FINAL REPORT

Massachusetts Bay Transportation Authority

MBTA Bus Maintenance Efficiency Study

Prepared for

MBTA

March 11, 2016

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Revision History

Rev	***Date***	***Changes***
0	*December 18, 2015*	*First release – Task 2.1 to 2.6*
1	*January 19, 2016*	*Updated per MBTA comments on Revision 0 and latest set of data*
2	*February 9, 2016*	*> Updated per MBTA comments on Rev. 1.* *> Added new sections per CH scope item 2.7 on: facility feasibility review, organizational management, and work standard implementation plan.*
3	*March 11, 2016*	*> Updated per MBTA comments on Rev. 2 and additional data provided by MBTA and industry review.*

1 EXECUTIVE SUMMARY

OVERVIEW

The CH2M team commenced the MBTA Bus Maintenance Efficiency Review Study on November 16, 2015 with a kick-off meeting, initial stakeholder meeting and site visits at MBTA and RTA bus maintenance facilities. The core questions for the study are:

- What short and long term actions can the MBTA take to improve cost efficiency of bus maintenance functions?
- What are the best metrics to measure cost-efficiency as a baseline and going forward?
- What are "best-in-class" industry standards for efficient bus maintenance practices?

This final report provides a summary of our approach, observations and findings, cost benefit analyses of potential efficiency improvement alternatives, and an initial set of recommendations.

APPROACH

Our approach to identify alternatives and develop recommendations for maintenance efficiency improvement includes the following:

- Conduct high level site visits to observe the maintenance operations at all 11 existing MBTA bus garages/facilities and two RTA facilities (selected by MBTA)
- Interview representatives from bus maintenance and supporting departments
- Review historical MBTA maintenance performance and financial information and compare to relevant industry practices
- Identify alternatives and define an optimized range of improvement options based on cost benefit impact analysis against six evaluation criteria: safety, cost reduction/saving, employee experience, customer experience, operations efficiency, and sustainability (green).

FINDINGS

Key findings from our review of current MBTA maintenance performance, financial information, and site visits includes the following:

- **MBTA's average fleet age is higher than peer agencies.** The average age of the active MBTA fleet was reported to be 9.7 years as of January 2016 (reference MBTA Integrated Fleet Plan.) This number is higher than its peer agencies and presents a challenge as an older fleet often has more mechanical troubles and requires more intensive maintenance. In addition, an older fleet may be further complicated by a lack of proactive replacement and/or an overhaul program.
- **MBTA's complex bus fleet contains many different models.** Most large agencies have a mixed fleet with various propulsion modes and models. However, MBTA maintains 11 different models, which is an excessive number for its size. (As reference, NYCT had 16 models for a fleet four times larger than the MBTA.) The lack of asset standardization will require more customization of spare parts, special tools, training, and shop equipment needed for each bus model. A best practice shared by all transportation modes (buses, trains, airplanes, ferries, etc.) to achieve cost savings is standardizing of fleet as much as possible to meet operating objectives and needs.
- **MBTA maintains an aging contingency fleet.** In light of special project activities and unexpected revenue service requirements, MBTA has elected to maintain an aging fleet which requires

significant resources (labor and materials.) Specially, the contingency fleet is use to support service diversions for all rail construction projects and inclement weather. Delayed fleet replacement has also contributed to the need for a contingency fleet.

- **MBTA maintenance facilities are old and over capacity**. The MBTS's aging facilities with widely varying conditions and capacities, are not in line with peer agencies. In most cases, the facilities are over capacity with no room for expansion. Based on ridership and service demands, it is infeasible to shut down any facility. Shutdowns will likely result in significant impact to the passengers.

RECOMMENDATIONS

Efficiency Improvement Opportunities

The review of MBTA current bus maintenance has identified 36 potential improvement opportunities (alternatives) with a total estimated net annual operating cost saving of approximately $23M to $27M. These items are organized by implementation timeline:

- 12 short term (within 1 year) alternatives with an estimated cost savings of $6M.
- 12 mid-term (within 1 to 3 years) alternatives with an estimated cost saving of $7M to $9M.
- 12 long term (over 3 years) alternatives with an estimated cost savings of $10M to $12M.

At this point, status of these 36 potential opportunities is:

- 1 completed
- 13 in progress for full implementation
- 13 under consideration for implementation
- 9 with consideration to be determined

Cost saving for certain alternatives have not been identified ("TBD"), due to unavailability of specific request data at the time of this final report. These items require further cost and benefit impact analysis.

Exhibit 1 below depicts an accumulative range of potential cost savings by improvement opportunity categories and by improvement timeline.

Review of Facility Consolidation and Re-purposing

While consolidation of small facilities/garages (100 buses or less) could offer potential efficiencies, it is not feasible to implement at MBTA unless a major expansion and rehabilitation is performed at the designed facility that receive the consolidated fleet.

Repurposing the Cabot Tire Shop and reassignment of some Everett Repair Shop maintenance bays should be considered further, which may require the MBTA to outsource some of the present component overhaul/rebuild activity.

Performance Metrics

It is recommended that MBTA initiate benchmarking of certain key metrics (e.g. MMBF, spare ratio, vehicle maintenance cost per miles, etc.). Key metrics would be compared with North American agencies similar in fleet size and operational environment. Suggested peer agencies are Baltimore MTA, CTA, NJT, NYCT, SEPTA, and WMATA. It should be noted that Nation Transit Database (NTD) data is lagging in reporting period and limited uniformity/clarity on data set and analysis methodologies used by each agency. MBTA would benefit by initiating a bus consortium (similar to the successful 1991

Railcar Consortium) which could provide a real time open forum for members to share technical and financial information in addition to successes and failures of common equipment by the same vendors.

Exhibit 1 – Potential Cost Saving by Implementation Timeline and Improvement Opportunity Categories *(Note: Some alternatives need back up cost data to complete cost benefit impact analysis.)*

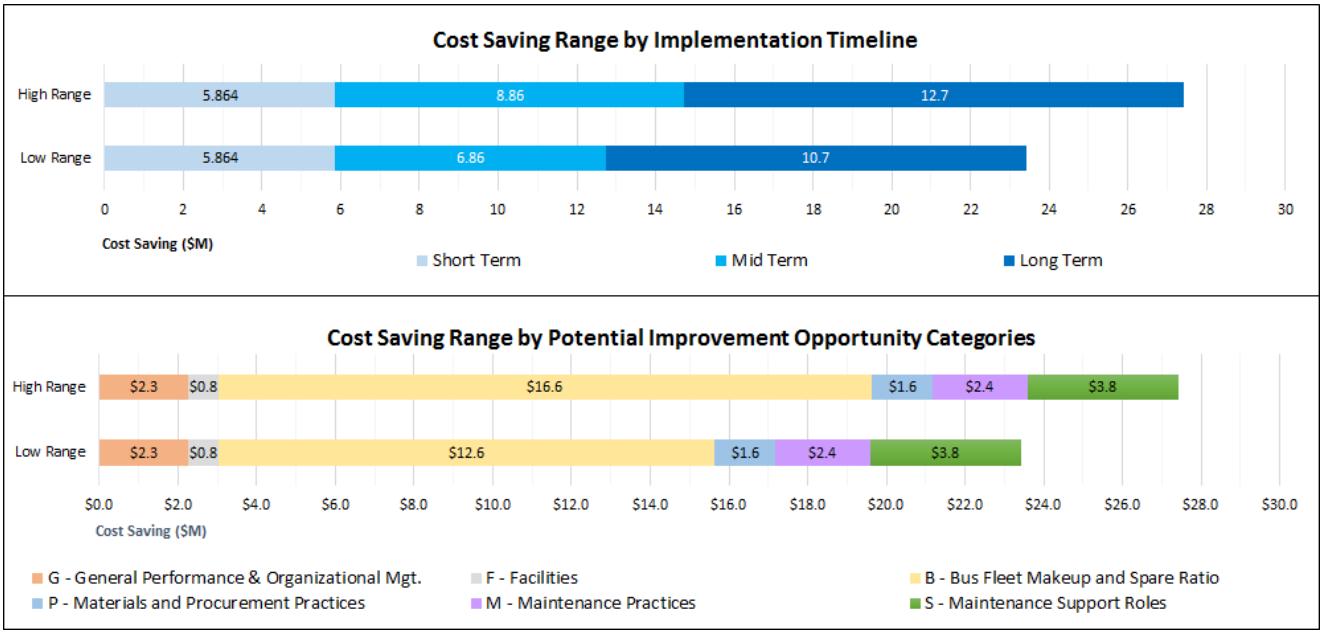


Table below summarized the 36 potential improvement alternatives. A complete analysis is provided in **Section 12**.

Item #	Improvement Opportunity Alternative	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Status
	Short Term Implementation Timeline			
G3	Clarify data reporting and then upgrade and standardize communication of key performance indicators (KPIs); including posting KPI charts in official communication boards at all maintenance locations.	N	$0 (Cost Neutral)	In Progress
G4	Start a pilot program setting up a compliance goal of 90% instead of present 100% for PM inspections to achieve an effective range of 95-97%.	N	$160K	Under Consideration
F1	Outsource Cabot Tire Shop repair work; four positions to be re- assigned.	N	$264K	Under Consideration
F2	Expand installation of Fastenal POU vending machines to all garages.	N	$0 (Cost Neutral)	In Progress
B2	Reduce the number of contingency buses from 75 to 60 by retiring 15 New Flyer CNG.	N	$600K	In Progress
P6	Explore outsourcing the overhaul/rebuild of components at the Everett Shop in terms of price, quality, and spare allocation.	N	TBD	In Progress

Item #	Improvement Opportunity Alternative	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Status
M1	Explore the potential savings in reducing daily bus washing frequency.	N	TBD	TBD
M2	Standardize all maintenance procedures for similar tasks by the machinists across the garages with a standard agreed upon time and including special tools and recordkeeping of critical PMI data.	N	$1M	In Progress
M5	Verify improvements made to Arborway's fueling to eliminate problems experienced during last winter months.	Y	$0 (Cost Neutral)	In Progress
S1	Budget a Quality Control staff to audit PMIs, CM, time standards and also incoming material inspection, MRB, storage, shelf life compliance, and warranty control.	N	$1.2M	Under Consideration
S2	Improve warranty recover process by upgrading organization and implementing standard procedures.	N	$2.64M	Under Consideration
S3	Issue training completion certificates to students for all classes.	N	$0 (Cost Neutral)	In Progress
	Mid Term Implementation Timeline			
G1	Realign vacant positions by filling some new key positions required for parts follow up, warranty control and production coordinator.	N	$0.6M	Completed
G2	Reduce overtime usage after filling vacant positions and implementation of repair standards.	N	$1.5M	In Progress
G5	Transfer to bus maintenance the budget and responsibility for minor facility maintenance repairs.	N	$0 (Cost Neutral)	Under Consideration
G6	Transfer the budget of vault agents from bus maintenance to the fare collection department.	N	$0 (Cost Neutral)	In Progress
F3	Apply lean methodology at garages: lean training, 5S reorganization, and form lean councils.	N	$0.5M	Under Consideration
F4	Explore replacement of fixed with pivoting wash brushes to clean fronts/rears except for trolley buses.	Y	TBD	TBD
F7	Expand capital program to budget periodic upgrade of facilities and germane shop equipment.	Y	N/A	Under Consideration
B1	Replacement of NABI CNG with 325 newly purchased New Flyer buses will reduce the unscheduled repairs and parts cost due to the high level of maintenance required for existing NABI buses and 44 articulated CNG. New articulated buses replacing the existing Neoplan buses.	Y	$3M to $5M	In Progress
P1	Streamline the materials management functions and reduce obsolete parts. Set up appropriate consistent min-max levels across the garages. Continue implementation of IDCS.	N	$260K	In Progress
P3	Explore procuring scheduled maintenance part kits from OEMs and/or systems suppliers.	N	TBD	In Progress
M3	Expand oil analysis program to include engines, transmissions, hydraulics, differentials to reduce component	N	$1M	Under Consideration

Item #	Improvement Opportunity Alternative	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Status
	failures and unscheduled repairs of critical components (condition based maintenance.)			
M7	Streamline reporting responsibility and Invest on data entry and analytic technology to expedite maintenance work order close-out procedures and data accuracy. Such as maintenance staff to have tablet for access to inspection checklist, reference maintenance procedures, OEM manual, training videos and generating integrated reports with multiple technologies.	Y	TBD	In Progress
	Long Term Implementation Timeline			
F5	Investigate under-roof parking alternatives where needed.	Y	TBD	TBD
F6	Replace oldest facilities with new ones: Improve efficiencies, availability of bus lifts, shop equipment and better working conditions. Explore consolidation/expansion of garages.	Y	N/A	Under Consideration
B3	Implement a five year bus replacement program to replace 100 buses each year based on 12 year useful life.	Y	$8 to 10M	Under Consideration
B4	Standardize fleet by reducing different bus types as much as possible.	Y	$1M	Under Consideration
P2	Staff all storerooms for all work shifts.	N	$0 (Cost Neutral)	Under Consideration
P4	Explore partnership with RTA and other bus agencies on buying to address supplier lead-time and quality via multi-year contracts.	N	TBD	TBD
P5	Explore Vendor Managed Inventory (VMI) Program to outsource this function at MBTA. It will reduce inventory, eliminate obsolete parts, and zero bus held out of service while awaiting parts.	N	$1.3M	TBD
M4	Examine by location the reorganization of daily service of buses by resolving contractual issues to have the buses serviced, cleaned and fueled by the same classification thus improving efficiencies.	N	$400K	TBD
M6	Implement real-time equipment failure tracking and repair scheduling through automatic vehicle maintenance (AVM) technology as a requirement in future contracts of new and/or overhauled buses.	Y	TBD	TBD
S4	Explore labor contract changes in collective bargaining agreement including use of part-time administrative employees, light duty positions, and improved sick leave reporting.	N	TBD	TBD
S5	Evaluate cost benefit of procuring extended warranty for major capital programs.	Y	TBD	Under Consideration
S6	Explore procurement of computer based training in future new bus contracts.	Y	$0 (Cost Neutral)	TBD

2 INTRODUCTION

2.1 Purpose

Under a task as part of MBTA Contract No. BUSPS11, CH2M was requested to perform a bus maintenance efficiency review. This task involved evaluation of the existing maintenance program and operations, highlight specific areas for improvement as observed, and to identify the most likely areas where substantial improvement may be realized. This study addresses the following core questions:

- What short and long-term actions can the MBTA take to improve cost-efficiency of bus maintenance functions?
- What are the best metrics to measure cost-efficiency as a baseline and going forward?
- What are "best-in-class" industry standards for efficient bus maintenance practices?

This report presents the interim findings, analysis, and recommendations based on information and analysis conducted so far.

2.2 Key Assumptions

The following key assumptions applied to the bus maintenance efficiency assessment:

- Analysis performed and documented in this report included historical maintenance and financial data that has been provided by MBTA.
- Cost benefit impact analysis is based on six evaluation criteria outlined in Section 12. For the purposes of this report, each criteria is assumed to have the same level of importance toward the agency's goals.
- Assessment excludes considering changes to current MBTA propulsion technology, as well as making recommendations regarding future propulsion choices.
- MBTA fiscal year is July 1st to June 30th and it is used as the basis to report MBTA "annual" performance and financial data in this report.

2.3 Organization of this Report

This report is organized to guide the reader through the analytical approach used to reach the conclusions and recommendations, with the following primary sections:

- Section 3 – Work approach.
- Section 4 to 9 – Summary of review on maintenance and financial data, bus maintenance facilities planning, fleet makeup and spare ratio, materials and procurement practices, maintenance practices, and maintenance support roles.
- Section 10 – Bus maintenance organization planning.
- Section 11 – Applicable comparison on industry metrics, standards and best practices
- Section 12 – Cost benefit impact analysis on potential efficiency improvement alternatives.
- Section 13 – Recommendations of potential initiatives identified by implementation timeline and by impact ranking.

3 WORK APPROACH

3.1 Overview

The potential efficiency improvement alternatives and recommendations developed are based on a comparison of current MBTA standards with industry practices for efficient and effective maintenance strategies. Our approach for this study is discussed in the following subsections.

3.2 Site Visit and Interview

The CH2M core team travelled to Boston between November 16 and 21, 2015 to attend the project kick-off meeting with MBTA Bus Maintenance department staff and to conduct a series of site visits and interviews. The primary purpose of this 6-day visit was to:

- Perform a high level observation of the maintenance operations at all 11 existing MBTA bus garages/facilities and two RTA facilities (selected by MBTA).
- Interview representatives from bus maintenance and supporting departments.
- Gather relevant maintenance and financial information.
- Project team had two additional site meetings and visits in January and February 2016 with MBTA staff to discuss interim reports and conduct follow-up site visits at selected facilities. **Exhibit 2** below summarizes key site visit and interviews performed by CH2M.

Exhibit 2 – Summary of Site Visit and Interview Activities

Site Visit #		Key Activities	
	Date	**Meeting / Interview**	**Garage/Facility Site Visit**
1	11/16/2015	• Kick off Meeting • Budget • Materials	• Albany
	11/17/2015	• Bus Engineering	• Bus Adm. Bldg. • Charlestown • Everett Main Repair Shops
	11/18/2015	• Labor Union • Facility Maintenance • Training	• Cabot • Cabot Tire Shop • Southampton • Lynn
	11/19/2015	• Bus Division Management	• Lowell RTA • Worcester RTA
	11/20/2015	• Budget • Human Resources • Service Planning/Schedules • Capital Planning • Vehicle Engineering / Warranty • Debrief Meeting	• Fellsway • North Cambridge
	11/21/2015		• Arborway • Quincy
2	1/28/2016	• Bus Maintenance	
	1/29/2016	• Bus Maintenance • Labor Union • Bus Engineering • Facility Maintenance	• Albany • Cabot • Southampton
3	2/12/2016	• Labor Union • Bus Maintenance	• Everett Main Repair Shops

3.3 Data Analysis

An initial list of requested data was submitted to MBTA the week before the CH2M Team arrived on site for the initial visit. Follow up requests were submitted for additional material identified as needed to support our analysis and development of potential improvement options. MBTA has provided CH2M with a significant amount of data and maintenance documentation before submission of the prior interim report of December 18, 2015. Some additional data has been furnished for preparation of this final report.

The review and analysis of data collected included comparison of MBTA standards to industry practice, as well as specific observations based on the CH2M team's professional knowledge of the industry. Based on this analysis, challenges and contributing factors to inefficiency were identified, and potential improvement opportunities identified.

Appendix A lists key data sources provided by MBTA for this study and also data requested but unavailable by submittal of this final report.

3.4 Industry Comparison

The National Transit Database (NTD) was determined to be the primary source for obtaining datasets to perform industry comparison. NTD data is self-reported by agencies, and assumptions and methods of measurement may vary among agencies based on policy and procedures used at each establishment. The challenges with the self-reporting approach, in particular on high level metrics, is the lack of assurance that data points and methodologies used by each agency are unbiased, valid, and comparable. Key criteria used for selecting a peer agency of MBTA are:

- Bus fleet technology, size, and age
- Ownership of assets and operating service
- Operating characteristics and condition

Details on applicable metrics for peer comparison and internal comparison and applicable industry standards and best practices are provided in Section 11 of this report.

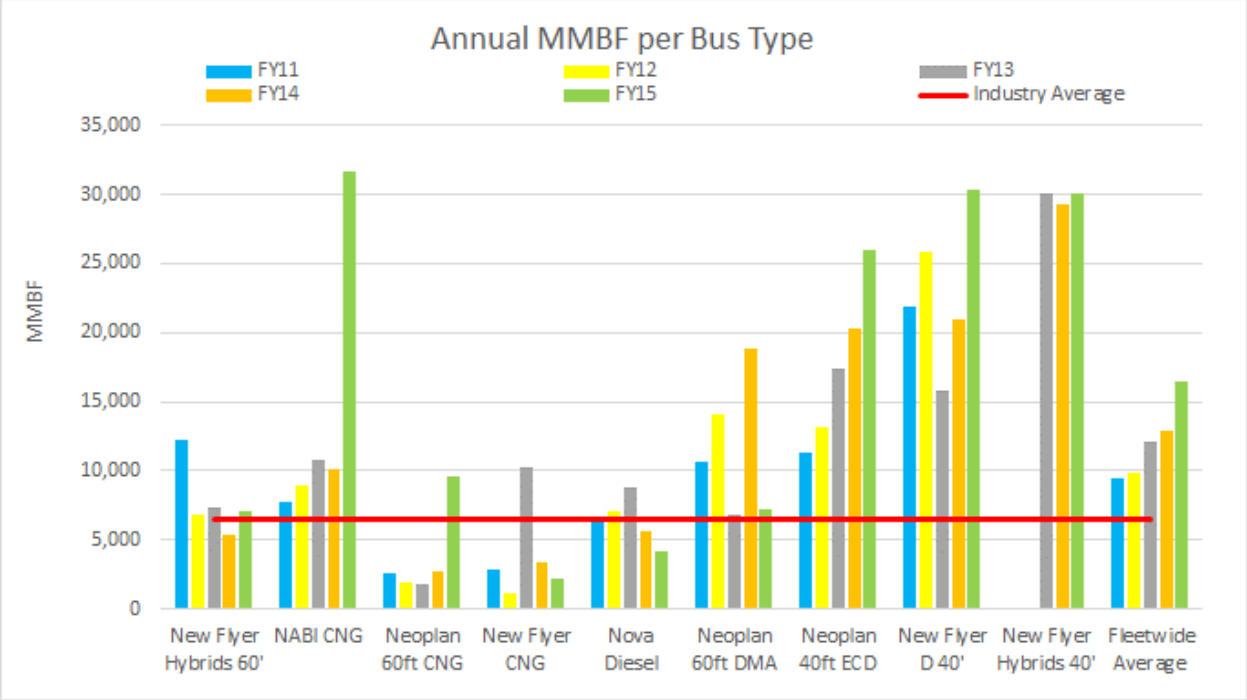
4 MAINTENANCE AND FINANCIAL INFORMATION REVIEW

4.1 Fleet Performance and Maintenance Review

Based on the review of the fleet performance reports provided by MBTA, the last five years have shown significant improvements in the Mean Miles between Failures (MMBF) of the MBTA's revenue fleet, as shown in **Exhibit 3**. The overall MBTA MMBF (14,000 to 15,000 miles per MBTA reporting for 2015) is high as compared to the typical range of 5,000 to 8,000 miles (average 6,500 miles) for major transit agencies, meaning MBTA buses infrequently breakdown in service. The agencies compared to MBTA have very similar fleet mix, operating characteristics and weather conditions. However, unscheduled repairs both for labor and parts currently account for 70 to 80% of MBTA maintenance activity.

In the transit industry as a whole, Preventative Maintenance (PM) and inspection defects are 70% and unscheduled repairs are about 30%, which is quite opposite of MBTA's. The unscheduled repair (running repair) data should be further analyzed as it is the main cost driver for bus maintenance. MBTA has checked this data and believes that many such records while charged to the operating budget are more appropriately capital items and have not been coded that way. MBTA is working to improve its recordkeeping.

