tables and Figures

TABLE A-1: CURRENT S&I AND RUNNING REPAIR CAPACITY

S&I and Running Repair Capacity				
Shop	Present Capacity	Yard	Revenue Vehicle Storage	Shop to Storage Ratio
Shady Grove	*36*	Shady Grove	*166*	
		Glenmont	*132*	
Brentwood		Brentwood	*90*	
Total	36		388	9%
Alexandria	*20*	Alexandria	*176*	
Total	20		176	11%
New Carrollton	*16*	New Carrollton	*120*	
		Largo	*38*	
Total	16		158	10%
Greenbelt	*16*	Greenbelt	*270*	
Branch	*8*	Branch	*174*	
Total	24		444	5%
West Falls Church	*20*	West Falls Church	*188*	
WFC-Annex	*8*	West Falls Church		
Total	28		188	15%
Dulles	*20*	Dulles	*168*	
Total	20		168	
Total S&I	144		1552	11%
HR&O Shop Capacity				
Brentwood	*42*	Brentwood	-	
Greenbelt	*4*	Greenbelt	-	
Total HR&O	46		1552	3%
Total Shop Capacity	190		1552	12%

TABLE A-2: FUTURE S&I AND RUNNING REPAIR CAPACITY

S&I and Running Repair Capacity				
Shop	Present Capacity	Yard	Revenue Vehicle Storage	Shop to Storage Ratio
Shady Grove	*36*	Shady Grove	*166*	
		Glenmont	*132*	
Brentwood	*30*	Brentwood	*90*	
Total	66		388	17%
Alexandria	*20*	Alexandria	*176*	
Total	20		176	11%
New Carrollton	*16*	New Carrollton[64]	*176*	
		Largo	*38*	
Total	16		214	7%
Greenbelt	*16*	Greenbelt	*270*	
Branch Avenue	*8*	Branch	*174*	
Total	24		444	5%
West Falls Church	*20*	West Falls Church	*188*	
WFC-Annex	*8*	West Falls Church		
Total	28		188	15%
Dulles	*20*	Dulles	168	
Total	20		168	
Total S&I	174		1578	11%
HR&O Shop Capacity				
Brentwood	-	Brentwood	-	
Greenbelt	*4*	Greenbelt	-	
HR&O Facility	*40*	HR&O Facility	*24*	
Total	44		1602	3%
Total Shop Capacity	218		1602	14%

[64] Assumes planned expansion of New Carrollton revenue storage by 56 spaces.

TABLE A-3: SHOP CAPACITY – DETAIL

		Maintenance Bay												
		Lifts												
Yard	**Location**	**w/o Body Jacks**	**w/ Body Jacks**	**Total Lifts**	**Posted Rail**	**Flat Track**	**Total Maint. Bay**	**Blow Pit**	**Lathe/ Wheel Truing**	**Clean-ing Tank**	**Paint**	**Body**	**Comm. Fac.** [65]	**Train Wash** [66]
A99	Shady Grove	6	8	14	20	2	36	4	1	0	0	0	0	Yes
B98	Glenmont	0	0	0	0	0	0	0	0	0	0	0	0	Yes
B99	Brentwood	28	6	34	6	2	42	0	1	0	0	0	0	Yes
C99	Alexandria	2	4	6	10	4	20	2	1	0	0	0	0	Yes
D99	New Carrollton	4	4	8	6	2	16	4	1	0	0	0	0	Yes
E99	Greenbelt	12	4	16	2	2	20	4	1	4	2	2	8	Yes
F99	Branch Avenue	4	4	8	0	0	8	0	0	0	0	0	0	Yes
G05	Largo	0	0	0	0	0	0	0	0	0	0	0	0	No
K99	West Falls Church	2	8	10	10	8	28	2	1	0	0	0	0	Yes
N99	*Dulles* [67]	*8*	*8*	*16*	*2*	*2*	*20*	*2*	*1*	*2*	-	-	-	*Yes*
Z99	*HR&O* [68]	-	-	-	-	-	*40*	-	-	-	-	-	-	-
Total		**58**	**38**	**96**	**54**	**20**	**170**	**16**	**6**	**4**	**2**	**2**	**8**	

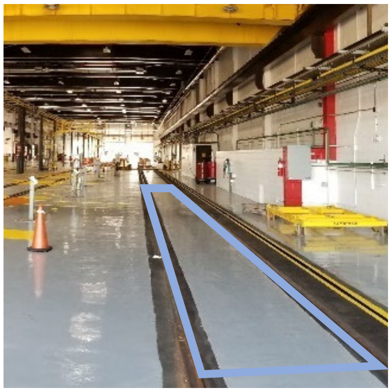
65 Commissioning Facility: Reserved for the commissioning of railcars and engineering campaigns.