Exhibit 3 – Annual MMBF per Bus Type in Fiscal Year 2011-2015

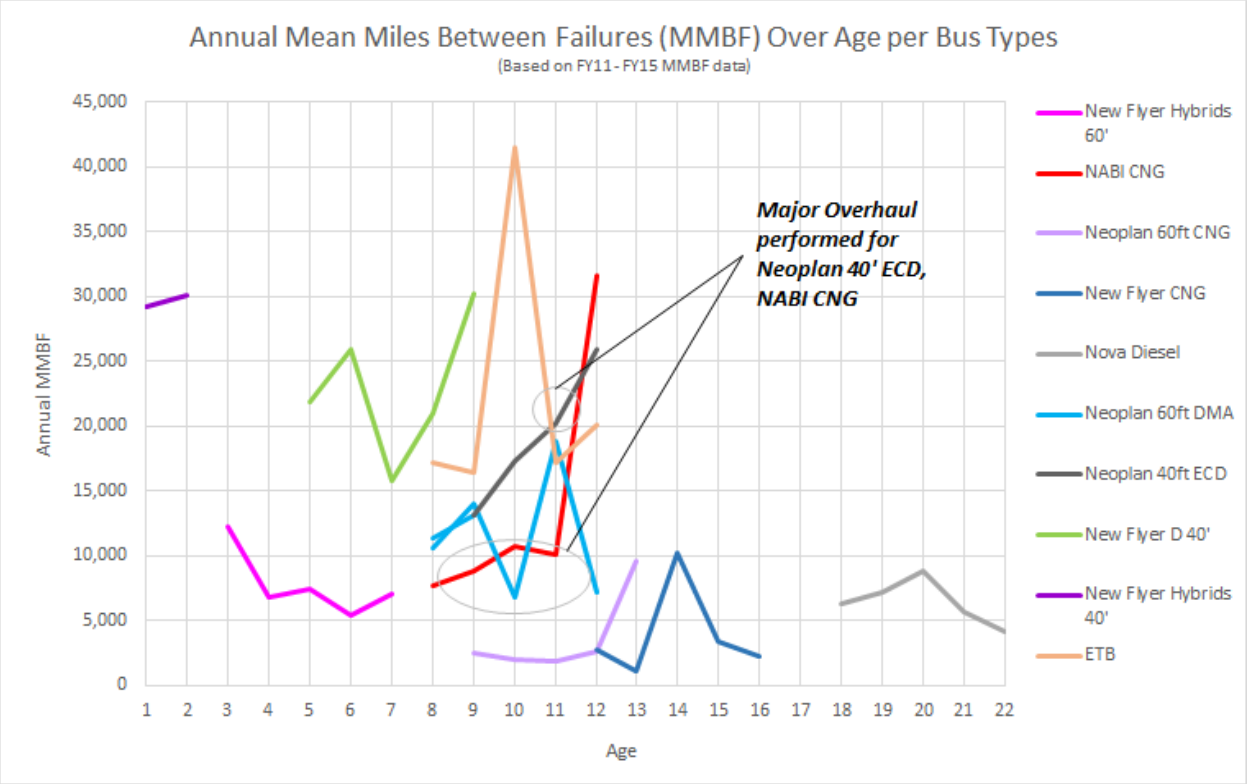


Among the top five failures, engine exhaust system has the highest failure rate. It is very evident from the high value and high usage parts reports that the Diesel Particulate Filter (DPF) and turbos top the list. In an effort to address this issue, MBTA has made significant changes in DPF cleaning procedures, moving to in–house cleaning at regular intervals. Also, in our experience, turbo failures are a root cause of DPF failures as the oil is dumped in the exhaust system when the turbo fails. MBTA needs to develop a proactive maintenance program to replace turbos at a designated interval based on the MBTA's duty cycle. This will likely reduce exhaust system failures and resulting repair costs.

The MBTA still operates a large number of 20 year old Nova diesel buses. These buses require higher labor hours to maintain, parts are difficult to procure, and the structure is corroded. The rear door

wheel chair lifts are still being repaired in-house as required and there is a contract in place with the OEM to overhaul up to 40 lifts with eight units already being sent out. These buses are currently operating as a contingency fleet. However, due to their age and condition, the Nova buses require a disproportionate amount of resources to maintain. MBTA should look at reducing the size (and the age) of the contingency fleet to reduce the operating and maintenance cost. **Exhibit 4** depicts the reliability vs. age for each bus types (including Electric Trolley Bus) with older buses have with lower MMBF.

Exhibit 4 – Annual MMBF over Age per Bus Types



As shown in **Exhibit 4**, the MMBF starts to drop as the fleet ages. Also, the MMBF improves once the mid-life overhaul is performed to keep the buses in the state of good repair, along with a supporting PM program. MBTA to establish the targeting goal for MMBF.

The tire maintenance and repairs are performed in-house. It is a high value component costing MBTA approximately $1.8 million per year. Numerous other bus agencies currently contract out this function.

Overall, MBTA needs a reliability centered maintenance strategy and lean process approach to reduce redundant functions and lower their operating costs.

4.2 Maintenance Staffing Review

As of January 2016, MBTA has 499 budgeted headcounts in bus maintenance, plus 45 vacant positions. The overtime usage in FY 2015 was approximately $8.3 million. Analysis of the available reports shows that there is a high absenteeism rate in critical positions such as fueler and machinist. Although there is currently a surplus in the machinist position (17 over target), the overtime usage for machinists was quite high. One of the factors causing temporary surpluses is the fact that MBTA has a program to hire six new machinists every 6-8 weeks to overcome a slow hiring process and to accommodate the 2-year training program.

Maintenance supervisors and forepersons perform numerous clerical functions, which take their time away from their normal responsibilities. Also, there is no coverage in the stock room in the second and third shifts. Supervisors have the responsibility to perform storeroom functions, PM scheduling and closing work orders etc.

The Quality Assurance/Quality Control (QA/QC) functions should be reorganized, as the percentage of unscheduled repairs cost as recorded is very high (70-80%). In line with industry standards and best practices, most the defects should be repaired through the PM inspection process at regular intervals. MBTA has started working to improve coding of repair tasks to improve tracking, failure analysis and budget control.

4.3 Material Usage Review

From the analysis of the reports, it seems that the procurement department is providing and tracking high value and high usage parts in various categories. The procurement department also appears to have made significant progress in availability of parts. Other findings pertaining to material usage are:

- The min/max levels are not consistent for common components across the garages. Inventory levels, once set by garages and storerooms based on historical usage, are now controlled by Materials.
- Some on-hand inventory levels were very low and at zero and inconsistent across the garages. In some garages parts are not ordered even when the inventory level goes to zero. As such, mechanics are forced to chase parts which is time consuming and inefficient especially if Everett is closed (open Monday to Friday 6 am – 2 pm.) When a part is not available, a staff member typically travels to another MBTA facility to get it. MBTA wants to move towards a zero buses down for parts stocking system where no stock level is allowed to get to zero thus limiting staff running for parts.
- There is a lack of space at each location and sometimes it is difficult to track parts usage at the stock room. The bar code system has been introduced in the storeroom and bus maintenance is helping procurement in forecasting the parts usage and demand.
- Parts dispensing kiosks, as shown in are being installed at certain locations for a pilot program and this should help in collecting real time data on repairs and maintenance programs.

Exhibit 5 - Parts Dispensing Kiosks in a MBTA Garage

4.4 Financial Review

Summary of financial review is depicted in:

- **Exhibit 6 – FY13 to FY15 Actual Bus Maintenance Cost Summary**
  - Annual bus maintenance cost has a marginal increase from FY13 to FY15 and labor cost continued to account for about 55% of the total cost.
  - Based on major cost categories in the exhibit, overtime cost is showing the largest increase over the 3-year period and fuel cost and labor fringe benefit costs are showing a small declining trend.

- **Exhibit 7 – Bus Maintenance Cost and Staffing from FY13 to FY15 per Location**
  - Cabot Tire Shop is the only location that non-labor cost is significantly higher than the labor cost. This is due to the high component cost for the tire maintenance and repair program.
  - Total maintenance cost per location is showing marginal changes over the three years. The most significant cost increases are incurred at Arborway and Everett.
  - Head counts at most locations show an increasing trend.
- **Exhibit 8 - FY13 to FY15 Bus Maintenance Cost Metric and Fleet Age per Location**
  - Three cost metrics are reviewed over the fleet average age at each location: total maintenance cost per mile, total maintenance cost per bus, and maintenance labor cost per staff. There are indirect correlations between the bus mileage, number of bus assigned, and maintenance staffing level.
  - When evaluated against the fleet age, the cost per mile, cost per bus and cost per head count are not always higher at a location assigned with an older fleet. As the bus reliability, technology complexity, service route operating condition, and prior scheduled maintenance performed on the bus are all critical drivers to the maintenance cost and life-cycle performance.
  - Identifying, analyzing, and resolving the root cause of a problem is essential to improve maintenance cost efficiency and effectiveness. This follows the Lean process approach to Define, Measure, Analyze, Improve, and Control the root cause. MBTA, after analysis of their maintenance and cost data, should dig deeper to identify the root causes and implement corrective actions to make continuous process improvements.
- **Exhibit 9** depicts maintenance cost, staffing, mileage and fleet age data for charts in **Exhibit 7** and **Exhibit 8.**
- **Exhibit 10 - Capital Improvement Cost, New Bus in Service and Fleet Reliability**
  - The bus facility capital cost includes some repairs which should have been included in the operating budget.
  - Annual bus overhaul program spending varied significantly over the years.
  - MBTA currently does not have a regular capital program to keep the bus and facility equipment in a state of good repair with long term planning on asset overhaul, upgrade or end-of-life replacement.
- **Exhibit 11 – FY13 - FY15 Service Demand and Fleet Reliability**
  - Annual bus ridership is trending upward with small increase of about 1% and 1.5% in FY 14 and FY 15, respectively. During the same period, the annual bus mileage is trending downward with small decrease of about 1% in FY14 and 1.5% in FY15.
  - Fleet reliability (based on MMBF) has continued to show a fairly significant increase of 7% in FY14 and 27% in FY15. This improvement is critical to maintain service, in particular to keep up with the anticipated ridership demand from new residential and commercial real estate construction and development in Boston and nearby areas.

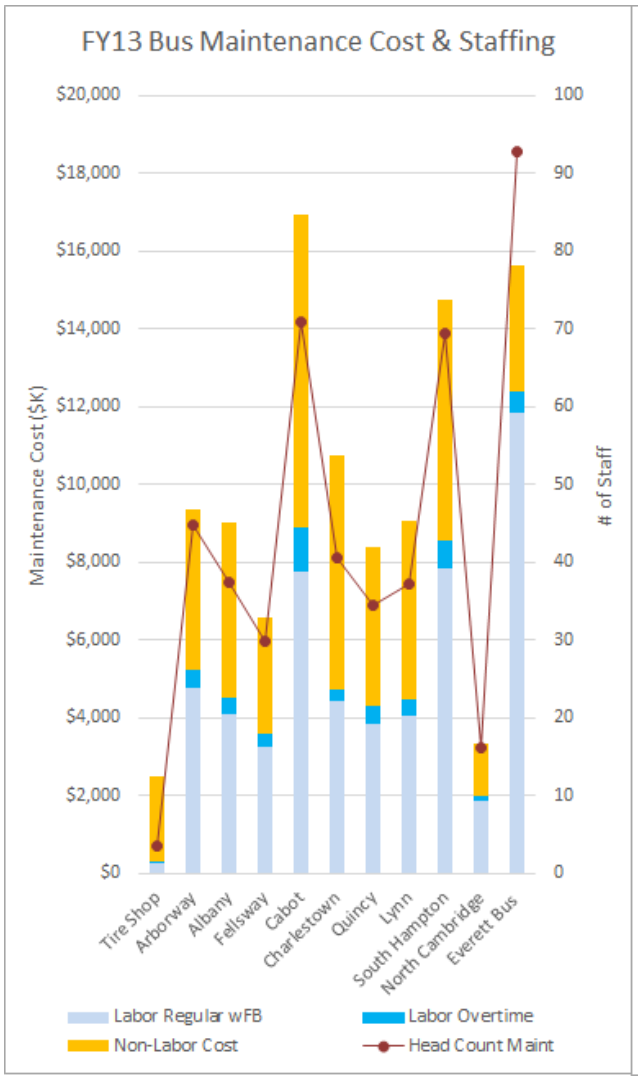
Exhibit 6 – FY13 to FY15 Actual Bus Maintenance Cost Summary

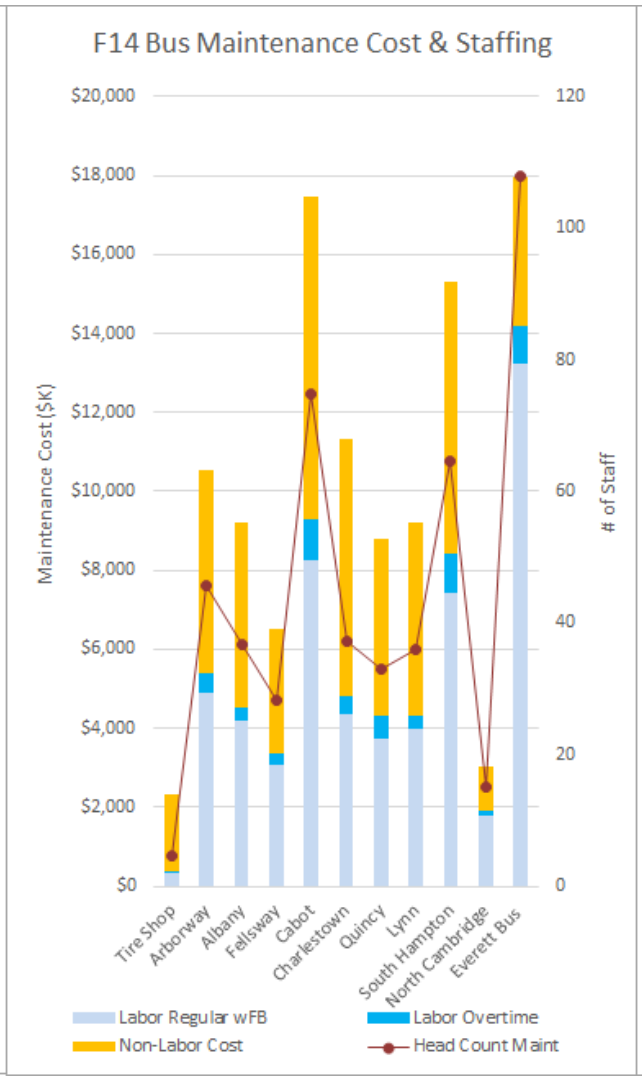
	FYI 13			FY14			FY15		
Key Cost Catgories	**Subtotal Cost**	**% of Total**		**Subtotal Cost**	**% of Total**		**Subtotal Cost**	**% of Total**	
Total Regular Wages	$38,273,597		33%	$39,101,970		32%	$39,126,693		32%
Fringe/Benefit	$20,162,531		18%	$20,340,845		17%	$18,968,621		16%
Overtime	$5,190,395		5%	$6,015,399		5%	$8,336,678		7%
Labor Cost Sub-Total	$63,626,523	55%		$65,458,213	54%		$66,431,991	55%	
Fuel	$23,752,346		21%	$23,477,418		19%	$21,535,471		18%
Uniforms / Unifirst	$148,899		0%	$67,326		0%	$149,176		0%
Vehicle Cleaning	$2,608,388		2%	$2,918,184		2%	$3,190,284		3%
Materials/Services	$24,927,593		22%	$29,120,683		24%	$29,653,962		25%
Non-Labor Cost Sub-Total	$51,437,227	45%		$55,583,612	46%		$54,528,893	45%	
Total Maintenance Cost	**$115,063,750**	**100%**	**100%**	**$121,041,825**	**100%**	**100%**	**$120,960,884**	**100%**	**100%**

Based on review of available information, the following are key cost drivers for bus maintenance:

- Diverse mixed fleet type and technology – 11 bus types (included NFI CNG fleet) from five different OEMs and four bus technologies (diesel, hybrid, electric trolley, and CNG) yield high materials and training cost and restrict flexibility on vehicle assignment to different routes.
- Unscheduled running repairs – 70-80% of MBTA maintenance performed vs. industry standard 30%. The labor and materials costs are both in the 70 to 80% range.
- Overtime – Increasing usage due to a combination of present vacancies, absenteeism rate, and significant maintenance inefficiencies as recorded in this report.
- Absenteeism – It is high (16% in FY2014 and 21% in FY2015 among bus maintenance employees), thus causing high overtime spending.
- The relatively large number of buses within the contingency fleet most with an age of 20 years. While the MBTA contingency fleet is in compliance with FTA guidelines, a 2013 TCRP Synthesis 109 survey showed that less than half (18 out of 38) respondent agencies maintained a contingency fleet.
- Bus fleet and facility capital replacement/investment program:
  - There is no dedicated fleet replacement program and no predictable overhaul funding at mid-life.
  - Aging facilities with widely varying conditions and capacities and almost no capacity to expand. Based on ridership and service demands, it is infeasible to shut down any facility due to a major negative impact to the passengers. A long term facility requirement plan and programs, with major capital investment, is needed.

Exhibit 7 – Bus Maintenance Cost and Staffing from FY13 to FY15 per Location





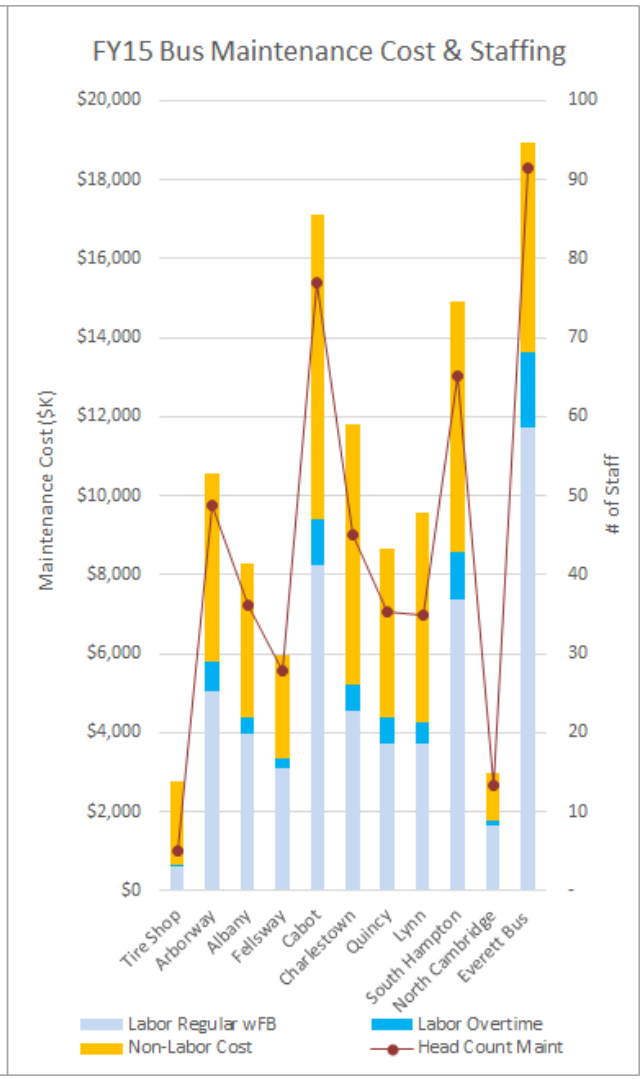


Exhibit 8 - FY13 to FY15 Bus Maintenance Cost Metric and Fleet Age per Location

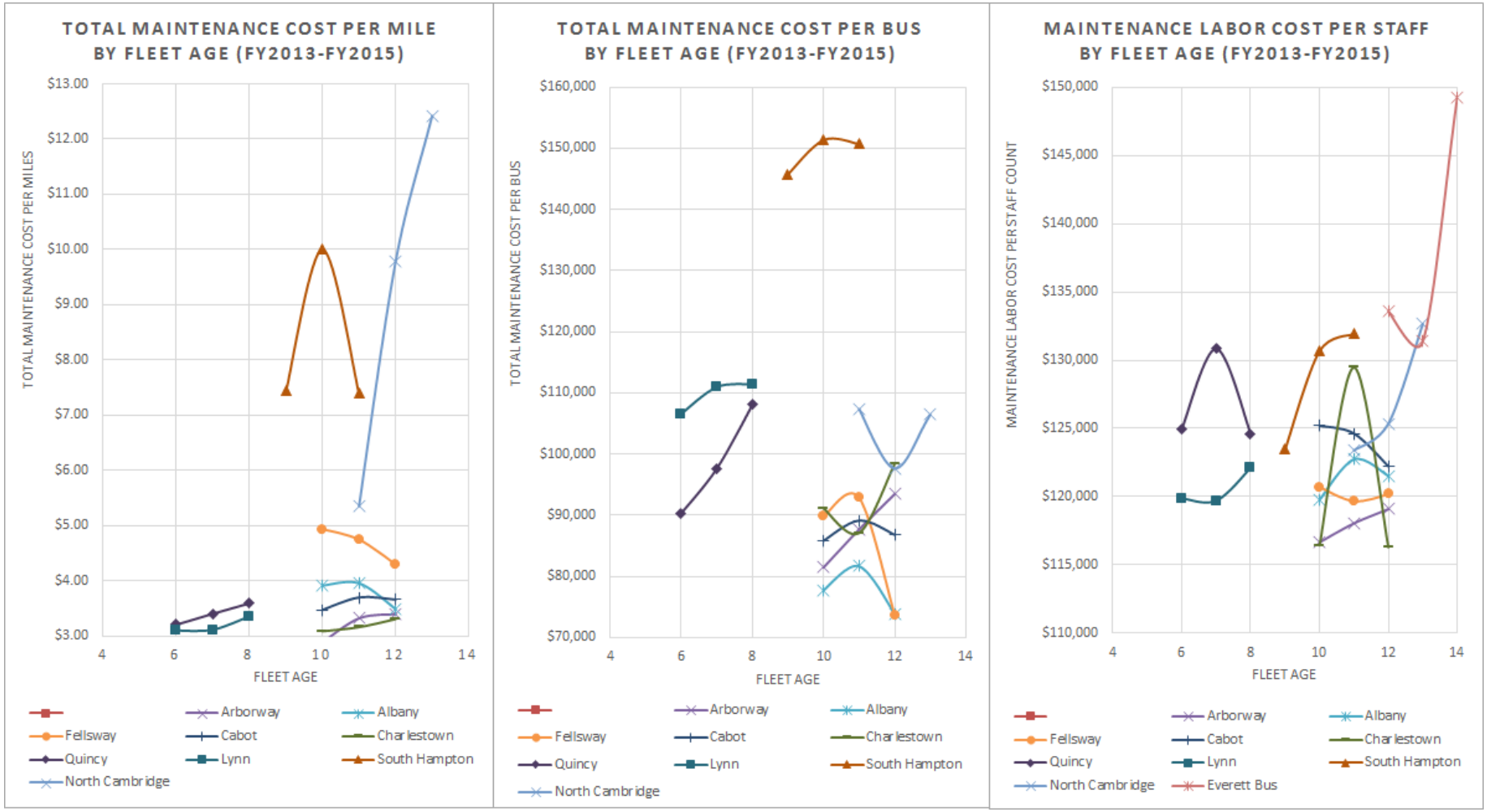


Exhibit 9 – FY13 to FY15 Maintenance Cost, Staffing, Mileage and Fleet Age Data Summary

	Classification	Tire Shop	Arborway	Albany	Fellsway	Cabot	Charlestown	Quincy	Lynn	South Hampton	North Cambridge	Everett Repair Shop
FY13	Labor Regular wFringe & Benefit	$258,144	$4,775,970	$4,092,475	$3,265,319	$7,752,116	$4,430,400	$3,818,769	$4,069,812	$7,817,396	$1,876,165	$11,828,996
	Labor Overtime	$34,138	$445,822	$399,185	$328,184	$1,121,893	$294,577	$488,836	$379,595	$745,276	$108,094	$572,334
	Non-Labor Cost	$2,202,320	$4,146,260	$4,526,906	$2,962,801	$8,036,248	$6,026,656	$4,093,441	$4,611,250	$6,160,285	$1,343,191	$3,236,735
	Total Maintenance Cost	**$2,494,602**	**$9,368,052**	**$9,018,566**	**$6,556,304**	**$16,910,257**	**$10,751,633**	**$8,401,046**	**$9,060,657**	**$14,722,957**	**$3,327,451**	**$15,638,064**
	Head Count Maint	3	45	38	30	71	41	34	37	69	16	93
	Mileage		3,250,670	2,306,252	1,328,595	4,871,249	3,486,160	2,622,625	2,924,912	1,980,783	621,866	
	Labor Cost per Maint Staff		$116,662	$119,778	$120,709	$125,198	$116,436	$124,967	$119,898	$123,470	$123,399	$133,577
	Cost Per Mile		$2.88	$3.91	$4.93	$3.47	$3.08	$3.20	$3.10	$7.43	$5.35	
	Bus Count		115	116	73	197	118	93	85	101	31	16
	Cost Per Bus		$81,461	$77,746	$89,812	$85,839	$91,116	$90,334	$106,596	$145,772	$107,337	
	Fleet Age		10	10	10	10	10	6	6	9	11	12
FY14	Labor Regular wFringe & Benefit	$327,570	$4,911,940	$4,183,028	$3,091,843	$8,269,587	$4,367,430	$3,730,613	$3,977,448	$7,427,308	$1,801,276	$13,213,343
	Labor Overtime	$35,857	$468,807	$331,321	$286,470	$1,037,732	$439,829	$587,163	$322,264	$1,007,600	$100,377	$976,056
	Non-Labor Cost	$1,959,380	$5,142,570	$4,711,496	$3,121,168	$8,164,453	$6,517,225	$4,470,196	$4,911,521	$6,853,291	$1,125,765	$3,782,694
	Total Maintenance Cost	**$2,322,807**	**$10,523,318**	**$9,225,844**	**$6,499,481**	**$17,471,773**	**$11,324,483**	**$8,787,972**	**$9,211,233**	**$15,288,198**	**$3,027,418**	**$17,972,093**
	Head Count Maint	5	46	37	28	75	37	33	36	65	15	108
	Mileage		3,170,789	2,333,399	1,369,728	4,726,466	3,586,466	2,584,569	2,959,866	1,994,836	309,533	
	Labor Cost per Maint Staff		$118,051	$122,739	$119,671	$124,629	$129,471	$130,842	$119,702	$130,672	$125,356	$131,371
	Cost Per Mile		$3.32	$3.95	$4.75	$3.70	$3.16	$3.40	$3.11	$7.66	$9.78	
	Bus Count		120	113	70	196	130	90	83	101	31	2
	Cost Per Bus		$87,694	$81,645	$92,850	$89,142	$87,111	$97,644	$110,979	$151,368	$97,659	
	Fleet Age		11	11	11	11	11	7	7	10	12	13
FY15	Labor Regular wFringe & Benefit	$606,854	$5,042,060	$3,977,498	$3,115,188	$8,255,638	$4,555,852	$3,731,380	$3,743,428	$7,375,948	$1,655,347	$11,722,632
	Labor Overtime	$41,599	$757,610	$421,675	$225,819	$1,143,733	$677,422	$668,055	$518,272	$1,210,010	$112,345	$1,919,242
	Non-Labor Cost	$2,110,618	$4,762,312	$3,876,815	$2,624,191	$7,701,193	$6,581,176	$4,245,663	$5,319,808	$6,333,599	$1,212,962	$5,289,651
	Total Maintenance Cost	**$2,759,071**	**$10,561,982**	**$8,275,988**	**$5,965,199**	**$17,100,564**	**$11,814,449**	**$8,645,098**	**$9,581,508**	**$14,919,558**	**$2,980,654**	**$18,931,525**
	Head Count Maint	5	49	36	28	77	45	35	35	65	13	91
	Mileage		3,112,649	2,373,002	1,388,759	4,674,786	3,576,008	2,408,289	2,856,452	2,019,438	239,974	
	Labor Cost per Maint Staff	$648,453	$119,090	$121,524	$120,180	$122,228	$116,295	$124,630	$122,112	$131,929	$132,660	$149,255
	Cost Per Mile		$3.39	$3.49	$4.30	$3.66	$3.30	$3.59	$3.35	$7.39	$12.42	
	Bus Count		113	112	81	197	120	80	86	99	28	19
	Cost Per Bus		$93,469	$73,893	$73,644	$86,805	$98,454	$108,064	$111,413	$150,703	$106,452	
	Fleet Age		12	12	12	12	12	8	8	11	13	14

Exhibit 10 - Capital Improvement Cost, New Bus in Service and Fleet Reliability

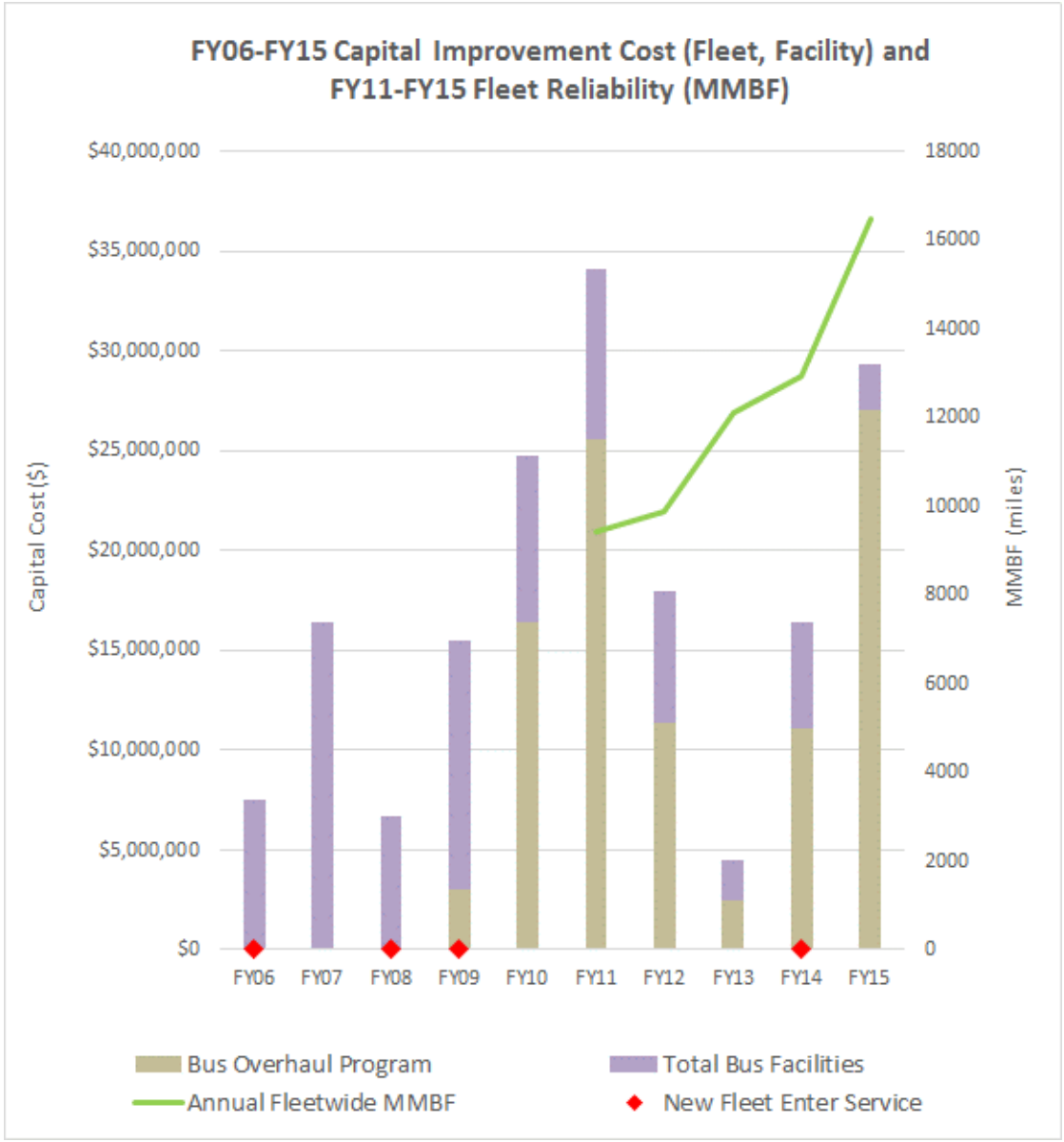
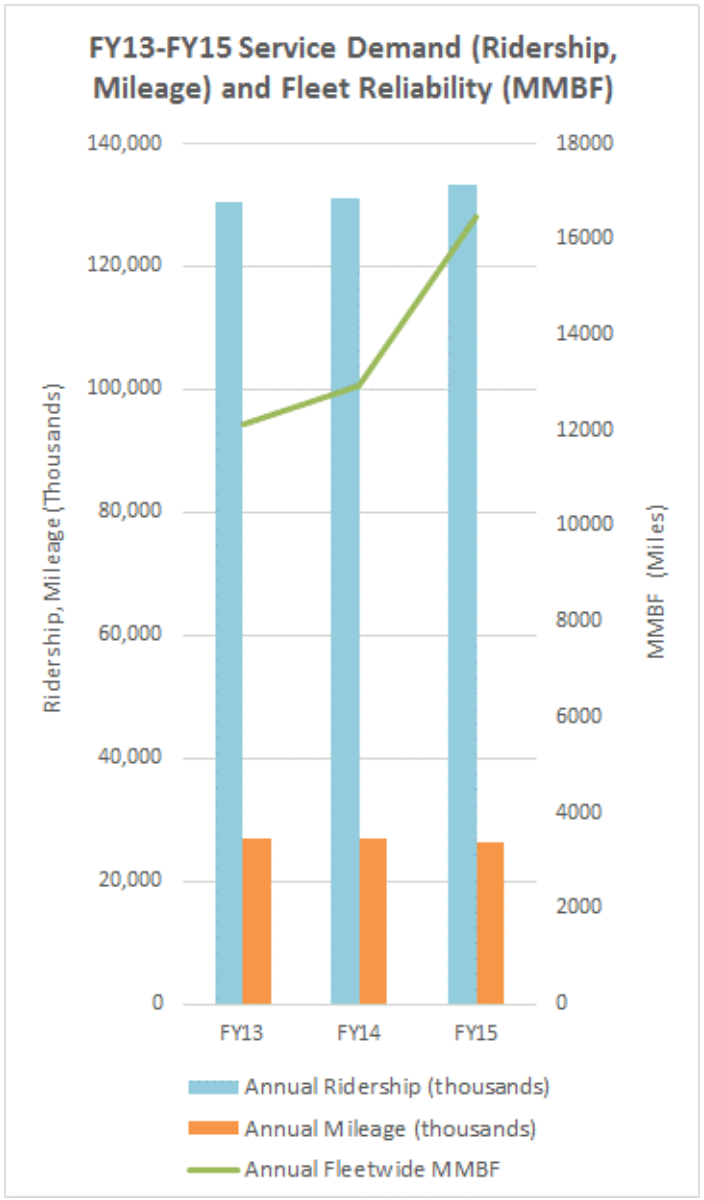


Exhibit 11 – FY13 - FY15 Service Demand and Fleet Reliability



5 BUS MAINTENANCE FACILITIES REVIEW

5.1 Existing MBTA Facilities

5.1.1 Facility General Review

All nine MBTA maintenance garages were visited and toured by the CH2M team. The team's focus during these visits was on the condition and capacity of the maintenance areas, storerooms and the property in general. The goal was to identify issues that may have an impact on the operational efficiencies of the garages. Following are a number of observations the team made, primarily those that may impact efficiencies. Detailed information collected during these visits is provided in Appendix B.

- Every bus maintenance facility has unique issues that impact operational efficiencies, including:
  - Age of the facility
  - Physical layout of property impacting traffic, bus storage capacity, and bus flow
  - Physical layout and constraints of the maintenance area impacting work flow
  - Quantity and condition of equipment (doors, lifts, bus washers, fueling stations)
  - Bus fleet makeup and age
  - Quantity of indoor bus storage varies by garage
- Parts and Storeroom issues that impact operational efficiencies:
  - Location with respect to maintenance area and size
  - Consistent parts usage procedures
  - Having the right type and quantity of spare parts seems to be an issue with most of the garages
  - Most garages do not have storeroom coverage during all working hours making it necessary for machinists to locate needed parts and/or supervisors to perform storeroom functions
  - Often car cleaners or machinists must locate and retrieve missing parts from other facilities
  - Organization and condition of the storerooms vary greatly from very good to poor
- Performance Metrics are not consistent across the garages:
  - Although performance metrics may be recorded at all garages, not all garages post them for their employees
  - MBTA needs to decide which metrics are important for measuring efficiency, and consistently record and post them across all garages
  - Some garages have developed their own processes and procedures, which could be considered MTBA targets. If adopted by other garages, these practices may improve efficiencies. This initiative may already be implemented informally among some garages.
- Maintenance and Bus Storage Capacity and Capabilities:
  - Fleet deployment is consistent across the garages as to the quantity of buses maintained on a property and the number of maintenance bays on the same property
  - Indoor bus storage capability and efficiency varies across the garages. Those garages with more indoor storage capability should show better efficiencies during inclement weather conditions

5.1.2 Facility Capacity Utilization

As mentioned in other sections of this report, electric trolley buses (ETBs) like the ones maintained at North Cambridge are often not considered as buses but rather as rail cars in the bus industry. There are two key facts justifying this classification. The first is the fact that the main systems making up the ETB configuration resemble more those typical of an electric rail car instead of a diesel, CNG or hybrid bus. The second fact is that ETBs are powered by an overhead catenary system (OCS) just like an electric rail car and must get its power feed via a third rail or catenary. Without this electric feed, ETBs cannot be operated or maintained in non-OCS territory and therefore they must be located at North Cambridge the only MBTA facility equipped with OCS. The fact that ETBs have similar maintenance plans as those of a rail car also explains why the ETBs are significantly the most expensive technology type to maintain.

In order for accurately measure the overall maintenance capacity of the 11 MBTA bus facilities, the North Cambridge garage should be excluded in the capacity utilization calculation for being a unique and standalone location to maintain the captive electric trolley fleet only. This required excluding the assigned fleet of 28 buses and the four maintenance bays at the North Cambridge facility from the total 1,046 buses and 99 maintenance work bay systemwide.

Exhibit 13 shows a profile of assigned fleet, facility maintenance capabilities, and storage and maintenance capacity utilization by each garage. The calculation of maintenance capacity shown in this exhibit is based on a targeted number of bus per maintenance bay of 8.7. Refer to **Appendix E** for discussion on methodology to estimate number of bus maintenance bays and ratio on number of buses per bay.

By excluding the North Cambridge garage, the overall MBTA bus ratio is 10.7 (based on 1018 buses over 95 bays.) and is 23% higher than the ideal ratio of 8.7 buses per bay that is recommended by CH2M as the most maintenance productive ratio. Even though a 9-10 ratio is mostly used today in construction of new bus facilities. In CH2M's opinion, the 8.7 ratio best accommodates the scenario of a mechanic performing repairs on a lift only to become idle once facing the situation of his/hers bus staying idle while awaiting parts. If more bays would have been available, the mechanic could have easily moved and worked on a bus lifted on an adjacent bay without registering any labor down time. The 8.7 ratio also has a built-in time margin for lifts or hoists which are down for preventive and/or corrective maintenance.

Exhibit 12 below summarized maintenance capacity with different targeted # of bus per bay. When excluding the North Cambridge garage, the overall MBTA maintenance bay capacity is 23% over capacity compared to the ideal ratio of 8.7.

Exhibit 12 – Maintenance Facility Utilization Based on Ideal and Actual Fleet Size

	Actual # of Maintenance Bays *(A)*	Targeted # of Bus per Bay *(B)*	"Ideal" Fleet Size *(C) = (A) x (B)*	"Actual" Fleet Size *(D)*	% Over Capacity *(E) = (D – C) / D*
All 11 facilities	99	8.7	861	1046	21%
	99	10	990	1046	6%
Excluded North Cambridge	95	8.7	827	1018	23%
	95	10	950	1018	7%

Exhibit 13 – Summary of MBTA Facility Capabilities and Capacity

FLEET ASSIGNED [3]

Bus Model / Type	AN460 CNG	40LFW-24 CNG	SR1105 ECD	SR1222 ECD	SR1393 Hybrid	SR1881 Hybrid	AN460 DMA	AN440 ETB	AN440LF ECD	T80206 RTS	SR612 CNG[1]	SR765 CNG[1]
Technology	CNG	CNG	Diesel	Diesel	Hybrid	Hybrid	Diesel	Electric	Diesel	Diesel	CNG	CNG
Bus Make Year	2003	04'-05'	2006	2008	2009	2014	2004	04'-05'	04'-05'	94'-95'	1999	2001
Fleet Number [4]	1001-1044	2001-2299	0600-0754	0755-0910	1200-1224	1400-1459	1101-1132	4101-4128	0401-0593	0001-0400	6000-6001	6002-6016
Years in Service	13	12	10	8	7	2	12	12	12	22	17	15
Major Overhaul Year		09'-13'					In Prog.		14-'15	01'-03'		

Facility Name	Year Built	Facility Type	CNG Bus Fleet	Electric Bus Fleet	Diesel Bus Fleet	Neoplan 60' CNG	NABI 40' CNG	NFI 40' ECD	NFI Option40' ECD	NFI 60' Diesel-Hybrid	NFI 40' Diesel Hybrid	Neoplan Dual Motor	Electric Trolley Bus	Neoplan ECD 2nd 40'	TMC/NOVA 40 FT[7]	NFI CNG	NFI CNG	Spare Buses (Garage Total - AM Peak)	Garage Total Fleet [2]	Fleet Avg. Age
Revenue Service Locations																				
Albany	1941	Garage			X									116				24	116	12
Arborway	2000	Garage	X				118											21	118	12
Cabot	1970's	Garage	X				180											27	180	12
Charlestown	1970's	Garage			X			134			60				60			60	254	11
Fellsway	1925	Garage			X									76				21	76	12
Lynn	1936	Garage			X			21	68									14	89	8
North Cambridge [5]	1979	Garage		X									28					18	28	12
Quincy	1930	Garage			X				86									27	86	8
Southampton	2002	Garage	X		X	42				25		32						39	99	11
Non-Revenue Service Locations																				
Cabot Tire Shop		Repair	X		X													0	0	
Everett Repair Shop		Repair	X		X	2												2	2	13
Total Revenue Fleet Only >						42	298	155	154	25	60	32	28	192	60	0	0	251	1046	
Spare Ratio >																		24%		

FACILITY CAPACITY UTILIZATION

Facility Name	Service Requirements (# of Bus) [8]: AM Peak Service Req. [3]	PM Peak Service Req. [3]	Peak-of-Peak Service Req. [3]	Storage Capacity (# of Bus): Overnight Storage Capacity	Overnight Storage Assignment [9]	Overnight Storage Capacity Utilization	Maintenance Capacity (# of Bus): Maintenance Assignment [9]	# of Maintenance Work Bays	# Bus per Bay	% over Capacity (based on Targeted)
Revenue Service Locations										
Albany	92	86	92	116	116	100%	116	4	29.0	233%
Arborway	97	96	97	118	118	100%	118	6	19.7	126%
Cabot	153	140	153	160	180	113%	180	12	15.0	72%
Charlestown	191	194	194	310	254	82%	254	18	14.1	62%
Fellsway	55	49	55	74	76	103%	76	6	12.7	46%
Lynn	75	71	75	99	89	90%	89	10	8.9	2%
North Cambridge [5]	10	8	10	32	28	88%	28	4	7.0	-20%
Quincy	59	52	59	90	86	96%	86	8	10.8	24%
Southampton	56	60	60	101	99	97%	99	14	7.1	-19%
Non-Revenue Service Locations										
Cabot Tire Shop				1	0		0	0		
Everett Repair Shop					2		2	17		
Total Revenue Fleet Only >	788	756	795	1100	1046	95%	1046	99	10.6	22%
Revenue Fleet Excluded North Cambridge >							1018	95	10.7	23%

FACILITY CAPACITY

Facility Name	# of Storage Spot: Indoor Spot	Outdoor Spot	Total # of Storage Spot	# of Service Lane: Fuel - Hydrogen	Fuel - CNG	Fuel 0 Diesel	Coolant/Lubricant/Oil	Total # of Lane	# of Dispenser / Lane	# of Fare Collection Bay	# of Wash Bay: Drive Thru Washer	Stream Bay	# of Paint Bay	# of Maintenance Work Bay: Flat for Portable Lift	In Ground Hoist	Access Ramp	Pit	Total # of Work Bay	Facility Space (Thousands sq. ft.): Exterior Service Lane	Interior Service Lane	Bus Wash	Bus Storage	Maintenance	CNG Detached Facility	Total	# of Employee Parking Spot
Revenue Service Locations			*937*															*82*								*435*
Albany	20	96	116			1	1	1	1	1	1	1		4				4		4.85		28	12.3		45.2	19
Arborway	0	124	124		2		2	2	2	2	1			5		1		6	3.65		2.05		10.2		15.9	20
Cabot	0	28	28		4	2	6	6	6	2	2			4	7		1	12	4.3	15.8		100	39.8		159.9	255
Charlestown	220	50	270	1		2	2	2	4	2	2	2		6	10		2	18		13.8		114	22.3	2.4	152.9	22
Fellsway	0	74	74			1	1	1	3	1	1			4	1	1		6		3			10		13.0	40
Lynn	60	40	100			1	1	1	2	1	1	1		1	3		6	10		4.2		26	16		46.2	14
North Cambridge [5]	**4**	30	**34**								1			1	2		1	4							0.0	25
Quincy	34	56	90			1	1	1	1	1	1	1		2			6	8		3.1		20.3	11.2		34.6	20
Southampton	0	101	101		2	2	2	2	2	2	1	1		3	2	4	5	14		7.8		32.8	16.8		57.4	20
Non-Revenue Service Locations																		*17*								*187*
Cabot Tire Shop																										67
Everett Repair Shop												2	2		17			17								120
Total Revenue Fleet Only >																		**99**								

MAINTENANCE STAFFING

Facility Name	# Employee - Wkday	# of Employee - Wkend	# of Shift - Wkday	# Shift - Wkend
Revenue Service Locations	*358*	*159*		
Albany	36	0	3	0
Arborway	32	14	3	3
Cabot	68	39	3	3
Charlestown	86	36	5	4
Fellsway	32	0	3	0
Lynn	16	14	3	3
North Cambridge [5]	10	3	2	2
Quincy	26	17	3	5
Southampton	52	36	3	6
Non-Revenue Service Locations	*107*	*0*		
Cabot Tire Shop	4	0	1	0
Everett Repair Shop	103	0	2	0
Total Revenue Fleet Only >	**465**	**159**		

Average # Bus per Bay (among all Garages)	**13.8**
Targeted # of Bus per Bay [6]	**8.7**
% over capacity	**59%** (based on average of the # of bus per bay at each garage)

Notes (1) MBTA reported all New Flyer CNG buses were retired by January 2016.

(2) Source: Bus Operations Fleet Distributions Fall 2015 data.

(3) Based on MBTA input on January 28, 2016.

(4) Active Bus Fleet.

(5) Normal peak pullout of 22 buses temporally reduced to 10 am and 9 pm due to roadwork.

(6) Targeted # of bus of 8.7 buses per bay (Based on average of 1.15 bays per 10 buses: 0.50 bay for general repair, 0.20 for PMI, 0.17 for major repair, 0.10 for brake repair, 0.05 of tire repair, 0.13 for body repair).

(7) Contingency Fleet remaining. Assumed all 17 New Flyer CNG buses are retired.

(8) Based on winter service requirement which is higher than the fall and the summer seasons.

(9) Assumed 100% of Garage Total Fleet size.

5.1.3 Albany Garage

The Albany Garage provides PM Inspections, repairs, refueling and servicing of a current fleet of 116 Neoplan ECD 40 foot buses. It is the 4th largest garage in MBTA Bus Maintenance from a bus quantity standpoint. Built in 1941, it is the 4th oldest garage in the system. Its overall condition is fair and, currently, the only capital upgrade requested for this garage is to replace the fueling lane concrete floor.