66 The train wash facilities at Branch Avenue, Brentwood and New Carrollton are inoperative, while others need improvements. The train wash facilities at Brentwood and New Carrollton are inoperable for environmental reasons. The Brentwood train wash facility has been inoperative for many years and consists of some track-level equipment. A train wash improvement program is in development to assess and address train wash needs throughout the system.

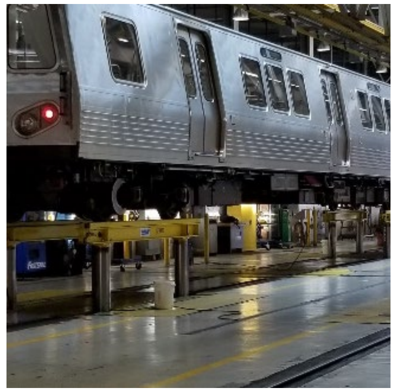
67 Dulles and HR&O not included in total counts.

68 HR&O facility is under construction.

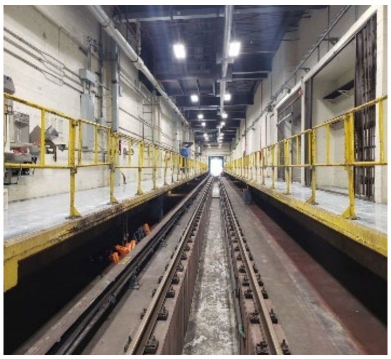
FIGURE A-1: SHOP EQUIPMENT EXAMPLES



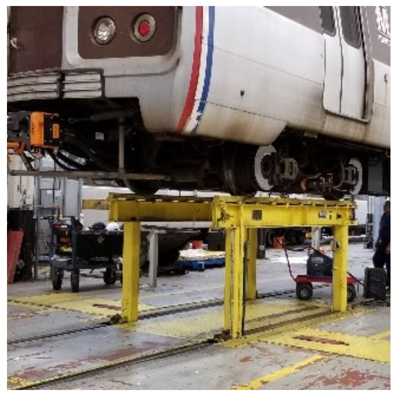
Flat Track



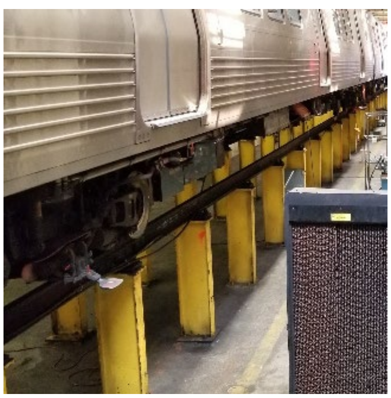
Lifts



Blow Pit

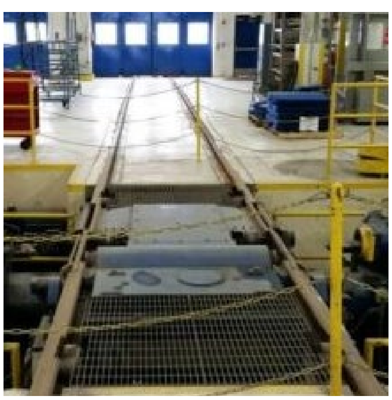


Lifts with
Body Jacks
Collapsed



Posted
Rail

Lifts with
Body Jacks
Fully Extended



Wheel
Lathe

TABLE A-4: FORECAST AM PEAK HOUR MAXIMUM PASSENGER FLOW BY LINE, FISCAL YEAR 2020-2040[69]