5.1.3.1 Maintenance Capabilities & Capacity

There are 28 employees assigned to Albany Garage maintenance which operates 24 hours per day, 5 days per week. With 6 bus service bays, 2 bus storage areas, 1 service lane with 2 diesel fuel nozzles, 1 bus wash alley with chassis wash capability and outside bus storage, the bus maintenance capability is about 29 buses per bay and the bus storage capacity utilization is about 100%..

There is no room to expand bus maintenance or bus storage capacity at Albany in its current single-story configuration.

5.1.4 Arborway Garage

5.1.4.1 General Purpose & Condition

The Arborway Garage provides PM Inspections, repairs, refueling, and servicing of a current fleet of 118 NABI CNG 40 foot buses. It is the 3th largest garage in MBTA Bus Maintenance from a bus quantity standpoint. Built in 2000, it is one of the newer garages in the system. Arborway was built as a temporary facility but funding has not been available to replace it with permanent structures. Its overall condition is good and, currently, the only capital upgrade requested for this garage is to improve the CNG fueling station to increase its reliability during cold weather.

5.1.4.2 Maintenance Capabilities & Capacity

There are 52 employees assigned to Arborway Garage maintenance which operates 24 hours per day, 7 days per week. With 6 bus service bays, a one story CNG building with the CNG fueling station on its West side, 1 Wash Alley, the bus maintenance capability is about 19 buses per bay and the bus storage capacity utilization is about 100%.

Arborway Garage is a large property which could be expanded to increase overall bus maintenance capacity. However, due to an agreement with the city, only alternative-fuel buses can operate from this garage.

5.1.5 Cabot Facility

5.1.5.1 General Purpose & Condition

The Cabot Garage provides PM Inspections, repairs, refueling, and servicing of a current fleet of 180 NABI CNG 40 foot buses. It is the 2nd largest garage in MBTA Bus Maintenance from a bus quantity standpoint. Cabot is one of 3 garages within the system that were built in the 1970's. Its overall condition is good and, and there are currently capital plans to replace 3 lifts, compressors, repair the roof, replace roof exhausts and repair the steam heating system.

5.1.5.2 Maintenance Capabilities & Capacity

There are 92 employees assigned to Cabot Garage maintenance which operates 24 hours per day, 7 days per week. With 14 bus repair bays with 9 lifts, 2 inspection bays, 1 touch-up and body work bay, 2 wash alleys, 2 diesel fueling islands, 1 outdoor gasoline dispensing island, 6 CNG outdoor fueling stations and

an overnight bus storage area, the bus maintenance capability is about 15 buses per bay and the bus storage capacity utilization is about 113%.

The bus maintenance capacity could be expanded at Cabot Garage with the outsourcing of the Tire Shop operations. Refer to Section 5.3.2.1 of the report for discussion on the repurposing opportunity of the Tire Shop.

5.1.6 Charlestown Garage

5.1.6.1 General Purpose & Condition

The Charlestown Garage provides PM Inspections, repairs, refueling, and servicing of a current fleet of 134 NFI ECD 40 foot buses, 60 NFI Diesel-Hybrid 40 foot buses and 60 TMC/NOVA 40 foot buses for a total of 254 buses. It is the largest garage in MBTA Bus Maintenance from a bus quantity standpoint. Charlestown is one of 3 garages within the system that were built in the 1970's. Its overall condition is good and the only current capital plan is to repair the bus washers. The Sea Wall that borders the property is in need of repair and currently restricts traffic circulation around the property. Due to the elimination of two storage lanes which allow through movement of vehicles, a capital project has recently started for "Immediate Repair" to be followed in the future by total reconstructions of the Sea Wall.

5.1.6.2 Maintenance Capabilities & Capacity

There are 96 employees assigned to Charlestown Garage maintenance which operates 24 hours per day, 7 days per week. With 14 bus repair bays with 12 lifts, 2 inspection pits, 1 touch-up and body work bay, 2 wash alleys, 1 steam bay with bus hoist and 2 diesel fueling islands, the bus maintenance capability is about 14 buses per bay and the bus storage capacity utilization is about 82%.

The bus maintenance capacity could not be expanded at Charlestown Garage within its current configuration.

5.1.7 Fellsway Garage

5.1.7.1 General Purpose & Condition

The Fellsway Garage provides PM Inspections, repairs, refueling, and servicing of a current fleet of 76 Neoplan ECD 40 foot buses. It is the 2nd smallest garage in MBTA Bus Maintenance from a bus quantity standpoint. Built in 1925, it is the oldest garage within the system. Although the condition of the maintenance building is fair, there is no indoor parking for buses and an old underground steam distribution system has caused the paved parking areas and driveways to collapse creating many potholes. The only current capital plan is to repair the roof of the main building.

5.1.7.2 Maintenance Capabilities & Capacity

There are 32 employees assigned to Fellsway Garage maintenance which operates 24 hours per day, 5 days per week. With 6 bus repair bays with 3 portable lifts, 1 parallelogram lift, 1 2-post lift 1 flat floor bay, 1 wash alley and 1 service lane with 1 diesel fueling nozzle, the bus maintenance capability is about 12 buses per bay and the bus storage capacity utilization is about 105%.

The bus maintenance capacity could not be expanded at Fellsway Garage within its current configuration. Also, this property may not be a good candidate to rebuild a new facility on due to the improvements needed to remove the steam distribution system under the pavement.

5.1.8 Lynn Garage

5.1.8.1 General Purpose & Condition

The Lynn Garage provides PM Inspections, repairs, refueling, and servicing of a current fleet of 21 NFI ECD 40 foot buses and 68 NFI Option ECD 40 foot buses for a total of 89 buses. It is the 4th smallest garage in MBTA Bus Maintenance from a bus quantity standpoint. Built in 1936, it is the 3rd oldest garage within the system. Although the condition of the maintenance building is fair, the building is poorly lighted and the property is small making it necessary to use the adjacent street for bus circulation. Also, the property is low and storm water can flood the pits and basement.

5.1.8.2 Maintenance Capabilities & Capacity

There are 23 employees assigned to Lynn Garage maintenance which operates 24 hours per day, 7 days per week. With 10 bus repair bays including 6 inspection bays with pits, 3 bays with hoists and 1 bay with portable lifts, in-house storage for 60 buses, 1 bus wash alley and a service lane with 2 diesel fueling pumps, the bus maintenance capability is about 8 buses per bay and the bus storage capacity utilization is about 90%.

The bus maintenance capacity cannot be expanded at Lynn Garage within its current configuration. Also, this property is not a good candidate to rebuild a new facility on due to the property size, the storm water drainage issue and the traffic conditions on the adjacent surface street.

5.1.9 North Cambridge Garage

5.1.9.1 General Purpose & Condition

The North Cambridge Garage provides PM Inspections, repairs, and servicing of a current fleet of 28 Electric Trolley 40 foot Buses. It is the smallest garage in MBTA Bus Maintenance from a bus quantity standpoint. It is one of 3 garages within the system that were built in the 1970's. Its overall condition is good and there are currently no plans in place for capital improvements.

5.1.9.2 Maintenance Capabilities & Capacity

There are 10 employees assigned to North Cambridge Garage maintenance which operates 2 shifts per day, 6 days per week. With 5 bus repair bays and 1 bus wash alley, the bus maintenance capability is about 7 buses per bay and the bus storage capacity utilization is about 88%.

North Cambridge Garage is equipped to maintain only electric trolley buses and has the capacity for addition trolleys to be added to its fleet.

5.1.10 Quincy Garage

5.1.10.1 General Purpose & Condition

The Quincy Garage provides PM Inspections, repairs, refueling, and servicing of a current fleet of 86 NFI Option ECD 40 foot Buses. It is the 3rd smallest garage in MBTA Bus Maintenance from a bus quantity standpoint. Built in 1930, it is the 2nd oldest garage within the system. The building and property are in poor condition. The repair bay pits are barely being maintained structurally and there is currently temporary structure holding up the floor around the pits. The ceiling heights are too low to allow full lift height jacking. Entrance door heights would not accommodate taller buses such as Hybrids. The problems on this site that require capital spending are the pits, floors and the replacement of fuel tanks.

5.1.10.2 Maintenance Capabilities & Capacity

There are 43 employees assigned to Quincy Garage maintenance which operates 24 hours per day, 7 days per week. With 7 bus repair bays including 5 bays with pits and 2 floor bays with portable lifts, indoors storage for 26 buses, 1 bus wash alley and a single service lane with 1 diesel fueling nozzle, the bus maintenance capability is about 10 buses per bay and the bus storage capacity utilization is about 96%.

The bus maintenance capacity could not be expanded at Quincy Garage within its current configuration. There is also a problem with the electrical service to this facility. This property would not be a good candidate for rebuilding.

5.1.11 Southampton Garage

5.1.11.1 General Purpose & Condition

The Southampton Garage provides PM Inspections, repairs, refueling, and servicing of a current fleet of 41 Neoplan CNG 60 foot Buses, 25 NFI Diesel-Hybrid 60 foot Buses and 32 Neoplan Dual Mode Articulating Buses (DMAs) for a total of 98 buses. It is the 5th largest garage in MBTA Bus Maintenance from a bus quantity standpoint. Built in 2002, it is the newest garage within the system. The building and property are in fairly good condition. The issues that require capital funds are that the property is low requiring that storm water and sewage to be lifted off the site with pumps requiring replacement every 6 months to 1 year and that the heating system also needs to be replaced.

5.1.11.2 Maintenance Capabilities & Capacity

There are 88 employees assigned to Southampton Garage maintenance which operates 24 hours per day, 7 days per week. With 10 bus repair bays, 1 bus wash alley and 2 service lanes with CNG and diesel fueling nozzle, the bus maintenance capability is about 7.1 buses per bay and the bus storage capacity utilization is about 97%.

This property would be a good candidate for expansion if adjacent property could be acquired.

5.1.12 Everett Repair Shop

5.1.12.1 General Purpose & Condition

The Everett Repair Shop provides heavy maintenance and repairs and major component rebuilds on the current MBTA fleet of 1,045 buses. Built in 1940's, the building and property are in fairly good condition. The issues that require capital are TBD.

5.1.12.2 Maintenance Capabilities & Capacity

There are 103 employees assigned to the Everett Repair Shop which operates two shifts per day, 5 days per week; some of these employees support both bus and rail work, e.g. seats. The facility has 17 bus repair bays, two wash bays, and two paint bays..

5.1.13 Summary of Existing Facility Efficiency Improvement Opportunities

Facility	Description	Capital Funding Needed	Impact
Albany Garage	(1) Remove old, broken or unneeded materials from all garage areas and reorganize (2) Add 1 set of portable lifts	(1) None (2) Cost of lifts	> Lower Operating Cost > Improve Maintenance Efficiency
Arborway Garage	(1) revisit spare part min/max levels (2) Add chassis wash capability	(1)Small increase due to increased spare part quantities (2) Cost of pressure washer for chassis	> Lower Operating Cost > Improve Maintenance Efficiency
Cabot Garage	(1) Remove old, broken or unneeded materials from all garage areas and reorganize (2) Repair or replace bus lifts	(1) None (2) Cost to replace lifts	> Lower Operating Cost > Removing unneeded material would gain bus bay positions and increase capacity
Charlestown Garage	(1) Reorganize garage perimeter (2) Resolve parts shortages (3) Improve facility maintenance (4) Repair Sea Wall	(1) None (2) Small increase due to increased spare part quantities (3) None unless equipment needs replaced (4) Regain full use of indoor space	> Lower Operating Cost > Improve Maintenance Efficiency
Fellsway Garage	(1) Scope out removal of storm pipes below parking lot to eliminate sinkholes (2) Improve facility maintenance issues with lifts	(1) Cost of pavement fix (2) None	> Lower Operating Cost > Improve Maintenance Efficiency
Lynn Garage	(1) Some reorganization of maintenance area	(1)None	> Lower Operating Cost > Improve Maintenance Efficiency
North Cambridge Garage	(1) Reorganize Storeroom	(1) None	> Lower Operating Cost > Improve Maintenance Efficiency
Quincy Garage	(1) Reorganize all areas (2) Major repairs are needed for the pits and floors (3) Resolve parts shortages	(1) None (2) Major capital cost (3) Small increase due to increased spare part quantities	> Lower Operating Cost > Improve Maintenance Efficiency
Southampton Garage	(1) Reorganize Storeroom	(1) None	> Lower Operating Cost > Improve Maintenance Efficiency
Everett Repair Shop	(1) Some reorganization of maintenance area	(1)None	> Lower Operating Cost > Improve Maintenance Efficiency

Other potential improvement opportunities that could improve efficiency without significant capital investment include applying a lean approach at garages, which includes lean training, 5S reorganization, and formation of lean councils. Refer to **Appendix C** for further details.

5.2 Regional Transportation Authority (RTA) Facilities

The CH2M Team visited Lowell RTA and Worcester RTA, and conducted tours similar to those conducted at the nine MBTA garages. These two RTA's have a number of advantages over the MBTA garages that most likely enable them to operate more efficiently. Detailed information collected during these visits is provided in Appendix B.

- The RTA's are funded differently, seemingly providing more capital. RTA operating contracts do not include responsibility for capital fleet and funding upgrades. Some projects are implemented by the operator but the RTA is responsible for designing and funding capital projects. As a result the bus fleets are significantly newer and the facilities are well equipped and maintained
- Contractor at each RTA facility has full responsibility and accountability over all aspects of its operations:
  - Capital spending for fleet and facility upgrades
  - Facility maintenance
  - Spare parts management
  - Bus maintenance
  - Bus services
- Both RTA facilities can store all buses indoors during inclement weather
- Both facilities have large, well equipped and maintained maintenance areas
- Garage personnel belong to one union
- Machinists' wages are lower than MBTA machinists
- Service lane operators conduct fueling, bus cleaning and vaulting.

5.3 MBTA Bus Facility Consolidation and Re-Purposing Feasibility Review

5.3.1 Alternative 1 - Consolidation without Major Facility Construction

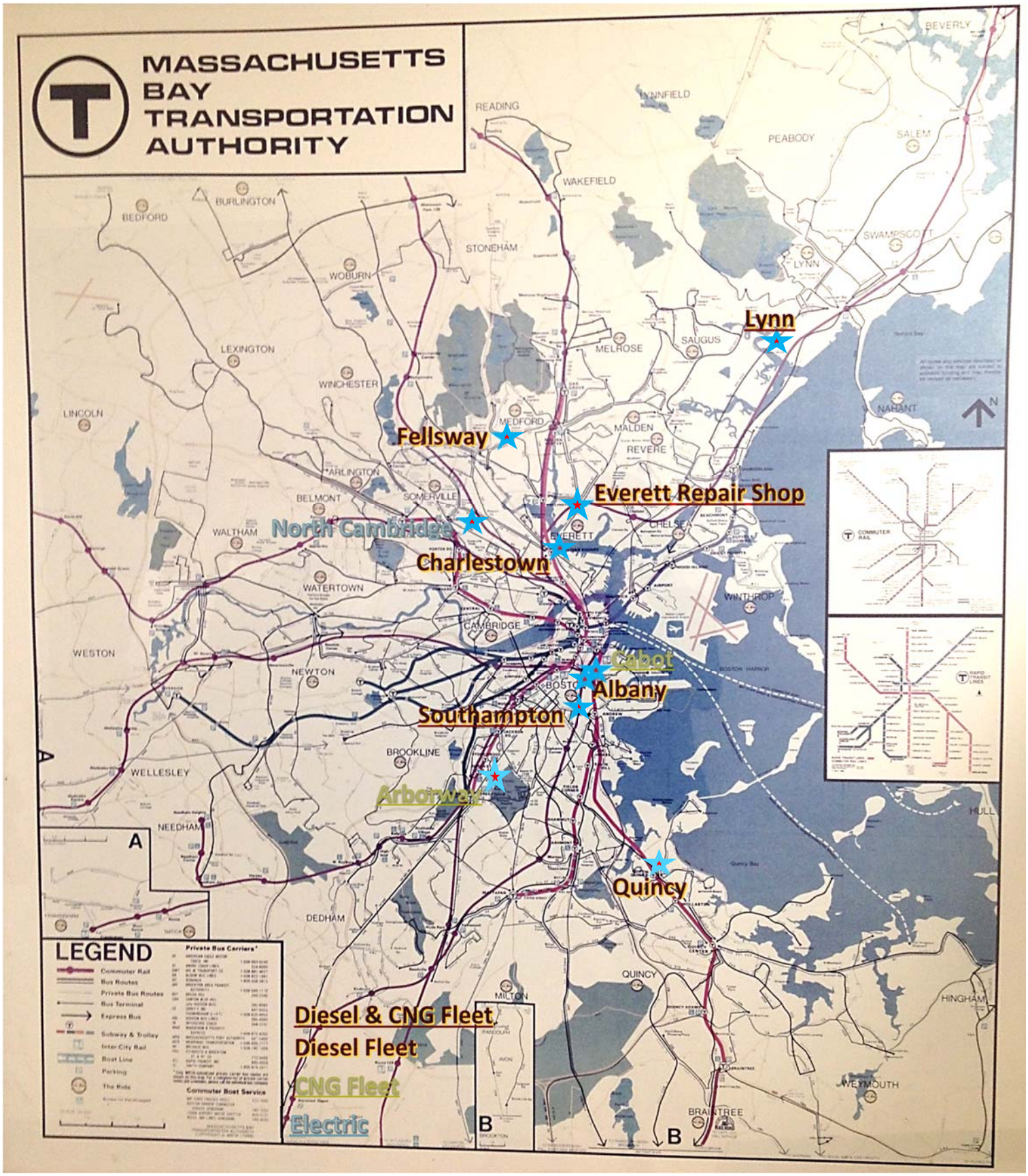
MBTA has a large number of buses with various propulsion technologies. This makes it difficult to mix and match the buses at the garages, as each technology (CNG or Electric Trolley) needs its unique infrastructure to support the maintenance and repairs. On the other hand, the diesel and hybrid – electric buses might have a common fuel but the configuration of hybrid bus batteries on the roof of the bus limits its usage in a bus garage designed for diesel buses with lower roof heights. Changing the height of doors and roof might require a major capital investment to consolidate buses into certain garages. Also, most of the garages are either at full capacity or over their limit to accommodate more buses in the limited space. Therefore, in the present condition and with space constraints, only very minor shifts in bus allocation are possible.

Table below lists the address and bus types of each bus maintenance facility. **Exhibit 14** shows the general location of all of these facilities on a map.

Facility Name	Address	Bus Types
Albany Garage	421 Albany Street, Boston, MA 02118	Diesel
Arborway Garage	3550 Washington Street, Boston MA 02130	CNG
Cabot Garage	275 Dorchester Ave., Cabot, MA 02127	CNG, Diesel

Facility Name	Address	Bus Types
Cabot Tire Shop	275 Dorchester Ave., Cabot, MA 02127	NA
Charlestown	21 Arlington Ave., Charlestown, MA 02129	Diesel
Everett Repair Shop	80 Broadway, Everett, MA 02149	NA
Fellsway Garage	447 Salem Street, Medford, MA 02155	Diesel
Lynn Garage	985 Western Ave., Lynn, MA 01904	Diesel
North Cambridge Garage	2375 Massachusetts Ave., N. Cambridge, MA 02140	Electric
Quincy Garage	459 Hancock Street, Quincy, MA 02169	Diesel
Southampton Garage	238 Southampton Street, Boston, MA 02118	Diesel, CNG

Exhibit 14 - MBTA Bus Maintenance Facility Location Map



5.3.2 Alternative 2 - Re-Purposing Existing Facilities

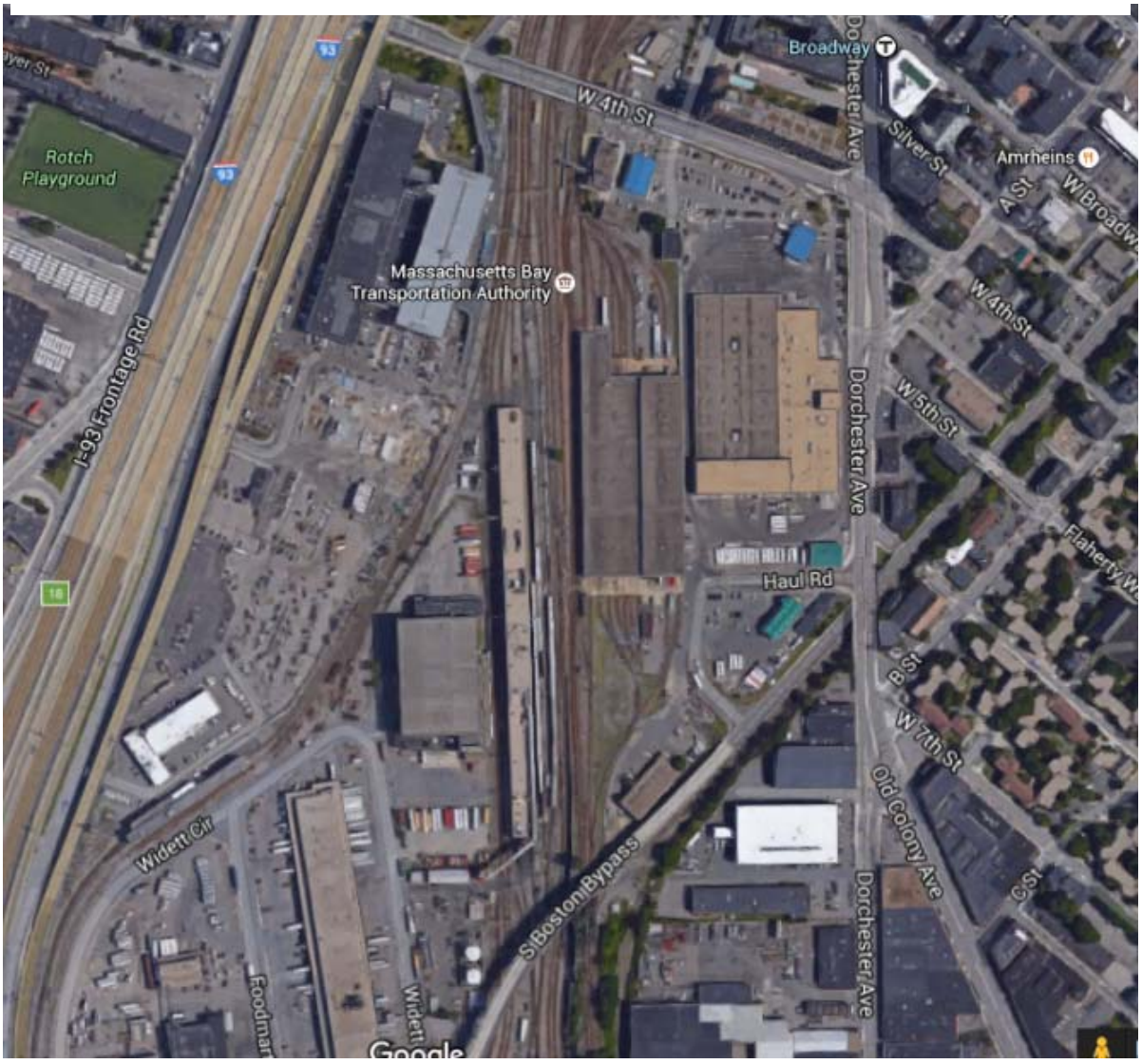
5.3.2.1 Alternative 2A – Re-Purposing Cabot Repair Facility

In our opinion, one improvement opportunity includes outsourcing Cabot Tire Shop repair work. This facility can be repurposed in ways to accommodate different bus maintenance activities. Final solutions should be selected after analyzing each options:

a. Use as a centralized training center. Machinists can be trained regularly on Standard Repair Times (SRT's), heavy repairs, and troubleshooting. In the current On-the –Job-Training set up, a bay or lift is used in the maintenance shop to conduct a half day or a full day of training, causing loss in productivity due to shortage of bays/lifts. Also, it helps getting the message out to the employees that MBTA is investing in its employees to improve their knowledge and productivity.

b. Since Cabot garage, like other MBTA garages, has an insufficient number of maintenance bays (only 14 for a fleet of 180 buses), the former tire shop can be reshaped, with the only cost of some additional shop equipment, to accommodate up to two flat bays to perform corrective maintenance or potential systems upgrade campaigns without affecting the productivity of PM and running repairs at the garages.

Exhibit 15 - Cabot Garage



5.3.2.2 Alternative 2B – Re-Purposing Everett Repair Facility

Everett Repair Facility currently is set up to perform overhauls, component rebuilds and heavy repair including major bus body work and painting. If a decision is made to outsource most, if not all, of the overhauls and retain only the heavy repair, some of its present 17 maintenance bays can be reassigned to do the PMI and running repair typical of a garage operation. This repurpose will allow MBTA the option of consolidating at Everett some of the heavy repair functions that are now performed at multiple garages.

Exhibit 16 - Everett Repair Facility

5.3.3 Alternative 3 – Consolidation with Existing Facility Modification/Expansion

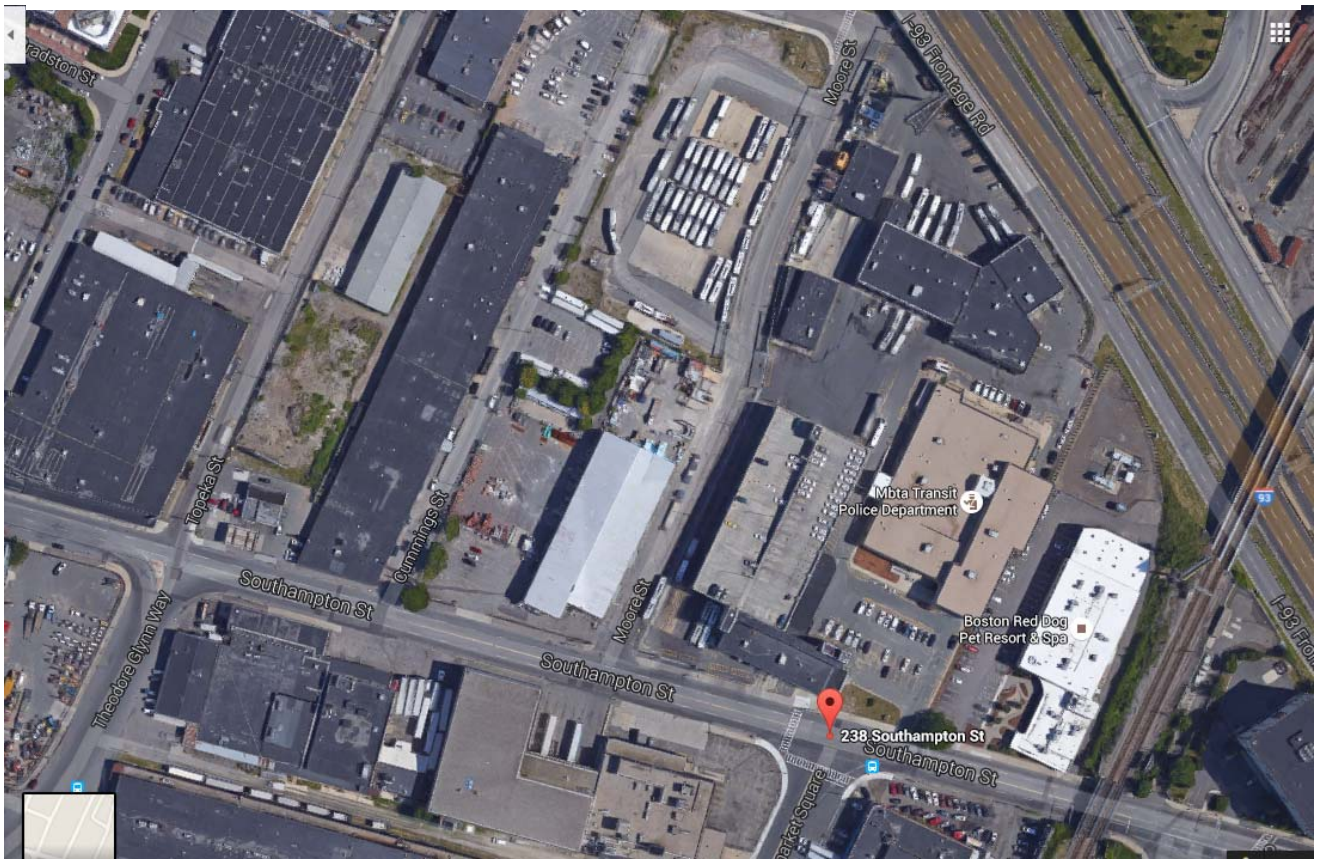
5.3.3.1 Alternative 3A – Consolidation at Southampton Facility

While all MBTA garages have limited overall building dimensions and overall property useful square footage, a series of high level site visits has shown that Southampton appears to have the highest potential for major expansion to allow future consolidation with another garage (i.e. Cabot or Albany.)

Even if no consolidation is planned, an expanded Southampton could temporarily accommodate a bus fleet from another garage while that garage is being rehabilitated or undergoing a major reconstruction.

Southampton, the only facility equipped to maintain DMAs in addition to Hybrids and CNGs, has a young age (built in 2002) to justify capital investments and its central location is a key to minimize deadhead mileage. The most important criteria to select it is because it has room for expansion within the present perimeter including the feasibility to relocate its Transit Police building somewhere else or by procuring adjacent west side property presently occupied by small private companies, one located right next to the outdoor bus storage area.

Exhibit 17 - Southampton Garage



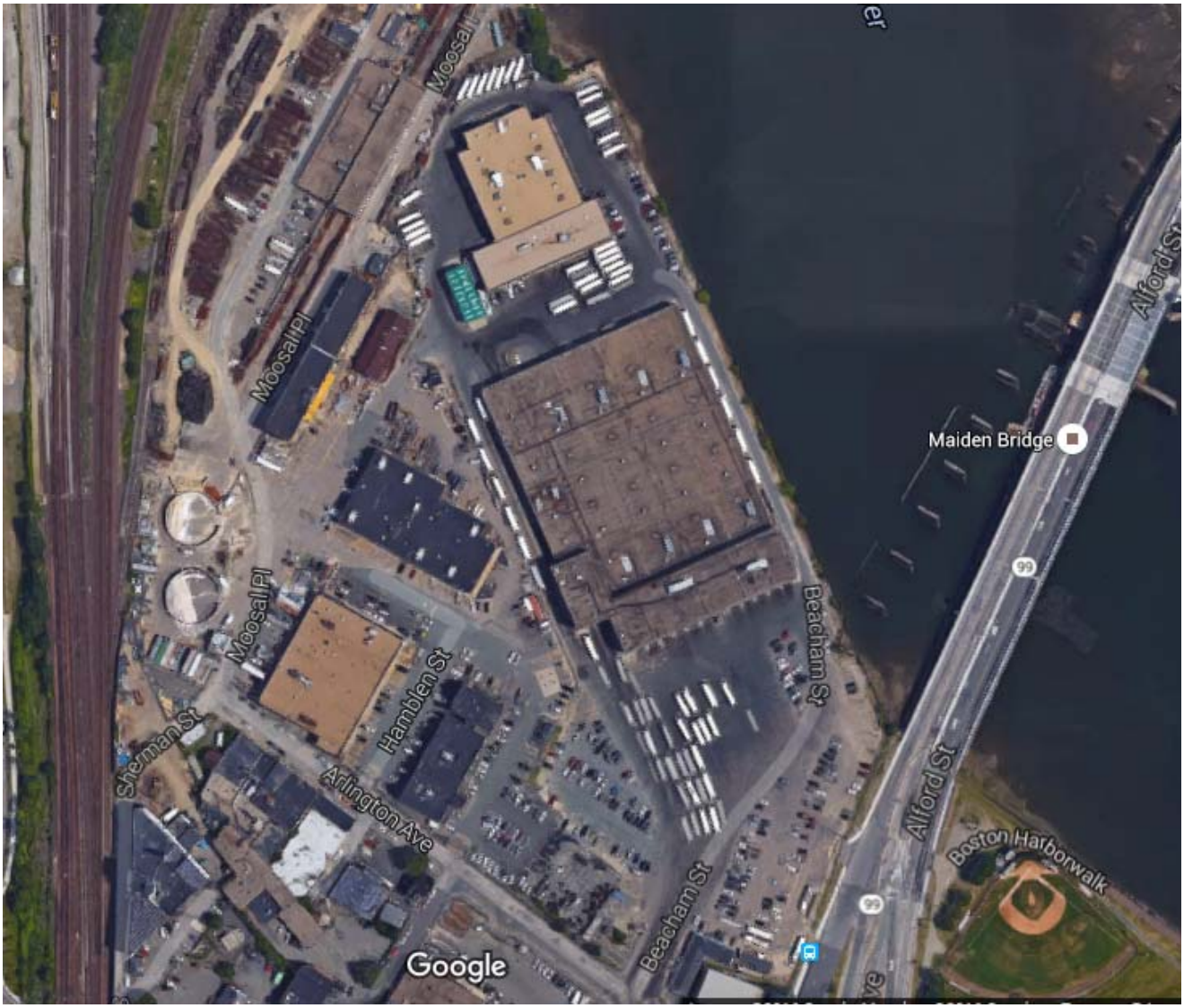
5.3.3.2 Alternative 3B – Closure of Fellsway

The closure of Fellsway is more problematic because its closest facility is at North Cambridge which can only maintain ETBs and not the Fellsway's ECDs.

Another option is closing Fellsway and combining Fellsway's ECD fleet with Charlestown. This, however would require a major expansion of Charlestown maintenance and bus storage capacity. One concept to achieve this expansion is to build a large, multi-story parking garage for bus storage and employee parking and reconfigure enough of the current bus storage area for 8 additional bus repair bays.

The Fellsway property could either be sold or hold for future expansion or partially used for Transit Police Headquarters in conjunction with a Southampton expansion discussed as Alternative 3A above. A negative consequence of this option is that the Fellsway fleet would have additional non-revenue miles to travel to and from its revenue routes.

Exhibit 18 - Charlestown Garage



5.3.4 Alternative 4 – Consolidation with New Facility

At some point, MBTA will need to build a new Bus Maintenance Garage, either to increase fleet capacity or to replace an older garage such as Quincy or Lynn. Neither of these properties are good candidates for placement of a new facility due to their current lot sizes. However, both garages are in suburban areas where it may be easier to find land more suitable for building new garages.

A new MBTA facility to maintain a fleet of 150 buses should include the following main features:

- A 2-story brick building with approximately 400,000 square feet of space
- Green design: solar air heating, rainwater recycling, green roof, energy efficient HVAC, waste oil/antifreeze storage system, etc.
- Indoor parking for all 150 buses
- 2 fully automated drive-through bus washers with water recycling system
- 17 maintenance bays (combination for 40' and 60' bus) most of them in ground hoists with only 3-4 pits
- Overhead cranes to service roof-mounted equipment
- 2-3 service lanes for daily fueling/cleaning
- All support areas (technical, training, administrative, locker room, cafeteria, etc.) to be located on the second floor.
- Managerial/supervision offices located on second floor with windows looking down at shop floor.
- Capital cost vary depending on selection of amenities and design; the average cost per square feet to be approximately $250 for single level to $350 for a bi-level garage.

As reference of a new and modern bus depot with operating environment similar to MBTA, Exhibit 19 depicts the exterior view and main features of the New York City Transit Mother Clara Hale Bus Depot.

Exhibit 19 – NYCT Mother Clara Hale Bus Depot Exterior View and Main Features

- New Facility opened in 2014 replacing original 1939 trolley barn on the same site
- LEED gold level certification: "green" roof, thermal insulation, solar wall, rainwater rooftop collection, bus wash water reclamation system, cost effective and energy efficient rooftop heat recovery system, etc.
- 390,000 sq. ft. at construction cost of $262M (approximately $672/sq. ft.)
- Multi-level structure with indoor parking for 150 buses
- Service 150 clean air hybrid electric (40 ft. and 60 ft.) buses
- 12 bays with 4-unit portable lifts, 2 articulated bays with 6-unit portable lifts
- Waste oil and waste antifreeze systems with a 1,000 gallon waste storage tank for each; stations for ultra-low-sulfur diesel fuel refueling and urea dispensing
- The façade is embellished by the first art project coordinated by MTA Arts & Design for a bus depot.

5.4 Summary of Facility Review

Numerous potential minor improvements can be made to the existing garages that will increase efficiencies without significant capital investment. Based on high-level visits made to each garage and information obtained during meetings and discussions with MBTA personnel, CH2M team identified a few possible alternatives at this point. Any garage expansion that requires significant capital spending needs a detailed study and financial analysis.

6 FLEET MAKEUP AND SPARE RATIO REVIEW

6.1 Current Service Demands and Operations

Following are key findings and observations based on review of MBTA and the two Regional bus operations included in this study:

- Recent operating statistics show that bus maintenance most of the time meet the service "pullout" requirements, but trips are at times cancelled due to driver not being available to operate the buses.
- MBTA's current service requirement for the conventional fleet is 795 vehicles operated in maximum service (VOMS). Total active conventional fleet, vehicles available for service (VAMS), is 926 buses, excluded the 120 buses in the non-conventional fleet and contingency fleet.
- MBTA has a total of 60 buses in the non-conventional fleet:
  - Southampton garage has 32 DMA Neoplan 60' buses to support Silver Line service: 8 buses provide service to Logan airport and are owned by MassPort while 24 operate service to the South Boston Pier and Innovation District (trolley poles in the South Station Transitway Tunnel and diesel power above ground)
  - North Cambridge has 28 Neoplan 40' ETBs (electric trolley buses) for a maximum pullout of 22 to service Cambridge, Watertown, and Belmont on fixed routes with overhead catenary wires. Due to present road work, the temporary pullout requirements are 10 buses for the am peak and 8 for the pm peak. ETBs are not part of the conventional fleet
- A contingency fleet of 60 Nova RTS (MBTA in process of retiring 15 New Flyer CNG):
  - Used to supplement the "snow shift" of buses when rear axle articulated buses are pulled out of service.
  - Used to supplement mid-life overhaul programs, emergency services, special events, rail service, and unforeseen emergencies.
  - In the past, contingency fleets were utilized by transit agencies to support bus service when new buses were delivered with fleet defects.
  - Deployed to support bus bridges (revenue service supports) during rail construction activities. The cost of this service is borne by MBTA bus maintenance.

6.2 Fleet Profile and Spare Ratio Review

Federal Transit Administration (FTA) has an established formula for calculating spare ratio; details on the calculation are shown in **Exhibit 20**. Based on the MBTA'S conventional bus fleet of 926, the spare ratio is to be 17.9% and it is comparable to the FTA standard for its grantee and the two local RTA operations.

FTA specifies that the number of spare buses in an active fleet for grantees operating 50 or more fixed-route revenue vehicles is not to exceed 20% of VOMS. Exclusion of electric trolley buses (MBTA has 28) from the bus spare ratio is generally allowed and at time ETBs will be considered part of the rail fleet. Also the mixed operational use of the 32 DMAs justifies the exclusion from the conventional bus fleet. Further, FTA allows agencies to stock pile buses at the end of their useful life in an inactive contingency fleet in preparation for emergencies as long as the buses are properly stored, maintained, and documented in a contingency plan (MBTA has such a plan).

Detail on MBTA bus fleet profile and size is in **Exhibit 13** above.

Exhibit 20 – MBTA Bus Fleet and Spare Ratio by Garage

Location	Fleet Available (VMS = Vehicles Available for Services)	Peak Fleet Requirement (VOMS = Vehicle Operated in Maximum Service)	Spare Ratio (a)
MBTA by Garage (Included contingency buses)			
Albany Garage	116	92	26.1%
Arborway Garage	118	97	21.6%
Cabot Garage	180	153	17.6%
Charlestown Garage	**254**	**194**	30.9%
Fellsway Garage	76	55	21.1%
Lynn Garage	**89**	**75**	18.7%
North Cambridge	**28**	**22** (b)	27.3%
Quincy Garage	86	59	45.8%
Southampton Garage	99	60	65.0%
MBTA Active Fleet (Excluded non-conventional & contingency buses)			
Systemwide	926 (c)	795	17.9%
INDUSTRY COMPARISON			
FTA Standard			20%
Lowell RTA	50 (d)	42	19%
Worcester RTA	52 (e)	43	21%

Note: (a) Spare Ratio = (VAMS – VOMS) / VOMS.

(b) Temporarily reduced to 10 due to roadwork.

(c) Calculated based on exclusion of 120 buses (32 DMA at Southampton, 28 ETB at North Cambridge and 60 contingency buses) from the total 1045 buses in MBTA system.

(d) Lowell bus fleet profile: 23 35-ft Gillig, 18 29-ft Gillig and 9 vans.

(e) Worcester RTA bus fleet profile: 46 Gillig including 17 Hybrid and 6 electric Protera. There is an additional 40 vans used in different service.

6.3 Improvement Opportunities

The MBTA contingency fleet is in compliance with FTA guidelines. The MBTA has reduced this fleet from 95 buses in April 2015 down to 75 buses in September 2015 and in process of an additional reduction to 60. However, the number of the contingency fleet is still significant (60 or about 6% of total fleet of 1046) and so is its maintenance cost. A high number, 60 out of 75 of the contingency fleet are 20 year old Nova RTS buses, which are less reliable and costly to maintain. The average annual maintenance cost for an active bus is $98K including fuel. Even if the cost of a contingency bus is less than half that of an active bus i.e. $40K, a reduction of 15 (75 down to 60) buses could result in $600K annual savings. Further, it would help free valuable storage areas and create more available time spots on the inadequate number of maintenance bays.

For the long term, efforts should be made to keep the bus fleet as homogenous and uniform as possible with a minimum number of different bus models/size/manufacturers and fuel/propulsion technologies. MBTA has a relatively diverse fleet, with 11 different vehicle models for a fleet of 1, 046 compared to NYCT 16 models for a fleet of 4,431 buses (in Year 2013).

Recognizing requirements with overall procurement policies, fleet standardization can also promote an easier replacement and a lower spare ratio. Stocking various parts, providing constant training and conducting specialized maintenance for multiple and distinct sub-fleets makes the management of bus maintenance difficult and more expensive. Therefore, future new bus procurements should attempt to standardize on as few types as feasible.

6.4 Summary of Findings

Key findings from review on feet makeup and spare ratio are as follows:

- Reduce the number of contingency fleet based on actual requirements to meet the service. This will help lower operating and maintenance cost and focus the maintenance and repair activities on the revenue fleet. As bus manufacturing technology has made progress due to intensive on-site inspection and QA processes, there is no longer a need for a large contingency fleet when new buses are deployed. Agencies are experiencing fewer fleet defects than in the past.
- In the transit industry, the cost of bus services and associated maintenance incurred by bus divisions as needed to support rail divisions (due to construction or special events) are reimbursed to ensure accurate tracking of expenses for different cost centers. An alternative option is to outsource special bus services and include in the rail budget. This will also allow reducing the number of contingency buses.
- Continuously replace the contingency fleet, specifically the 20 year old Nova RTS, to reduce the repair and parts costs.

7 MATERIALS AND PROCUREMENT PRACTICES

7.1 Procurement and Material Logistics Review

The procurement department materials procures, stores and manages the materials at each garage, and manages the various storerooms. Due to diversity of fleet and high mileage of the buses, almost every type of part is stocked to support activities for the entire life cycle of the buses. These include PM inspections, running repairs, body work and overhaul. Active inventory also includes parts required for maintaining the contingency fleet which has many 20 year old buses.

Key observations and findings from procurement and material logistic review include:

- Bus maintenance staff is responsible for finding parts during most shifts when storeroom clerk is not budgeted.
- Limited use of kits for scheduled maintenance work.
- Min/max levels for satellite storerooms seem to be low and inconsistent across the garages.
- No incoming material inspection, no Material Review Board (MRB).
- Insufficient storeroom space and lack of compliance to shelf life. In some garages, parts are stored along the bus bays.
- Position of maintenance planner/production control is not included in the budget.

In order to address some of the above material issues, MBTA has recently kicked off the Inventory Data Control System (IDCS) improvement program. This program focuses on the following three areas:

Areas of Focus	Improvement Area	Status
Part Scanner	All bus operation garages	Completed
Parts Kiosk	All bus operations garages hardware and network set up	Completed
	Application: Upgrade and modify software to more user-friendly	In Progress
Maintenance Control and Reporting System (MCRS)	Maintenance type, code, task, and work order are under review and being modified to improve reporting	In Progress

The IDCS-Part Scanner application's goal is to provide real-time capture of inventory parts usage via handheld barcode scanning devices that feeds data directly to the MCRS and Financial and Materials Information System (FMIS). This new process is intended to realize the following benefits:

- Material Management
  - Timely recording of parts usage in appropriate system as the materials leaves the shelf.
  - Improved accuracy of parts usage by using part number barcodes and feeding multiple systems at the same time without duplicate entry.
  - Flexibility by allowing usage to be recorded using a handheld device anywhere in the facility where inventory is located.
  - Accountability through the monitoring of transactions and control reports that can highlight training opportunities and provide data to resolve inventory conflicts.
  - IDCS-Scanners assist stockperson with warehouse activities, data entries, monitoring part usage, and management of other material related activity.

- Bus Operations
  - Reduces labor hours of foreperson for work order data entry and prevents human error entering wrong part number.
  - Allows foreperson and supervisor staff to focus on business efficiencies such as productivity, garage operations and compliance to standards.
  - Reduces material "No Stock" issue and improves min-max inventory system.

Potential improvement opportunities for procurement and material logistics are:

- Continue with implementation of Inventory Data Control System (IDCS) program
- Peer agencies only allow storeroom clerks to dispense parts from storerooms.
  - Stock rooms to be staffed in each shift for proper accountability and tracking of parts planning and usage. Minimum and maximum stocking levels appropriate for each fleet and work locations should be developed and monitored.
- Most peer agencies successfully use scheduled maintenance part kits from either system vendors or the bus OEM.
  - Some agencies are moving towards the control of stock rooms at garages under Bus Maintenance and ordering of parts under the procurement division. This helps in reducing inventories, as maintenance orders the parts which are actually required and plans the parts for repairs efficiently. It also helps in reducing obsolete parts and promotes efficient use of shelf space.
- Other bus agencies with large bus fleets like MBTA, have created a production coordinator position to plan PM inspections, repairs, parts and assure the closing of work orders. This allows the facility supervisory staff to focus on the actual supervision of the workforce. In each facility the creation of one production controller job would cost about $120K/yr. but it should result in $240K/yr. burdened labor/material cost savings.

7.2 Warranty Program Review

Key observations and findings from the warranty program review are:

- Warranty function not centralized with split responsibilities between Vehicle Engineering and Bus Maintenance.
- Ad hoc warranty control for contracts germane to legacy buses.
- Warranty program only limited to new and overhaul buses. Need to include option to secure extended warranty with service contracts after the regular warranty is over.
- Garages not following consistent procedures in filing and recovering warranty claims. The rate of warranty "recovery" against warrant "filed" is very low for each vendor. Out of all vendors, only EMP paid the entire warranty filed with a high rate of recovery as analyzed from warranty reports.

Potential Improvement opportunities for the warranty program are:

- Peer agencies have a centralized warranty control staff for their new and legacy bus fleets.
- Expand the warranty program to service and supply contracts to recover monies in labor and materials.
- By adding 2-3 positions ($240K to $360K/yr.), MBTA could recover additional claims from a procurement contract that may yield a total value between about 1% of a contract line item estimate and about 3% of a bus unit price.