Line	Segment From-To	2018 (July 2017)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Red	Judiciary Square - Gallery Place/Chinatown	10,922	11,860	12,128	12,396	12,664	12,932	13,200	13,304	13,408	13,512	13,616	13,720	13,814	13,908	14,002	14,096	14,190	14,284	14,378	14,472	14,566	14,660
Red	Dupont Circle - Farragut North	10,482	10,540	10,676	10,812	10,948	11,084	11,220	11,284	11,348	11,412	11,476	11,540	11,592	11,644	11,696	11,748	11,800	11,852	11,904	11,956	12,008	12,060
Red	Gallery Place/Chinatown - Metro Center		11,390	11,532	11,674	11,816	11,958	12,100	12,184	12,268	12,352	12,436	12,520	12,596	12,672	12,748	12,824	12,900	12,976	13,052	13,128	13,204	13,280
Blue	Rosslyn - Foggy Bottom-GWU		5,150	5,268	5,386	5,504	5,622	5,740	5,800	5,860	5,920	5,980	6,040	6,076	6,112	6,148	6,184	6,220	6,256	6,292	6,328	6,364	6,400
Blue	L'Enfant - Smithsonian		3,510	3,530	3,550	3,570	3,590	3,610	3,668	3,726	3,784	3,842	3,900	3,948	3,996	4,044	4,092	4,140	4,188	4,236	4,284	4,332	4,380
Blue	Pentagon - Arlington Cemetery	5,171	4,470	4,588	4,706	4,824	4,942	5,060	5,104	5,148	5,192	5,236	5,280	5,328	5,376	5,424	5,472	5,520	5,568	5,616	5,664	5,712	5,760
Orange	Courthouse - Rosslyn	6,603	7,580	7,724	7,868	8,012	8,156	8,300	8,348	8,396	8,444	8,492	8,540	8,587	8,634	8,681	8,728	8,775	8,822	8,869	8,916	8,963	9,010
Orange	L'Enfant - Smithsonian		4,150	4,256	4,362	4,468	4,574	4,680	4,714	4,748	4,782	4,816	4,850	4,889	4,928	4,967	5,006	5,045	5,084	5,123	5,162	5,201	5,240
Silver	Courthouse - Rosslyn	4,837	6,490	6,566	6,642	6,718	6,794	6,870	6,886	6,902	6,918	6,934	6,950	6,976	7,002	7,028	7,054	7,080	7,106	7,132	7,158	7,184	7,210
Silver	L'Enfant - Smithsonian		2,430	2,472	2,514	2,556	2,598	2,640	2,646	2,652	2,658	2,664	2,670	2,699	2,728	2,757	2,786	2,815	2,844	2,873	2,902	2,931	2,960
Green	Waterfront - L'Enfant Plaza	5,252	5,560	5,704	5,848	5,992	6,136	6,280	6,356	6,432	6,508	6,584	6,660	6,745	6,830	6,915	7,000	7,085	7,170	7,255	7,340	7,425	7,510
Green	Shaw-Howard - Mt. Vernon Square	6,087	6,130	6,196	6,262	6,328	6,394	6,460	6,514	6,568	6,622	6,676	6,730	6,764	6,798	6,832	6,866	6,900	6,934	6,968	7,002	7,036	7,070
Yellow	Pentagon - L'Enfant Plaza	4,765	5,450	5,548	5,646	5,744	5,842	5,940	5,970	6,000	6,030	6,060	6,090	6,135	6,180	6,225	6,270	6,315	6,360	6,405	6,450	6,495	6,540
All	System-Wide Total		84,710	86,188	87,666	89,144	90,622	92,100	92,778	93,456	94,134	94,812	95,490	96,149	96,808	97,467	98,126	98,785	99,444	100,103	100,762	101,421	102,080

[69] Ridership forecasts were modeled for the milestone years (2020, 2025, 2030, 2035, 2040) and interpolated for intermediate years for planning purposes The Green Line's peak hour is half an hour earlier (07:30-08:30) than that of the other lines (08:00-09:00).

TABLE A-5: RAIL YARD STORAGE CAPACITY TRACK DETAIL

A99—Shady Grove

Track #	Storage Capacity
21	8
20	10
19	12
18	14
17	14
16	14
15	16
14	14
13	12
12	12
11	10
10	10
10A	10
10B	10
Total	**166**

B98—Glenmont

Track #	Storage Capacity
Y1	10
Y2	10
Y3	10
Y4	12
Y5	14
Y6	14
Y7	14
Y8	12
Y9	12
Y10	12
Y11	12
Total	**132**

B99—Brentwood

Track #	Storage Capacity
17	10
18	10
19	8
20	6
21	6
1	8
2	8
3	8
4	8
5	8
6	10
Total	**90**

C99—Alexandria

Track #	Storage Capacity
26	8
25	8
24	10
23	12
22	14
21	14
20	14
19	14
18	12
17	12
16	10
15	8
14	8
13	8
12	8
11	8
10	8
Total	**176**

D99—New Carrollton

Track #	Storage Capacity
7	10
8	12
9	12
10	14
11	16
12	14
13	12
14	10
15	10
16	10
Total	**120**

E99—Greenbelt

Track #	Storage Capacity
20	8
17	6
16	16
15	16
14	16
13	16
12	16
11	16
10	16
9	16
8	16
7	16
6	16
5	16
4	16
3	16
2	16
1	16
Total	**270**

F99—Branch Avenue

Track #	Storage Capacity
15	12
14	12
13	12
12	12
11	12
10	14
9	14
8	12
7	12
6	12
5	10
4	10
3	10
2	10
1	10
Total	**174**

G98—Largo Tail Track

Track #	Storage Capacity
42	16
43	10
41	12
Total	**38**

K99—West Falls Church

Track #	Storage Capacity
1c	10
1b	10
1a	12
1	12
2	12
3	12
4	12
6e	8
6d	8
6c	8
6b	8
6a	8
6	8
7	10
8	12
9	12
10	12
11	14
Total	**188**