7.3 Summary of Findings

Key findings that show potential significant improvement opportunities from review of material and procurement practices are:

- Set up and monitor "number of buses down due to parts" as a key metric that is used by other transit agencies.
- The inventory carrying cost due to obsolescence is noteworthy as MBTA is still stocking parts for the 20 years old Nova RTS buses in the contingency fleet. MBTA should not carry obsolescent material which is no longer used when the buses are retired.
- Create a warranty department and establish appropriate policies and procedures to recover expenses from the new buses, overhaul programs and service contracts.
- In the new management structure, create the position of production coordinator to plan and monitor the parts and warranty.
- Continue the implementation of the IDCS program.

8 MAINTENANCE PRACTICES

8.1 Current Maintenance Practices

MBTA's PM program is based on mileage. The frequency of inspection increases with the miles traveled. The completion of work is tracked through work orders. MBTA owns and operates a very diverse fleet comprised of varying propulsion technologies. Each bus garage is unique in operating a variety of buses, which require skilled manpower, parts, tools and facilities to operate and maintain them for a minimum of 12 years.

The details of the MBTA bus maintenance program is summarized in **Exhibit 21**.

Exhibit 21 - MBTA General Maintenance Duration and Requirements

Maintenance Type		Perform In-house or Outsource?	Average Maintenance Duration or Metrics
Unscheduled		In-house	Varies with no work standards
Scheduled	**Daily Cleaning**	Outsource	Buses per day
	Daily Fueling/ Inspection	In-house	Buses per day
	Monthly Cleaning	Outsource	Buses per month
	6K to 72K Inspection	In-house	Buses per day
	Warranty repairs	Vendor/ In-house	Varies
	Tire service	In-house	Tires changed certain intervals
	Component overhaul	In-house / In-House	Varies
	Mid-life Overhaul	In-house / Outsource	Varies by programs

Key observations and findings from the maintenance practices review are:

- Unscheduled repairs
  - MBTA has maintained a high MMBF for an older and diverse fleet. Although the MMBF is high compared to other transit agencies, its unscheduled (as recorded) repair cost is very high averaging between 70 to 80% of total maintenance. This area needs focus to identify the major cost drivers in parts and labor.
  - Through financial reports and interviews with the garage personnel, it was found that the unscheduled repairs are the cost drivers, and have a major impact on the budget. This is due to the high fleet age, as well as the heavy repairs and labor needed to keep older buses in service for a longer period of time with no predictable schedule for overhauls or for regular replacement of buses after 12 years.
- Maintenance Work and Process
  - Each garage has its own maintenance process and approach due to space limitations and fleet mix. Non-standardized process, procedures, and fleet type impact labor cost.
  - Some garages have numerous open work orders which make it difficult to capture the actual maintenance cost.

  - MBTA has a goal of 100% on time PM compliance. This goal prioritizes the checking of all the inspections on-time at the expense of focusing on the repair of the defects found from the inspection.
  - The tire repair function is in-house while the tires are leased.
  - In the Everett Shop, a large number of small components are being rebuilt/overhauled along with the engines and transmissions.
  - Standard fluid analysis is not performed for high cost components like engines, transmissions, hydraulic and differentials at regular PM schedules.
  - Need specialized tools for performing specialized tasks, and measurement of critical information during the PM inspection.
  - Kiosks are being installed at the garages to record parts and detailed repair action performed.
- Maintenance Personnel
  - PM scheduling, parts availability and usage and tracking the repair tasks are performed by the forepersons and supervisors which takes time away from supervision of the workforce.
  - The daily fueling and cleaning functions are performed by different classifications, and the cleaners are contract personnel. This work assignment takes longer for a bus to be completed.
  - The vault agent is charged to the maintenance budget, rather than the fare collection department budget.

8.2 Comparison to Applicable Industry Standards

Key findings from comparison of MBTA maintenance practice with applicable industry standards are summarized in table below.

Topic	Relevant Industry Practices
Maintenance Work and Process	
Standard Work Standards and Procedures	Implement standard work standards and procedures at each garage by fleet type. Agencies are using kits for routine repair and maintenance tasks. This helps in standardizing the repair procedures.
Condition Based Maintenance Approach	The condition based maintenance approach with an effective fluid analysis program is being taken up by major transit agencies for proactive maintenance and has resulted in major reduction in premature failures of the components and helped extend the service life. Reducing the number of engines and transmissions requiring rebuild will result in a major reduction in the operating budget. Key elements of a fluid analysis program consists of flagging the critical limits for wear metals and physical properties of the lubricant before the catastrophic failure of the component. For example, viscosity may be the key property of the lubricant and might be good as shown by the oil analysis report but the Total Base Number (TBN) might not be in the range, which shows depletion of physical property to neutralize acid formed during high temperatures and pressures due to contaminants. So, the oil analysis has to be more detailed to relate other physical and chemical properties of the lubricant in order to avoid pre-mature failure of costly assets like engine, transmission and differentials. WMATA has a considerably matured oil analysis program. Other agencies like SEPTA, CTA, MDT, LACMTA, and NYCT are using oil analysis programs which might be limited to engines/transmissions only.
Work Order Closeout	Track and close open work orders to capture the labor and parts cost accurately.

Topic	Relevant Industry Practices
PM On-Time Goal	Other relevant transit agencies have set a 90% on time goal for PM; such as WMATA (90%), MDT (90%), MTA Baltimore (80%), and SEPTA (90-95%). With this goal, they normally exceed it and stay in the range of 95 to 97%. They have been able to deploy resources more efficiently on repairing defects.
Outsourcing Tire Maintenance	In order to improve efficiency and accountability, transit agencies across the country are outsourcing the maintenance and repairs of tires.
Specialized Tool Availability	Reliable availability of required specialized tools helps reduce the repair time.
Repair Work Entry	Agencies are moving towards the recording of repair through mechanics/ machinists to get a better handle on data for analysis and capture accurate repair cost.
Maintenance Personnel	
Production Coordinators	Production coordinator positions have been created to plan the PM inspections, repairs, parts and track the paperwork for work order closing. The supervisor and forepersons focus on the maintenance work.
Quality and Warrant Control	All mega (fleet of 1000+ buses) agencies have QC to perform maintenance audits. Material inspections and enforce compliance with warranty SOPs.
Vault Agents	The vault agents are covered and paid by the fare collection department and are independent of the maintenance for security and accountability of the process.
Capital Program	
Life-Cycle Capital Replacement Plan	Agencies are strategizing towards a capital plan to maximize the full life-cycle usage of the bus while minimize the unscheduled operating and heavy repair costs. This approach will result in regularly replacing a batch of 80 to 100 buses per year instead of the entire fleet of bus type with 300 or 400 units. Also, as the fleet ages, proper planning to replace the less reliable units helps offset the heavy repair costs.

Key findings from comparison of MBTA maintenance practice with the two RTA's (Lowell and Worcester) visited:

- Although the two RTA's had identical number of buses (50 to 51), the number of mechanics varied from 5 to 31. The one with six electric buses, needed more specialists to maintain the buses along with the electronic fare- box system etc. on the other buses in the fleet.
- The duty cycle and ridership of the RTA routes cannot be compared to MBTA's, even with a 50 bus garage. The wear and tear on MBTA buses is more severe due to heavy ridership, number of operating hours and stop and go operation. Therefore, MBTA needs more maintenance and scheduled mid-life overhaul. If the overhaul is not performed on time due to a lack of funding, then it results in heavy unscheduled repairs and high operating costs.

8.3 Time Standards Implementation Plan

In order to implement a productivity improvement program, a transit agency will start with a formal standardized process to document all maintenance tasks by determining standard repair times (SRTs). A 2004 TCRP survey on maintenance productivity practices showed that of the eight mega agencies (fleet of 1000+ buses) six had implemented SRTs while the other two had standardized procedures but elected not to use time standards. SRTs represent a list of maintenance work tasks (procedures) with the associated time required to perform the entire task. In addition to time, quality and safety factors are also part of the procedure. The procedures list the tasks required to assure that a vehicle or a component is ready to return to service with a quality repair at the lowest possible cost and with minimum delay. An SRT is equitable when the germane repair can be performed in a time period less

than or equal to the standard by a journeyman mechanic after he/she has performed that same repair in the same application at least once.

The formation and scope of a time standards implementation plan vary among agencies who have started the implementation phase. Agencies included CTA, LACMTA, SEPTA, TTC, and others have SRT plans. NYCT has one of the most comprehensive and detailed implementation programs partially due to its extensive technical resources, both in-house and via engineering consultants. **Exhibit 22** below provides a process flow (Source: 2004 TCRP Synthesis 54 Maintenance Productivity Practices) of NYCT program that started more than 20 years ago.

Exhibit 22 - Extract of "MTA NYCT SRT Development Process" Chart from 2004 TCRP Synthesis 54 Maintenance Productivitv Practices

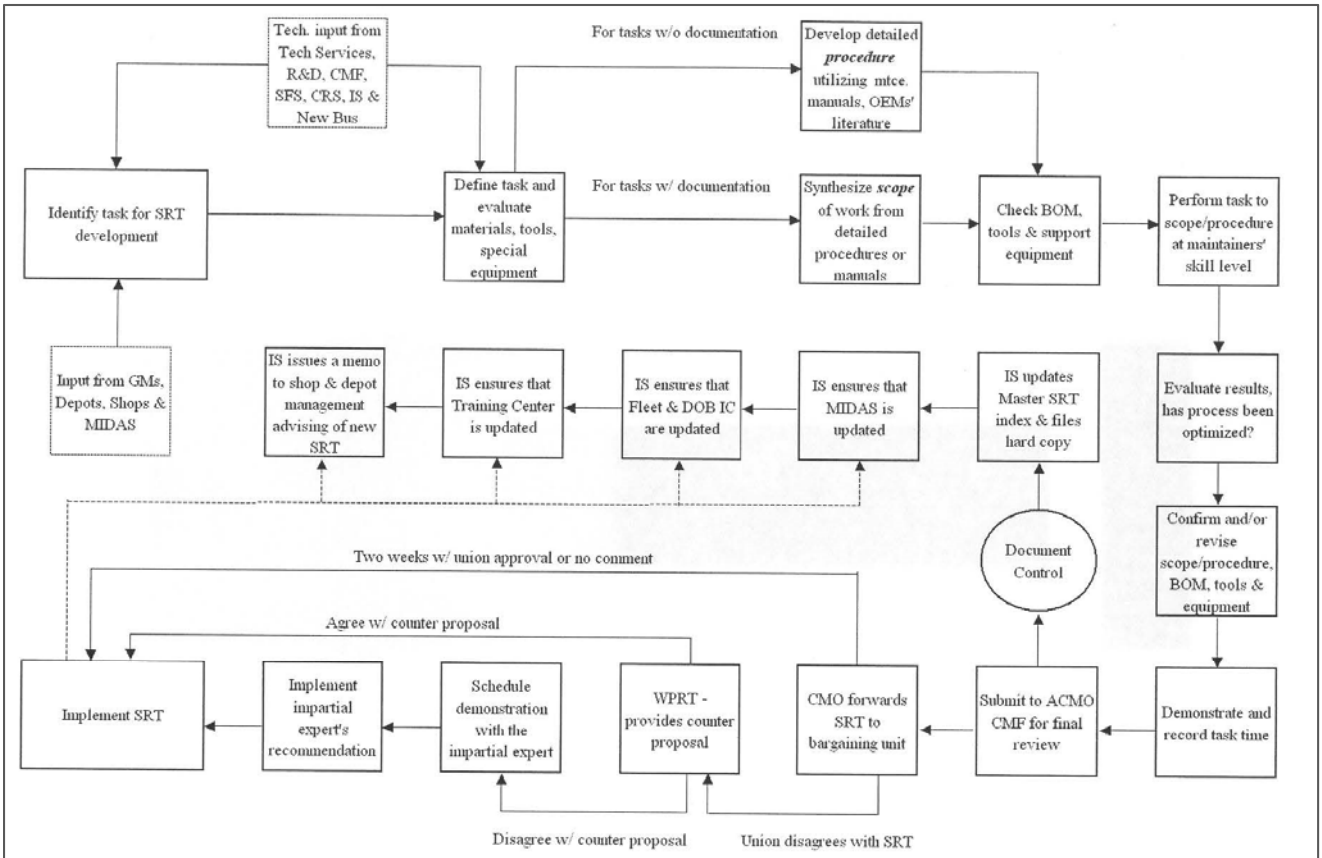


FIGURE 6 MTA NYCT SRT development process.

MBTA has recently started the introduction of SRTs for 37 various bus components. CH2M strongly endorses this program to improve maintenance efficiencies. Since the CH2M team has not witnessed any action related to the implementation of SRTs, this high level assessment is based on an oral presentation and some documents of common task standard repair times. Based on the review of MBTA SRTs and specifically the one for the starter change out, it is suggested to include the following items be included in the opportunities for improvement.

- Due to the different configuration and installation of same or similar components for various bus models, the formulation of each SRT should be repeated for each bus model. This is because the maintainability of the same component will vary due to different time required to access and work on it.
- The list of common and special tools required for the task needs to be defined for each SRT to make the job easier and safer.
- The repair time is to include testing after the repair is done. If an alternator is replaced, the voltage and current at idle and full idle should be checked. Whenever possible, inspect and measure that quality repairs have been performed using checklists to reduce any rework before bus is returned to service.

- SRTs should average time required by a highly experienced and mid-level mechanic in order to identify weak links and develop further training to improve efficiencies. After all SRTs have been formulated, an intensive training program should be implemented at all locations and closely monitored for compliance and continuous improvements.

Based on our overall preliminary assessment, the MBTA is taking appropriate steps to implement this program.

8.4 Summary of Findings

Key findings that show potential significant improvement opportunities from review of maintenance practices are:

- Major cost savings can be realized by implementing work standards, supported with specialized tools for repairs.
- Implement a condition based program to improve the life of critical components.
- Outsource tire maintenance function.
- Replace a fixed number of buses regularly at 12 years to spread the capital cost and also the maintenance and heavy repairs.
- Perform a cost benefit analysis on “in-house vs. outsource” for all components being rebuilt in the Everett Shop. Explore the possibility of outsourcing components which can provide better return on the investment in terms of price, quality, and space allocations.

9 MAINTENANCE SUPPORT ROLES

9.1 Training Support Review

Key findings from review of MBTA's training support practices:

- Training program
  - Students are given pre-test and final.
  - Introductory training to new hires with stratified training over time
  - Certificate of completion not given for all courses
  - No computer based training (CBT) to supplement instructors
- Responsibilities of the training department
  - Includes 1 Superintendent and 7 maintenance bus instructors
  - Develops and issues training updates and technical memos
  - Inspects and investigate major vehicle incidents
  - Addresses the challenge of increasing technological complexity
  - Issues all relevant service bulletins, configuration and document changes

Potential Improvement opportunities for training are:

- MBTA training program includes all key elements as other agencies but should consider:
  - At a negligent cost, issue electronic completion certificates to students enrolled in any class
  - As an option in the next bus procurement, explore the acquisition of a CBT training module to provide off hours and field training when an instructor is not available.
- More coordination between training and engineering department to have a better control of configuration changes and documents.
- Training should lead in assisting bus maintenance in developing work standards and train the machinists in performing the repairs in the standard time.

9.2 Technical / Engineering Support Review

Key findings from technical and engineering support review:

- Supported by training staff (see 9.1 above) and has a separate staff of 1 Superintendent and 4 engineers.
- Engineering is in charge of configuration management on legacy buses only; Vehicle Engineering addresses technical issues on new buses.
- Oil sampling performed independently and not tracked.

Potential Improvement opportunities for technical and engineering support are:

- At no additional cost, more cross training between new bus and maintenance technical staffs could be obtained by fostering rotational assignments.
- Consolidate engineering and maintenance engineering for better communication and controls.
- Move the oil analysis function under engineering/ warranty for tracking reports and failures of critical components.
- Track high usage components regularly to establish a failure trend and provide engineering /maintenance solution to reduce failures and unscheduled repair costs.

9.3 Quality Support Review

Key findings from quality support review:

- QA/QC exists only for new and overhaul bus contracts, mostly using consultants.
- No QC staff to perform maintenance audits in facilities.
- No material inspectors or material review board (MRB) at main storeroom.

Potential Improvement opportunity for quality support is:

- Budget a QC staff of 6 professionals ($720K/yr.) to address quality problems, resulting in a potential savings in maintenance costs of at least $1.21M/yr. Peer agencies have a QA/QC staff dedicated to bus maintenance and incoming material inspection. A 2004 TCRP survey showed that 14 out of 26 bus agencies had a formal QA/QC group; furthermore, this practice is in place at all eight mega agencies (fleet of 1000+ buses) including CTA, NYCT, SEPTA and TTC while it was less common among smaller agencies.

9.4 Personnel Management Review

Key findings from personnel management review:

- No (light duty) positions.
- High absenteeism rate especially during last winter storms.
- Doctor's note not required for first 24 hours of sick leave.
- High use of overtime (total $8.3M in 2015).
- Long lead times for hiring maintenance and support personnel.

Potential Improvement opportunities for personnel management are:

- Other agencies have (light duty) position and stricter rules for sick leave which result in a higher attendance rate and reduced usage of overtime.
- Collaborate with the unions to reduce absenteeism.
- Budget part time positions for administrative roles, i.e. clerical work.
- Create metrics to track time for hiring critical positions.

10 BUS MAINTENANCE ORGANIZATION PLANNING

10.1 Existing Organizational Structure

MBTA is presently reorganizing the Bus Maintenance structure which shows as many as 15 direct reports to the Director though his Deputy Director**. Exhibit 23** below shows the existing bus maintenance department organization chart issued in December 2015. While a "flat" organization encourages the flow of communication, it is our recommendation that a more traditional control span of a maximum six direct reports is more appropriate for an executive position like the Director of Bus Maintenance.

10.2 Proposed Bus Maintenance Organizational Structure and Staffing

Our proposed top level organizational structure is shown in **Exhibit 24**. By decreasing the number of senior staff positions to a proposed total of five, this change will allow the Director to dedicate more time to maintenance policy, planning, and strategic initiatives while still being responsible for the daily operations of Bus Maintenance. The addition of specialized Section Chiefs will increase the management oversight of the daily maintenance operations and performance.

All bus maintenance positions shown in the proposed organization chart will be managerial with the Director at a higher executive level. The five direct subordinates to the **Director of Bus Maintenance** and their key responsibilities are as follow:

- **Deputy Director of Bus Maintenance** - will manage all maintenance activities of the nine garages via two Section Chiefs, North (Charleston, Fellsway, Lynn, North Cambridge) and South (Albany, Arborway, Cabot, Quincy, Southampton). Additional direct reports to include Manager of Maintenance Planning & Production Control and Supervisor of Facility Repair.
- **Section Chief of Technical Services** - will have three direct report Managers: Maintenance Engineering, Training, and Quality & Warranty Control.
- **Section Chief of Nights & Weekend Operations** - will fill a present void which today is "ad hoc" filled by the Director and his Deputy. Direct reports to include two supervisors who will be the managerial "feet on the ground" for those work shifts. Dotted line reporting to the Deputy Director.
- **Section Chief of NRVs and Heavy Repairs** - will manage the daily activities of the non-revenue vehicles and all bus heavy repairs to be performed at Everett with a supervisor for NRVs and another one for Everett Heavy Repair Work.
- **Section Chief of Administration Services** - will have three Managers: Budget Control, Human Resources and one for all Service Contracts including cleaning activities.

Proposed direct and indirect reports to the **Deputy Director of Bus Maintenance** to include:

- **Section Chiefs of Garages** - will be two positions. The Section Chief of North Garages will manage the operations of Lynn, Fellsway, New Cambridge and Charleston while his/her counterpart will manage the South Garages i.e. Cabot, Albany, Southampton, Arborway, and Quincy. Their direct reports are the Garage Superintendents.
  - **Superintendents of Garages** - will be five Superintendents, under the two Chiefs of Garages, in charge of the nine garages: one for Charlestown and Lynn, a second for Fellsway and N. Cambridge, a third for Arborway and Quincy, a fourth for Albany and Cabot, and the fifth for Southampton. Supervisors will report to Superintendents with the only other change of eliminating through attrition the title of garage foreperson which is somehow duplicative of

a foreperson but without the authority to impose discipline. The control span of Supervisor or foreperson of a typical maintenance organization can be as high as 12 or more subordinates if the work is repetitive and of relatively low complexity.

- **Manager of Maintenance Planning & Production Control** - will be responsible for all activities related to scheduling and monitoring production (PMIs, campaigns, field modifications, etc.) This position will have the following two direct reports:
  - **Analyst of Vehicle Technology Services** - will establish repair and defect tables/codes to improve the accuracy of data entry, will assist with the serialization and bar coding of bus components and will audit the recorded computer information. Finally he/she will be the Bus Maintenance official interface with its personnel.
  - **Supervisor of Material Control** - will be responsible for management of unit spares, requisitioning special order material and equipment and coordination with storerooms on inventory levels and critical shortages. With exception of service contracts, he/she will be the Bus Maintenance official interface with procurement to assure timely deliveries of maintenance components.
- **Supervisor of Facility Repair** - will perform minor repair to the bus facilities and shop equipment.

Proposed direct reports to **Section Chief of Technical Services** and their primary responsibilities:

- **Manager of Maintenance Engineering** - same responsibilities as present organization.
- **Manager of QC & Warranty Control** - will be responsible for maintenance audits, material inspection, auditing of warranty process.
- **Manager of Training** - same responsibilities as present organization.

Proposed direct reports to **Section Chief of Nights and Weekend** and their primary responsibilities:

- **Supervisor of North Garages** - to support nights and weekend coverage.
- **Supervisor of South Garages** - to support nights and weekend coverage.

Proposed direct reports to **Section Chief of Heavy Repairs and NRV** and their primary responsibilities:

- **Supervisor of NRV** - same responsibilities as present organization.
- **Supervisor of Heavy Repairs at Everett** - coordination and monitoring of heavy repairs being performed at Everett.

Proposed direct reports to **Section Chief of Administrative Service** and their primary responsibilities:

- **Manager of Budget Control** - will be responsible for budget preparation and performance including overtime control.
- **Manager of Human Resource** - will be responsible for labor relations and personnel.
- **Manager of Service Contracts** - same responsibilities as present organization.

Exhibit 23 – Existing Bus Maintenance Organization Chart dated December 2015

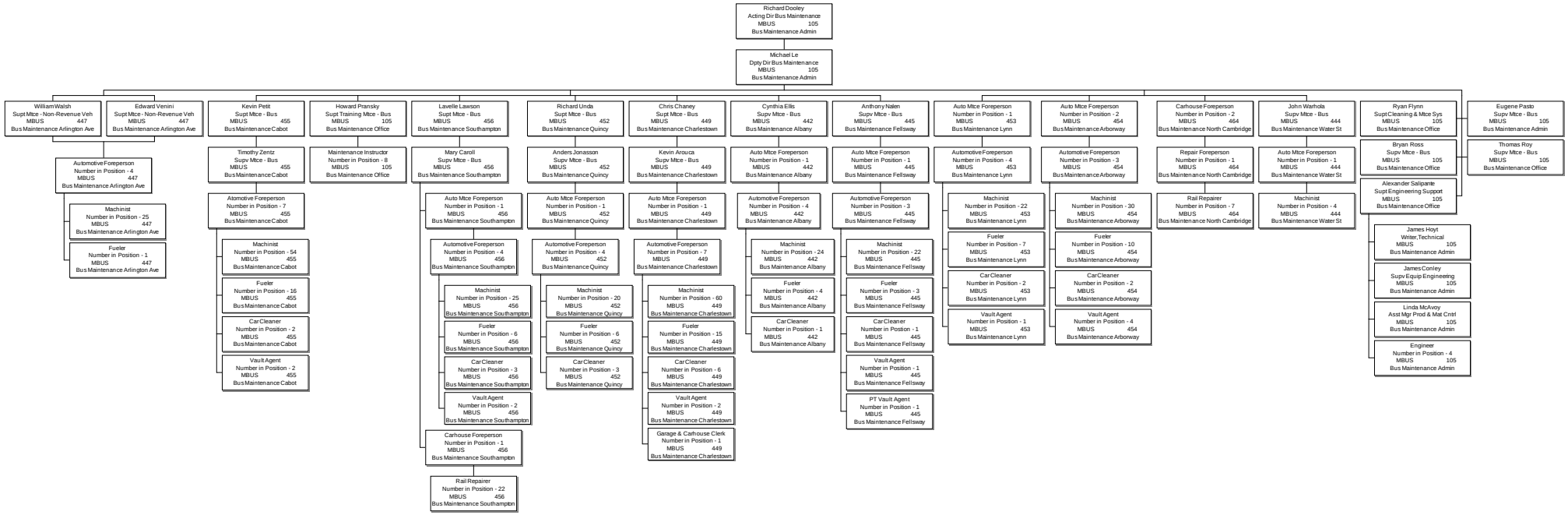
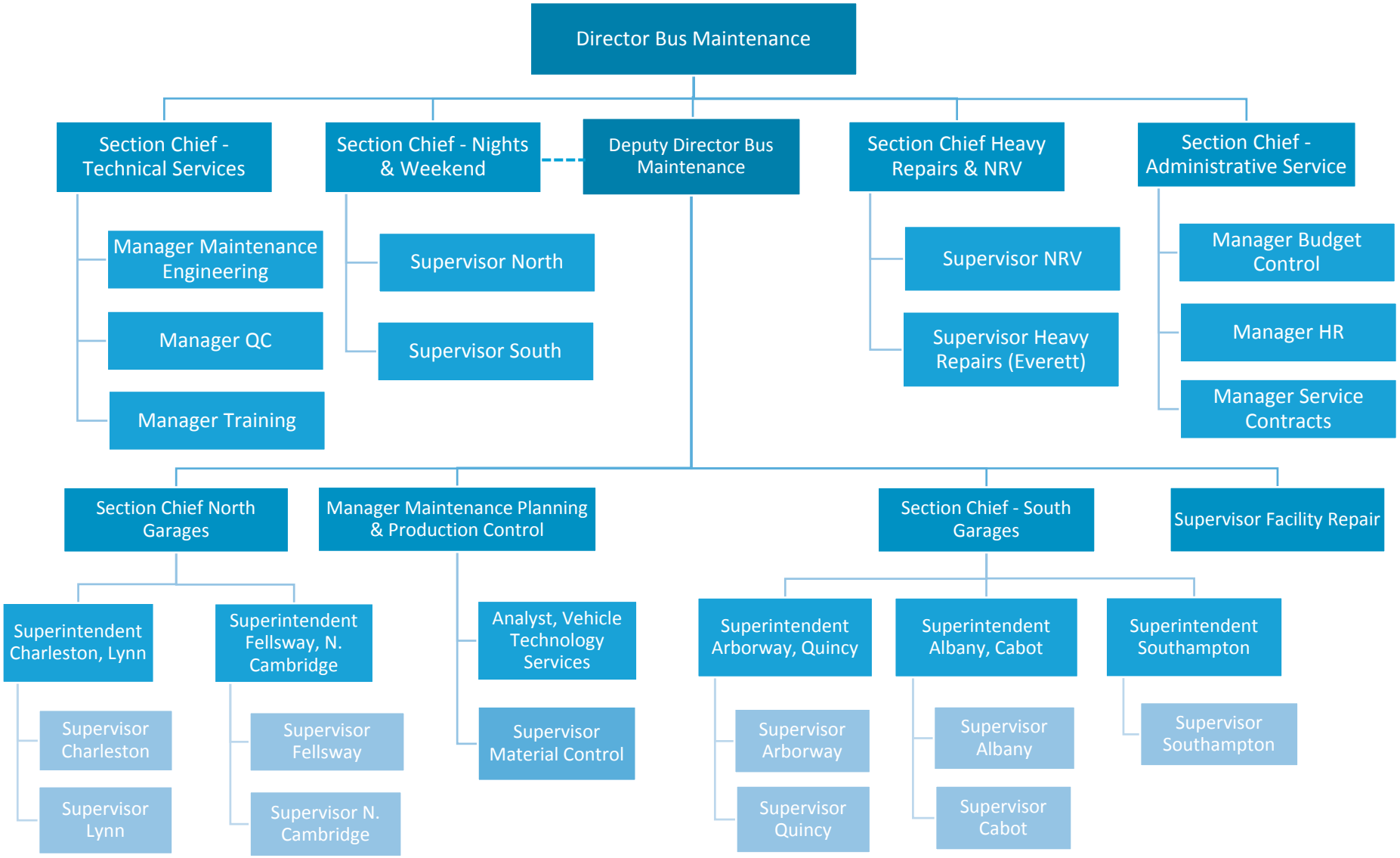


Exhibit 24 – Proposed Top Level Bus Maintenance Organization Top Level Structure



10.3 Summary of Organizational Planning

The changes provided in section 10.2 above will most likely be cost neutral but more effective to assure a successful path in the direction that Bus Maintenance has started to navigate. While Bus Maintenance is achieving a high level of performance reliability as measured by its MMBF, this is gained at a relative high maintenance operational cost when compared to its peer agencies. The proposed organization reinforces elements necessary in the garages to assure a high reliability level while introducing sorely lacking functions in Quality Control and Production Control to achieve higher efficiency levels, better control of all resources dedicated to production, and much needed improved overall management, oversight, and record keeping.

11 APPLICABLE INDUSTRY COMPARISON

11.1 Applicable Metrics for Peer Comparison

The table below lists performance metrics and the rationale for facilitating a fair and objective performance comparison among MBTA bus fleet and bus maintenance facilities with industry peers.

Metrics	Rationale
Bus Fleet	
Total Fleet Size	Agencies with large and mega fleets (about 1000 buses) face more challenges than ones with small fleets which usually are standardized with a few bus models, similar procedures, parts, training , modes of operation, maintainability requirements, etc.
Spare Ratio	While a larger ratio may increase the probability of always making service, it also comes with higher maintenance costs; also the higher the number of different bus models, the higher the overall spare ratio.
Mean Miles Between Failures (MMBF)	Many variables can impact service reliability including environmental conditions, passenger behavior and drivers' experience.
Average Fleet Age	It is correlated to the reliability curve of a typical bus whose performance will decline as it ages and nears the end of its useful life.
Average Operating Speed	The lower the average speed (usually due to traffic conditions), the higher the wear and tear on a typical bus.
Bus Maintenance Cost per Mile	The skills of the work force and the status of the bus facilities with germane shop equipment have an impact on the overall costs.
Standard Repair Times (SRTs)	This defines a standard work process including detailed procedures, time allocation, parts, tools, and final testing for the maintenance of bus systems/components (e.g. inspection time, repair job, etc.)
Bus Maintenance Facilities	
Ownership Type (Included for information purpose to document own vs. lease)	Types of property ownership impact expenditure spending and tracking, staffing count, organizational management, performance monitoring, and maintenance program.
Number of Garages, Number of Heavy / Main Repair Shops	Depending on the size and topography of its network, a large agency requires several localized garages to minimize deadhead mileage and at least one main repair shop to handle heavy repair work that is time consuming and done with specialized shop equipment.
Number of Maintenance Bays	Fleet mixture and topography of the system network impact the number of maintenance bays. This metric allows monitoring if maintenance causes defective or scheduled buses could be competing for available bays thus increasing overall down time.

11.2 Applicable Metrics for Internal Comparison

MBTA should use a balanced score card to measure each area of its business for effectiveness, and take corrective action to continuously improve the processes to achieve its goals. Normally, transit agencies use the score card for its maintenance area only. The balanced score card looks at performance of various divisions which support the maintenance function.

Although MBTA has a unique fleet mix utilizing different technologies at each garage, the basic performance measures remain the same. MBTA should set the goal based on historical performance and duty cycle of the buses by fleet type and also overall performance at each garage. For example, a garage with frequent stop- and- go service will have a more severe duty cycle than a garage with limited stops and with higher operating speeds. While setting the MMBF goal, the garage with severe service should be set at a lower MMBF than the garage with the higher operating speed.

At each division of MBTA, key cost drivers and performance metrics for a balanced score card should include:

- Actual results - current month; 12-month average
- Target goal for each metric and process for reporting and reviewing variances.

Daily garages comparison on goal vs. actual should include the following six key metrics:

- % of bus pullouts
- # of road calls per 1,000 miles
- % of PM compliance
- % of bus cleaning adherence
- # of buses down for parts
- Absenteeism % by classification

Exhibit 25 below lists key metrics and their rationale for inclusion in daily, weekly and monthly performance reporting. Weekly garages comparison to be the same as daily but showing Sunday and Saturday daily entries.

Exhibit 25 – Key Metrics for Internal Performance Comparison and Reporting

Metrics	Rationale	Reporting Frequency		
		Daily Garages Comparison	Weekly Garages Comparison	Monthly Review
Personnel/ Administrative Support				
Absenteeism (%) by Classification	This helps in justifying filling the vacant positions or actions required to reduce absenteeism	√	√	√
Employee Lost Time Injury	Target for injuries should always be “zero”. Setting a different target gives the impression that some injuries are acceptable. This should be tracked as hours worked without a “Lost Time Injury”. Another metric could be “Employee on-duty lost time accident rate”, a job related incident that results in death or the inability of an employee to perform full job duties for at least one working day beyond the day of the incident and prorated for 100 employees. Set goal levels by garage and across garages that when reached everyone gets rewarded/recognized (e.g. employees of facility with the lowest lost time accident rate receive a safety award certificate, small gifts, and/or brought-in lunch, etc.). The workman’s compensation paid each year is a good indicator to measure the effectiveness of training and use of safety processes at a garage.			√

Metrics	Rationale	Reporting Frequency		
		Daily Garages Comparison	Weekly Garages Comparison	Monthly Review
Budget Adherence	Each garage to meet its allocated budget. Reasons for variance should be corrected early in the budget year instead of waiting at the end of the financial year.			√
Overtime	Track overtime at each garage by job classification. Once a garage has been given its budgeted overtime, then it should be properly approved and justified by a Superintendent level person for accountability and control on day-to-day basis.			√
% of Bus Down for Parts	This measure affects the availability of buses for revenue service. Set a goal for buses down for parts. The industry standard is a maximum of 3 to 4% of buses down for parts per day. Bus down (or out of service) could base on unavailable for AM pull out.	√	√	√
Top Five Parts Used	Analyze the top five parts used in both value and quantity to monitor the pre- mature failure of components.			√
Parts/Service Contracts	Set a goal for processing and approval of the parts and service contracts so that the contracts do not expire, and are budgeted to support the critical functions.			√
Training	Set a goal for training of key positions for PM, standardized repairs and heavy overhauls.			√
Vacant Positions	Track and monitor the hiring and filling of vacant positions. Set a goal for number of days to fill the position.			√
Preventative Maintenance & Repairs				
% PM adherence	Set a realistic goal for PM adherence in the range of 90 to 95%.	√	√	√
% of Bus Pullouts (Bus Availability)	Goal 100 %. Measured as % of scheduled pull out. It more difficult to achieve 100% goal for an agency operating mixed bus models and sizes, i.e. standard vs. articulated, CNG vs. diesel vs. electric vs. hybrid vs. dual modes.	√	√	√
Top Five Road Calls	Track top five road calls and analyze the root cause for failure.	√	√	√
Number of Contingency Buses Used per Day	This measure will help to further reduce the dependence on contingency fleet and focus on the revenue fleet for daily pull out. It is more difficult to reduce # of contingency buses if there are long term and/or on-going needs provide special services due to construction diversions.			√
% of Bus Cleaning Adherence	Set a goal for daily, weekly and monthly cleaning service to include daily wash.	√	√	√
% of Unscheduled Repairs	Presently the unscheduled repairs are about 70 to 80% of the labor and parts budget. Have a goal to reduce it each year to reach the industry standard of 35 to 40 %. This will require investments in lean processes, reliability centered and maintenance, and an appropriate long term Capital Program.			√
Open Work Orders	Target for closing open work orders within 10 days.			√
Bus Accidents	Target for in-shop accidents by maintenance staff and prevent accidents.			√

Metrics	Rationale	Reporting Frequency		
		Daily Garages Comparison	Weekly Garages Comparison	Monthly Review
Mean Miles Between Failures (MMBF)	Set a goal for each garage based on duty cycle, propulsion type and bus age.			√
Warranty	Monitor warranty program to track warranty reimbursements and fleet defects.			√
Cost per Mile	Maintenance cost per mile by each fleet type at various garages. This will compare the cost of same bus at different garages and help implement the best practices for maintenance and repairs.			√
Customer Service / Operations				
Defects reported by Bus driver	Reduce pre-trip and route defects.			√
Customer complaints	Set a goal for customer complaints / 100,000 miles to include bus cleanliness, HVAC, and quality of ride etc. This will help identify the routes and garages with problems.			√
Wheel Chair Lift Availability (%)	Goal in the range of 90 to 95% to meet ADA compliance.			√
Destination Sign Operational (%)	Goal in the range of 90 to 95% to meet ADA compliance.			√

11.3 Applicable Industry Standards and Best Practices

The transit agencies have developed best practices for each area listed below based on their experience and the fleet make up. Information provided is based on recent phone contacts or our professional experience from other assignments. The agencies which provided most of their information are the following six agencies similar to MBTA:

- Chicago Transit Authority (CTA)
- Maryland Transit Administration (MTA) Baltimore
- Miami-Dade Transit (MDT)
- New York City Transit (NYCT)
- Southeastern Pennsylvania Transportation Authority (SEPTA)
- Washington Metropolitan Area Transit Authority (WMATA).

Exhibit 26 – Applicable Industry Standards and Best Practices and Reference Agencies

Bus Maintenance Facilities	
Bus Bays	1 bay for 9 to 10 buses as per Appendix E. MBTA is short of bays and space for maintaining and storing the bus fleet. This causes loss of productivity. Agencies: CTA, MDT, NYCT, WMATA
Storeroom	Other agencies have larger storerooms to stock parts for PM and running repairs. Agencies: CTA, MDT, NYCT, WMATA,

Bus Wash	The bus washes to have the capability to clean the front and rear of the buses without the need for manual cleaning. Agencies: All transit agencies in the list (CTA, MTA, MDT, NYCT, SEPTA, WMATA)
Tools & Equipment	Bus lifts and tools to match with the number of buses and type of repair Agencies CTA, MDT, NYCT, SEPTA, WMATA
Facility Rehab/ Replacement	Whitestone facility guideline based analysis indicates that 1.2% to 2.5% is needed on average over the life of the facility to maintain SGR (including both major rehabs and minor capital reinvestment actions). NYCT has had a policy to rehabilitate maintenance facilities every 17 years and reconstruct every 50 years. Periods are based on deterioration rates for roofs, walls, windows, plumbing and structural members; life expectancy of shop equipment; and changes in technology with associated changes in shop operating procedures. Rehabilitation covers repairs to shop systems and elements but not major work on structural envelop (walls, floor, foundation, roof) or changes to the internal layout. Reconstruction to include above rehab work plus work on structural envelope and internal configuration.
Fleet Makeup and Spare Ratio	
Average Spare Ratio	20% per FTA guideline Agencies: All agencies in the list (CTA, MTA, MDT, NYCT, SEPTA, WMATA)
Contingency Fleet	Agencies replace the older contingency buses with the latest retired buses whenever new buses are put in service. WMATA maintains a contingency fleet of 38 buses for an active fleet of 1552 buses. A TCRP 2013 survey showed that less than half (18 out of 38) bus agencies had a contingency fleet. Agencies: MTA (working), NYCT, SEPTA, WMATA
Fleet Age	Dedicated capital program to replace 12 years old buses in a lot of 100 buses per year. Capital funding for mid-life rehab. Average fleet age of 7.5 to 8 years. Agencies: CTA, MTA (planning stages), NYCT, SEPTA, WMATA
Material and Procurement	
Stock Levels	Planned stock level of parts for each type of bus. Agencies have a material planning section within bus maintenance which takes the lead in establishing and planning stock levels. Agencies: CTA (outsourced to NAPA), MDT, MTA, NYCT, WMATA
Shift Coverage	Stockroom is covered on all the shifts except the overhaul shop. Agencies: CTA, MDT, MTA, NYCT, SEPTA, WMATA
Part Kits	Kits used for PM and regular repairs like brakes, engine/ transmission overhauls etc. For control, issuance and QA of part kits, some agencies pick samples of the kits before issuing them to the garage at the receiving store and checks the kit for the fill of materials in the bid. If parts are missing then the entire shipment is rejected and the vendor has to ship the missing parts. Additionally, there are regular meetings on a monthly basis with the vendor to address these issues and mitigate reoccurrence. Agencies: CTA, LACMTA,MTA, NJT, NYCT, SEPTA, WMATA
Obsolete Parts	Continuously eliminate obsolete parts when the new buses enter service and older fleet are retired. Agencies: CTA(NAPA manages), MDT, NYCT, WMATA
Vendor Managed Inventory	Agencies are exploring this alternative to control inventory management costs Agencies: CTA (NAPA manages), MARTA (exploring), MDT(exploring), New Jersey (for MCI)
Quality Assurance/Control	Quality checks of incoming materials conducted at the main warehouse. QA representative be the chair of Material Review Board (MRB). Agencies: CTA, LACMTA, NYCT, SEPTA

Maintenance Program	
PM Goal	Within 90 to 95%. Agencies: CTA, MDT, MTA, SEPTA, WMATA
Fluid Analysis	Condition based program for engines and transmissions at major transit agencies Agencies: CTA, MDT, MTA, NYCT, SEPTA, WMATA
Fueling &Cleaning of Buses	One classification performs both tasks Agencies: CTA, MDT, MTA, NYCT, SEPTA, WMATA
Tire Repairs	Outsourcing the entire function with leased tires Agencies: All transit agencies (CTA, MTA, MDT, NYCT, SEPTA, WMATA)
Standardized Work Procedures	Standard procedures and labor time defined for PM and regular repairs Agencies: CTA, MDT(partial), MTA(partial), NYCT, SEPTA, WMATA(partial)
Maximo System	Agencies have shifted the function for entering the repair data to the mechanics with the MMS system kiosks on the shop floor. Agencies: MTA, NYCT, WMATA
Mid-life/Overhaul Program	Performed between 6.5 to 7 years. WMATA has extended the life of the bus another 3 years to 15 years after the mid-life overhaul at 7 years. NYCT performs systems' overhaul at 4-year and 8-year cycles instead of mid-life. Agencies: CTA, LACMTA, MTA (exploring), NYCT, SEPTA, WMATA
Production Coordinator/ Clerical Support	In order to reduce the administrative work for forepersons and supervisors, and allow them to focus on supervising the mechanics' work, agencies have created an administrative position to work on PM scheduling and parts planning etc. This helps with improving the quality of work on the shop floor. Agencies: CTA, MDT, NYCT, WMATA
Quality Assurance/Control	The repair work is checked randomly by a QA/QC staff. Daily quality control is being performed by the supervisors too. Agencies: CTA, MDT, MTA, NYCT, SEPTA, WMATA
Maintenance Support	
CBT Training	New bus procurements are including CBT training modules to help mechanics learn at their own time when an instructor is not available. Agencies: NYCT, WMATA
Work Standards	Training department helps train the mechanics with the work standards to complete the repair tasks in a standard time and work process. Agencies: CTA, MDT, NYCT, SEPTA, WMATA
Engineering	All engineering functions are consolidated under vehicle engineering group. Agencies: CTA, MDT, MTA, NYCT, SEPTA, WMATA
Warranty	A warranty department working directly under the supervision of vehicle engineering to track warranty for both new buses and service contracts Agencies: CTA, MDT, MTA, NYCT, SEPTA, WMATA
Light Duty	Injured mechanics work on light duty assignments and carry out clerical work Agencies: MDT, NYCT, WMATA
Absenteeism	Working with the union in reducing absenteeism rate Agencies: MDT, NYCT, MTA
Vacant Positions	Assigned clerical person in Bus Maintenance to follow up with HR on filling vacant positions on time Agencies: CTA, MDT, WMATA

11.4 Peer Agencies Comparison

National Transit Database (NTD) is the source for dataset applied for this high level peer agencies metric comparison. As noted in Section 3.4, NTD data is self-reported by agencies and the methods of measurement may vary between agencies. Comparison between MBTA and relevant peer agencies included key system-wide performance metrics discussed in Section 11.1 above, except for Standard Repair Times and most of the bus maintenance facility metrics for not being available in NTD.

Based on bus fleet size, composition and operating condition, there are seven North American agencies that MBTA could consider as relevant peers. Comparison of most recent performance metric from NTD is summarized in, **Exhibit 27** which has excluded TTC as NTD only record self-reported data from the US agencies .

Exhibit 27 – Peer Agencies Performance Metric Comparison

	Year 2013 Performance Metric in NTD								
	Fleet Profile			Operations	Performance				
Agencies	**Total Fleet Size**	**Fleet Spare Ratio**	**Avg. Fleet Age**	**Average Operating Speed (mph)**	**Reliability MMBF or MDBF**	**Financial Vehicle Maintenance Cost per Mile**	**Have Work Standard?**	**# of OEM and Bus Length**	**# and Type of Propulsion Technology**
MBTA									
Metric	955	22%	9.3	10	12,946	$5.99	Initial Implementation Phase	6; OEM - Neoplan, NABI, New Flyer, Nova, Skoda, TMC; Length - 40ft, 60ft	**4** - CNG, Diesel, Electric Trolley, Diesel-Electric Hybrid
Ranking Among Peers below	6th	1st	1st	3rd	1st	2nd			
Relevant Peer Agencies in North America									
MTA, Baltimore	729	20%	7.2	12	7,226	$2.13	Partial	**4**; OEM - NABI, MCI, Neoplan & New Flyer; Length - 40ft, 45ft commuter & 60ft	**2** - Diesel, Diesel-Electric Hybrid
CTA, Chicago	1,872	13%	7.0	9	3,008	$2.38	Yes	**2**; OEM - Nova, New Flyer; Length - 40ft & 60ft	**3** - Diesel, Diesel-Electric Hybrid, Electric
NJT, New Jersey	2,413	19%	6.8	14	6,821	$2.34	TBD	**6**; OEM - Nova, MCI, Neoplan, Goshen, NABI, Design Line; Length - 25ft, 32ft, 38.5ft, 40 & 45ft commuter, & 59ft	**3** - CNG, Diesel, Diesel-Electric Hybrid
NYCT, New York	3,840	16%	7.5	7	5,696	$6.13	Yes	**5**; OEM - Nova, Orion, MCI, Prevost, New Flyer; Length - 40ft, 42ft, 60ft, 62ft & 45ft Commuter	**3** - CNG, Diesel, Diesel-Electric Hybrid
SEPTA, Philadelphia	1,389	19%	8.7	10	4,128	$2.96	Yes	**5**; OEM - El Dorado, New Flyer, Nova, Freight Liner/Champion, Chevy/Champion; Length - 29ft, 40ft & 60ft	**3** - Diesel, Diesel-Electric Hybrid, Electric Trolley
TTC – Toronto		N/A – Not reporting in NTD					Yes		**2** - Diesel, Diesel-Electric Hybrid
WMATA – D.C.	1,541	15%	6.8	10	6,390	$2.96	Yes	**3**; OEM - Orion, New Flyer & NABI; Length - 30ft, 35ft, 40ft, 42ft & 60ft	**3** - CNG, Diesel, Diesel-Electric Hybrid

12 ALTERNATIVE ANALYSIS

12.1 Approach

Based on site visits, interviews, and information gathered and reviewed, CH2M has identified an initial list of potential improvement opportunity alternatives. This list was developed based on industry comparisons and their likeliness to yield cost and benefit impacts if selected for implementation. The mid and long term opportunities are intended to start immediately as they are likely to take longer to implement.