N99—Dulles

Track #	Storage Capacity
16	12
15	12
14	12
13	12
12	12
11	12
10	12
9	12
8	12
7	12
6	8
5	8
4	8
3	8
2	8
1	8
Total	**168**

TABLE A-6: YARD STORAGE UTILIZATION AS PERCENT OF TOTAL, BASELINE CAPACITY SCENARIO

		6- and 8-car trains	100% 8-car trains		
Code	Location	Current Headway	8-minute Headway	7-minute Headway	6-minute Headway
A99	Shady Grove	100%	102%	119%	153%
B98	Glenmont	100%	100%	115%	124%
B99	Brentwood	78%	100%	100%	100%
C99	Alexandria	105%	100%	100%	100%
D99	New Carrollton	105%	127%	168%	193%
E99	Greenbelt	93%	73%	83%	100%
F99	Branch Avenue	70%	48%	53%	62%
G05	Largo	100%	100%	100%	100%
K99	West Falls Church	105%	84%	100%	100%
N99	Dulles	-	100%	100%	114%

The Baseline Capacity scenario shows projected yard storage utilization in several service scenarios, given existing Metro railcar storage capacity as shown in Table A-5. It includes the completion of the Dulles Yard (168 spaces added). The yard storage utilization column reflects the service plan prior to the opening of the Dulles Yard and Silver Line Phase 2.

TABLE A-7: YARD STORAGE UTILIZATION AS PERCENT OF TOTAL, 8-MINUTE BUILD SCENARIO

		100% 8-car trains		
Code	Location	8-minute Headway	7-minute Headway	6-minute Headway
A99	Shady Grove	102%	119%	153%
B98	Glenmont	100%	115%	124%
B99	Brentwood	100%	100%	100%
C99	Alexandria	100%	100%	100%
D99	New Carrollton	100%	115%	132%
E99	Greenbelt	70%	83%	100%
F99	Branch Avenue	48%	53%	62%
G05	Largo	100%	100%	100%
K99	West Falls Church	81%	100%	100%
N99	Dulles	94%	100%	114%

The 8-Minute Build scenario shows projected yard storage utilization in several service scenarios, given existing Metro railcar storage capacity as shown in Table A-5. It includes the completion of the Dulles Yard (168 spaces added), the Heavy Repair and Overhaul Facility (24 spaces added) and the New Carrollton West Yard expansion (56 spaces added).

TABLE A-8: YARD STORAGE UTILIZATION AS PERCENT OF TOTAL, 7-MINUTE BUILD SCENARIO

		100% 8-car trains		
Code	**Location**	**8-minute Headway**	**7-minute Headway**	**6-minute Headway**
A99	Shady Grove	93%	100%	134%
B98	Glenmont	93%	100%	100%
B99	Brentwood	72%	100%	100%
C99	Alexandria	100%	100%	100%
D99	New Carrollton	96%	100%	100%
E99	Greenbelt	67%	77%	100%
F99	Branch Avenue	48%	53%	62%
G05	Largo	100%	100%	100%
K99	West Falls Church	74%	93%	100%
N99	Dulles	79%	100%	114%

The 7-Minute Build scenario shows projected yard storage utilization in several service scenarios, given existing Metro railcar storage capacity as shown in Table A-5. It includes the completion of the Dulles Yard (168 spaces added), the Heavy Repair and Overhaul Facility (24 spaces added), a larger New Carrollton expansion (112 spaces added), and storage expansion within Red Line yards (52 additional Red Line spaces resulting from 32 spaces added at Shady Grove, 32 spaces added at Glenmont, and 12 spaced removed at Brentwood).

TABLE A-9: YARD STORAGE UTILIZATION AS PERCENT OF TOTAL. 6-MINUTE BUILD SCENARIO

		100% 8-car trains		
Code	Location	8-minute Headway	7-minute Headway	6-minute Headway
A99	Shady Grove	69%	78%	98%
B98	Glenmont	98%	98%	100%
B99	Brentwood	51%	82%	92%
C99	Alexandria	100%	100%	100%
D99	New Carrollton	96%	100%	95%
E99	Greenbelt	67%	77%	100%
F99	Branch Avenue	48%	53%	62%
G05	Largo	100%	100%	100%
K99	West Falls Church	74%	88%	96%
N99	Dulles	58%	77%	93%

The 6-Minute Build scenario shows projected yard storage utilization in several service scenarios, given existing Metro railcar storage capacity as shown in Table A-5. It includes the completion of the Dulles Yard (168 spaces added), the Heavy Repair and Overhaul Facility (24 spaces added), a larger New Carrollton expansion (112 spaces added), storage expansion within Red Line yards (132 additional Red Line spaces resulting from 112 spaces added at Shady Grove, 32 spaces added at Glenmont, and 12 spaced removed at Brentwood), and an additional railcar storage expansion at Dulles Yard (60 spaces added).