Section 12.2 shows the list of improvement opportunity alternatives, grouped into six areas of focus. Each alternative is evaluated for cost and benefit impact based on the following:

- **Area of Focus**: based on six options
  - General Performance & Organization Management (M)
  - Facilities (F)
  - Bus Fleet Makeup and Spare Ratio (B)
  - Materials and Procurement Practices (P)
  - Maintenance Practices (M)
  - Maintenance Support Roles (S)
- **Timeline to Implement**: based on three options
  - Short Term: Within 1 year
  - Mid Term: Within 1 to 3 years
  - Long Term: Over 3 years
- Requirement for capital investment: based on two options
  - Yes (Y)
  - No (N)
- **Estimated net annual operating cost savings**: assumptions and details on cost estimated are provided in **Appendix D.**
- Likely Impact against six evaluation criteria:
  - Cost Reduction/Saving
  - Safety
  - Employee Experience
  - Customer Experience
  - Operations Efficiency
  - Sustainability (Green)
- **Scoring for each evaluation criteria:** based on a scale from 0 to 3 and either positive or negative value
  - Scale:
  - 0 = no impact
  - 1 = minor impact
  - 2 = some impact
  - 3 = major impact
  - Effect of impact:
  - “+” for positive impact
  - “-“ for negative impact

- **Total Score**: summation of score from the six evaluation criteria.
- **Status**: status of implementing the alternative
  - TBD: To be determined by MBTA
  - UC: Under consideration by MBTA
  - IP: In-progress with pilot program, initial planning, or on-going program
  - C: Completed implementation

Due to unavailability of certain requested data before submittal of this final report, a few potential cost saving measures are listed as TBD (to be determined). Information in section 12.2 could be refined in the future per data availability to develop an optimized range of improvement options.

12.2 Evaluation of Improvement Opportunity Alternatives

Item #	Improvement Opportunity Alternative by Area of Focus	Timeline to Implement			Capital Funding Required?	Estimated Annual Net Operating Cost Savings	Likely Impact on Evaluation Criteria < Scale Range from 0 to 3: 0=No Impact, 3=Major Impact > "+" = Positive Impact, "-"= Negative Impact							Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
		Short Term	Mid Term	Long Term			Cost Savings	Safety	Employee Experience	Customer Experience	Operational Efficiency	Sustainability	**Total Scores**	
	General Performance & Organizational Management													
G1	Realign vacant positions by filling some new key positions required for parts follow up, warranty control and production coordinator.		√		N	$0.6M	+3	+1	+1	+1	+2	0	8	C
G2	Reduce overtime usage after filling vacant positions and implementation of repair standards.		√		N	$1.5M	+3	+1	+1	+1	+2	0	8	IP
G3	Clarify data reporting and then upgrade and standardize communication of key performance indicators (KPIs); including posting KPI charts in official communication boards at all maintenance locations.	√			N	$0 (Cost Neutral)	+1	+1	+1	+1	+1	0	4	IP
G4	Start a pilot program setting up a compliance goal of 90% instead of present 100% for PM inspections to achieve an effective range of 95-97%.	√			N	$160K	+2	0	0	0	+2	0	4	UC
G5	Transfer to bus maintenance the budget and responsibility for minor facility maintenance repairs.		√		N	$0 (Cost Neutral)	0	+2	+2	0	+1	0	5	UC
G6	Transfer the budget of vault agents from bus maintenance to the fare collection department.		√		N	$0 (Cost Neutral)	0	0	0	0	+1	0	1	IP
	Facilities													
F1	Outsource Cabot Tire Shop repair work; four positions to be re-assigned.	√			N	$264K	+2	0	-1	0	+2	0	4	UC

Item #	Improvement Opportunity Alternative by Area of Focus	Timeline to Implement			Capital Funding Required?	Estimated Annual Net Operating Cost Savings	Likely Impact on Evaluation Criteria < Scale Range from 0 to 3: 0=No Impact, 3=Major Impact > "+" = Positive Impact, "-"= Negative Impact							Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
		Short Term	Mid Term	Long Term			Cost Savings	Safety	Employee Experience	Customer Experience	Operational Efficiency	Sustainability	**Total Scores**	
F2	Expand installation of Fastenal POU vending machines to all garages.	√			N	$0 (Cost Neutral)	0	+1	+1	0	+1	0	4	IP
F3	Apply lean methodology at garages: lean training, 5S reorganization, and form lean councils.		√		N	$0.5M	+2	+1	+2	+1	+2	+1	9	UC
F4	Explore replacement of fixed with pivoting wash brushes to clean fronts/rears (except for trolley buses).		√		Y	TBD	+1	+1	+2	+1	+1	+1	7	TBD
F5	Investigate under-roof parking alternatives where needed.			√	Y	TBD	+1	+1	+1	0	+1	+1	5	TBD
F6	Replace oldest facilities with new ones: Improve efficiencies, availability of bus lifts, shop equipment and better working conditions. Explore consolidation/expansion of garages.			√	Y	N/A	+2	+2	+2	+1	+2	+2	11	UC
F7	Expand capital program to budget periodic upgrade of facilities and germane shop equipment.		√		Y	N/A	+2	+2	+2	+1	+2	+1	10	UC
	Bus Fleet Makeup and Spare Ratio													
B1	Replacement of NABI CNG with 325 newly purchased New Flyer buses will reduce the unscheduled repairs and parts cost due to the high level of maintenance required for existing NABI buses and 44 articulated CNG. New articulated buses replacing the existing Neoplan buses.		√		Y	$3M to $5M	+2	+1	+1	+3	+2	+2	11	IP
B2	Reduce the number of contingency buses from 75 to 60 by retiring 15 New Flyer CNG.	√			N	$600K	+2	+1	+2	0	+3	+1	9	IP

Item #	Improvement Opportunity Alternative by Area of Focus	Timeline to Implement			Capital Funding Required?	Estimated Annual Net Operating Cost Savings	Likely Impact on Evaluation Criteria < Scale Range from 0 to 3: 0=No Impact, 3=Major Impact > "+" = Positive Impact, "-"= Negative Impact							Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
		Short Term	Mid Term	Long Term			Cost Savings	Safety	Employee Experience	Customer Experience	Operational Efficiency	Sustainability	**Total Scores**	
B3	Implement a five year bus replacement program to replace 100 buses each year based on 12 year useful life.			√	Y	$8 to 10M	+3	+3	+3	+3	+3	+3	18	UC
B4	Standardize fleet by reducing different bus types as much as possible.			√	Y	$1M	+2	+2	+2	+1	+2	+1	10	UC
	Materials and Procurement Practices													
P1	Streamline the materials management functions and reduce obsolete parts. Set up appropriate consistent min-max levels across the garages. Continue implementation of IDCS.		√		N	$260K	+2	+1	+3	+1	+3	+1	11	IP
P2	Staff all storerooms for all work shifts.			√	N	$0 (Cost Neutral)	0	0	+1	+1	+2	0	4	UC
P3	Explore procuring scheduled maintenance part kits from OEMs and/or systems suppliers.		√		N	TBD	+1	+1	+2	0	+2	+1	7	IP
P4	Explore partnership with RTA and other bus agencies on buying parts to address supplier lead-time and quality via multi-year contracts.			√	N	TBD	+1	0	+1	0	+1	+1	4	TBD
P5	Explore Vendor Managed Inventory (VMI) Program to outsource this function at MBTA. It will reduce inventory, eliminate obsolete parts and zero bus held out of service while awaiting parts.			√	N	$1.3M	+3	+1	+2	+1	+3	+1	11	TBD
P6	Explore outsourcing the overhaul/rebuild of components at the Everett Shop in terms of price, quality, and spare allocation.	√			N	TBD	+1	0	-1	+1	+1	0	2	IP
	Maintenance Practices													

Item #	Improvement Opportunity Alternative by Area of Focus	Timeline to Implement			Capital Funding Required?	Estimated Annual Net Operating Cost Savings	Likely Impact on Evaluation Criteria < Scale Range from 0 to 3: 0=No Impact, 3=Major Impact > "+" = Positive Impact, "-"= Negative Impact							Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
		Short Term	Mid Term	Long Term			Cost Savings	Safety	Employee Experience	Customer Experience	Operational Efficiency	Sustainability	**Total Scores**	
M1	Explore the potential savings in reducing daily bus washing frequency. (Policy would be to wash fleet once a day after PM pull out.)	√			N	TBD	+3	0	+1	-1	+1	+2	6	TBD
M2	Standardize all maintenance procedures for similar tasks by the machinists across the garages with a standard agreed upon time and including special tools and recordkeeping of critical PMI data.	√			N	$1M	+2	+2	+2	+1	+2	0	9	IP
M3	Expand oil analysis program to include engines, transmissions, hydraulics, differentials to reduce component failures and unscheduled repairs of critical components (condition based maintenance.)		√		N	$1M	+2	+1	+1	+2	+2	+1	9	UC
M4	Examine by location the reorganization of daily service of buses by resolving contractual issues to have the buses serviced, cleaned and fueled by the same classification thus improving efficiencies.			√	N	$400K	+2	0	-1	0	+2	0	3	TBD
M5	Verify improvements made to Arborway's fueling to eliminate problems experienced during last winter months.	√			Y	$0 (Cost Neutral)	0	+1	+1	+1	+1	0	5	IP
M6	Implement real-time equipment failure tracking and repair scheduling through automatic vehicle maintenance (AVM) technology as a requirement in future contracts of new and/or overhauled buses.			√	Y	TBD	+3	+1	+2	+2	+3	+1	11	TBD
M7	Streamline reporting responsibility and Invest on data entry and analytic technology to expedite maintenance work order close-out procedures and data accuracy. Such as maintenance staff to have tablet for access to inspection checklist, reference maintenance		√		Y	TBD	+2	+1	+1	+1	0	0	5	IP

Item #	Improvement Opportunity Alternative by Area of Focus	Timeline to Implement			Capital Funding Required?	Estimated Annual Net Operating Cost Savings	Likely Impact on Evaluation Criteria < Scale Range from 0 to 3: 0=No Impact, 3=Major Impact > "+" = Positive Impact, "-"= Negative Impact							Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
		Short Term	Mid Term	Long Term			Cost Savings	Safety	Employee Experience	Customer Experience	Operational Efficiency	Sustainability	**Total Scores**	
	procedures, OEM manual, training videos and generating integrated reports with multiple technologies.													
	Maintenance Support Roles													
S1	Budget a Quality Control staff to audit PMIs, CM, time standards and also incoming material inspection, MRB, storage, shelf life compliance, and warranty recovery.	√			N	$1.2M	+2	+1	0	+2	+2	0	7	UC
S2	Improve warranty recover process by upgrading organization and implementing standard procedures.	√			N	$2.64M	+3	+1	0	0	+2	0	6	UC
S3	Issue training completion certificates to students for all classes.	√			N	$0 (Cost Neutral)	0	0	+1	0	0	0	1	IP
S4	Explore labor contract changes in collective bargaining agreement including use of part-time administrative employees, light duty positions, and improved sick leave reporting.			√	N	TBD	+2	0	0	+1	+1	0	4	TBD
S5	Evaluate cost benefit of procuring extended warranty for future major capital programs.			√	Y	TBD	+1	+1	0	+1	+1	+1	5	UC
S6	Explore procurement of computer based training as part of future new bus contracts.			√	Y	TBD	0	0	+1	0	+1	0	2	TBD

13 OVERALL SUMMARY AND RECOMMENDATIONS

13.1 Summary

Based on evaluation of the MBTA bus maintenance program through review of historical performance and financial data, site visits of garages and repair shops, and interview of maintenance and supporting departments, a broad range of potential efficiency improvement opportunities are identified based on information gathered up to this point. The initial list of improvement alternatives are analyzed based on impact against six general evaluation criteria. For the purposed of this report, each criteria is assumed to have equal weight.

Overall, there is a total of 36 potential improvement opportunities that has a total estimated net annual operating cost saving of approximately $23M to $27M; cost saving for 11 alternatives are TBD and need further analysis to develop the estimates.

13.2 Recommendations by Alternative Implementation Timeline

Table below lists the 36 potential improvement alternatives by implementation timeline: 12 short term ($6M saving), 12 midterm ($7M to $9M saving), and 12 long term ($10M to $12M saving).

Item #	Improvement Opportunity Alternative	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
	Short Term Implementation Timeline				
G3	Clarify data reporting and then upgrade and standardize communication of key performance indicators (KPIs); including posting KPI charts in official communication boards at all maintenance locations.	N	$0 (Cost Neutral)	4	IP
G4	Start a pilot program setting up a compliance goal of 90% instead of present 100% for PM inspections to achieve an effective range of 95-97%.	N	$160K	4	UC
F1	Outsource Cabot Tire Shop repair work; four positions to be re- assigned.	N	$264K	3	UC
F2	Expand installation of Fastenal POU vending machines to all garages.	N	$0 (Cost Neutral)	3	IP
B2	Reduce the number of contingency buses from 75 to 60 by retiring 15 New Flyer CNG.	N	$600K	9	IP
P6	Explore outsourcing the overhaul/rebuild of components at the Everett Shop in terms of price, quality, and spare allocation.	N	TBD	2	IP
M1	Explore the potential savings in reducing daily bus washing frequency.	N	TBD	6	TBD
M2	Standardize all maintenance procedures for similar tasks by the machinists across the garages with a standard agreed	N	$1M	9	IP

Item #	Improvement Opportunity Alternative	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
	upon time and including special tools and recordkeeping of critical PMI data.				
M5	Verify improvements made to Arborway's fueling to eliminate problems experienced during last winter months.	Y	$0 (Cost Neutral)	4	IP
S1	Budget a Quality Control staff to audit PMIs, CM, time standards and also incoming material inspection, MRB, storage, shelf life compliance, and warranty recovery.	N	$1.2M	7	UC
S2	Improve warranty recover process by upgrading organization and implementing standard procedures.	N	$2.64M	6	UC
S3	Issue training completion certificates to students for all classes.	N	$0 (Cost Neutral)	1	IP
	Mid Term Implementation Timeline				
G1	Realign vacant positions by filling some new key positions required for parts follow up, warranty control and production coordinator.	N	$0.6M	8	C
G2	Reduce overtime usage after filling vacant positions and implementation of repair standards.	N	$1.5M	8	IP
G5	Transfer to bus maintenance the budget and responsibility for minor facility maintenance repairs.	N	$0 (Cost Neutral)	5	UC
G6	Transfer the budget of vault agents from bus maintenance to the fare collection department.	N	$0 (Cost Neutral)	1	IP
F3	Apply lean methodology at garages: lean training, 5S reorganization, and form lean counsels.	N	$0.5M	9	UC
F4	Explore replacement of fixed with pivoting wash brushes to clean fronts/rears except for trolley buses.	Y	TBD	7	TBD
F7	Expand capital program to budget periodic upgrade of facilities and germane shop equipment.	Y	N/A	10	UC
B1	Replacement of NABI CNG with 325 newly purchased New Flyer buses will reduce the unscheduled repairs and parts cost due to the high level of maintenance required for existing NABI buses and 44 articulated CNG. New articulated buses replacing the existing Neoplan buses.	Y	$3M to $5M	11	IP
P1	Streamline the materials management functions and reduce obsolete parts. Set up appropriate consistent min-max levels across the garages. Continue implementation of IDCS.	N	$260K	11	IP
P3	Explore procuring scheduled maintenance part kits from OEMs and/or systems suppliers.	N	TBD	7	IP
M3	Expand oil analysis program to include engines, transmissions, hydraulics, differentials to reduce component	N	$1M	9	UC

Item #	Improvement Opportunity Alternative	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
	failures and unscheduled repairs of critical components (condition based maintenance.)				
M7	Streamline reporting responsibility and Invest on data entry and analytic technology to expedite maintenance work order close-out procedures and data accuracy. Such as maintenance staff to have tablet for access to inspection checklist, reference maintenance procedures, OEM manual, training videos and generating integrated reports with multiple technologies.	Y	TBD	5	IP
	Long Term Implementation Timeline				
F5	Investigate under-roof parking alternatives where needed.	Y	TBD	5	TBD
F6	Replace oldest facilities with new ones: Improve efficiencies, availability of bus lifts, shop equipment and better working conditions. Explore consolidation/expansion of garages.	Y	N/A	11	UC
B3	Implement a five year bus replacement program to replace 100 buses each year based on 12 year useful life.	Y	$8 to 10M	18	UC
B4	Standardize fleet by reducing different bus types as much as possible.	Y	$1M	10	UC
P2	Staff all storerooms for all work shifts.	N	$0 (Cost Neutral)	4	UC
P4	Explore partnership with RTA and other bus agencies on buying parts to address supplier lead-time and quality via multi-year contracts.	N	TBD	4	TBD
P5	Explore Vendor Managed Inventory (VMI) Program to outsource this function at MBTA. It will reduce inventory, eliminate obsolete parts, and zero bus held out of service while awaiting parts.	N	$1.3M	11	TBD
M4	Examine by location the reorganization of daily service of buses by resolving contractual issues to have the buses serviced, cleaned and fueled by the same classification thus improving efficiencies.	N	$400K	3	TBD
M6	Implement real-time equipment failure tracking and repair scheduling through automatic vehicle maintenance (AVM) technology as a requirement in future contracts of new and/or overhauled buses.	Y	TBD	11	TBD
S4	Explore labor contract changes in collective bargaining agreement including use of part-time administrative employees, light duty positions, and improved sick leave reporting.	N	TBD	4	TBD

Item #	Improvement Opportunity Alternative	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
S5	Evaluate cost benefit of procuring extended warranty for major capital programs.	Y	TBD	5	UC
S6	Explore procurement of computer based training in future new bus contracts.	Y	$0 (Cost Neutral)	2	TBD

13.3 Recommendations by Alternative Ranking

Table below lists the 36 potential improvement alternatives from the highest to the lowest total impact scores.

Item #	Improvement Opportunity Alternative	Timeline to Implement	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
B3	Implement a five year bus replacement program to replace 100 buses each year based on 12 year useful life.	L	Y	$8 to 10M	18	UC
B1	Replacement of NABI CNG with 325 newly purchased New Flyer buses will reduce the unscheduled repairs and parts cost due to the high level of maintenance required for existing NABI buses and 44 articulated CNG. New articulated buses replacing the existing Neoplan buses.	M	Y	$3M to $5M	11	IP
P1	Streamline the materials management functions and reduce obsolete parts. Set up appropriate consistent min-max levels across the garages. Continue implementation of IDCS.	M	N	$260K	11	IP
F6	Replace oldest facilities with new ones: Improve efficiencies, availability of bus lifts, shop equipment and better working conditions. Explore consolidation/expansion of garages.	L	Y	N/A	11	UC
P5	Explore Vendor Managed Inventory (VMI) Program to outsource this function at MBTA. It will reduce inventory, eliminate obsolete parts, and zero bus held out of service while awaiting parts.	L	N	$1.3M	11	TBD
M6	Implement real-time equipment failure tracking and repair scheduling through automatic vehicle maintenance (AVM) technology as a requirement in future contracts of new and/or overhauled buses.	L	Y	TBD	11	TBD
F7	Expand capital program to budget periodic upgrade of facilities and germane shop equipment.	M	Y	N/A	10	UC
B4	Standardize fleet by reducing different bus types as much as possible.	L	Y	$1M	10	UC
B2	Reduce the number of contingency buses from 75 to 60 by retiring 15 New Flyer CNG.	M	N	$600K	9	IP

Item #	Improvement Opportunity Alternative	Timeline to Implement	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
M2	Standardize all maintenance procedures for similar tasks by the machinists across the garages with a standard agreed upon time and including special tools and recordkeeping of critical PMI data.	S	N	$1M	9	IP
F3	Apply lean methodology at garages: lean training, 5S reorganization, and form lean councils.	M	N	$0.5M	9	UC
M3	Expand oil analysis program to include engines, transmissions, hydraulics, differentials to reduce component failures and unscheduled repairs of critical components (condition based maintenance).	M	N	$1M	9	UC
G1	Realign vacant positions by filling some new key positions required for parts follow up, warranty control and production coordinator.	M	N	$0.6M	8	C
G2	Reduce overtime usage after filling vacant positions and implementation of repair standards.	M	N	$1.5M	8	IP
S1	Budget a Quality Control staff to audit PMIs, CM, time standards and also incoming material inspection, MRB, storage, shelf life compliance, and warranty recovery.	S	N	$1.2M	7	UC
F4	Explore replacement of fixed with pivoting wash brushes to clean fronts/rears except for trolley buses.	M	Y	TBD	7	TBD
P3	Explore procuring scheduled maintenance part kits from OEMs and/or systems suppliers.	M	N	TBD	7	IP
M1	Explore the potential savings in reduce daily bus washing frequency.	S	N	TBD	6	TBD
S2	Improve warranty recover process by upgrading organization and implementing standard procedures.	S	N	$2.64M	6	UC
G5	Transfer to bus maintenance the budget and responsibility for minor facility maintenance repairs.	M	N	$0 (Cost Neutral)	5	UC
F5	Investigate under-roof parking alternatives where needed.	L	Y	TBD	5	TBD

Item #	Improvement Opportunity Alternative	Timeline to Implement	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
M7	Streamline reporting responsibility and Invest on data entry and analytic technology to expedite maintenance work order close-out procedures and data accuracy. Such as maintenance staff to have tablet for access to inspection checklist, reference maintenance procedures, OEM manual, training videos and generating integrated reports with multiple technologies.	M	Y	TBD	5	IP
S5	Evaluate cost benefit of procuring extended warranty for future major capital programs.	L	Y	TBD	5	UC
G3	Clarify data reporting and then upgrade and standardize communication of key performance indicators (KPIs); including posting KPI charts in official communication boards at all maintenance locations.	S	N	$0 (Cost Neutral)	4	IP
G4	Start a pilot program setting up a compliance goal of 90% instead of present 100% for PM inspections to achieve an effective range of 95-97%.	S	N	$160K	4	UC
P2	Staff all storerooms for all work shifts.	L	N	$0 (Cost Neutral)	4	UC
P4	Explore partnership with RTA and other bus agencies on buying parts to address supplier lead-time and quality via multi-year contracts.	L	N	TBD	4	TBD
M5	Verify improvements made to Arborway's fueling to eliminate problems experienced during last winter months.	S	Y	$0 (Cost Neutral)	4	IP
S4	Explore labor contract changes in collective bargaining agreement including use of part-time administrative employees, light duty positions, and improved sick leave reporting.	L	N	TBD	4	TBD
F1	Outsource Cabot Tire Shop repair work; four positions to be re- assigned.	S	N	$264K	3	UC
F2	Expand installation of Fastenal POU vending machines to all garages.	S	N	$0 (Cost Neutral)	3	IP
M4	Examine by location the reorganization of daily service of buses by resolving contractual issues to have the buses serviced, cleaned and fueled by the same classification thus improving efficiencies.	L	N	$400K	3	TBD

Item #	Improvement Opportunity Alternative	Timeline to Implement	Capital Funding Required	Estimated Annual Net Operating Cost Savings	Total Impact Scores	Status TBD=To be Determined UC = Under Consideration IP = In-Progress C = Completed
P6	Explore outsourcing the overhaul/rebuild of components at the Everett Shop in terms of price, quality, and spare allocation.	S	N	TBD	2	IP
S6	Explore procurement of computer based training in future new bus contracts.	L	Y	TBD	2	TBD
S3	Issue training completion certificates to students for all classes.	S	N	$0 (Cost Neutral)	1	IP
G6	Transfer the budget of vault agents from bus maintenance to the fare collection department.	M	N	$0 (Cost Neutral)	1	IP

Appendix A
Reference Data

Appendix A - Reference Data

Table below lists the status of key MBTA data requested, reviewed, and integrated for this study. It also included items that were available at the time of developing this final report and some are backup cost data required to develop estimates for all the potential improvement alternatives outlined in Section 12.

Data Request Items (Red=priority item; FY = Jul 1st to Jun 30th)	**Status**
1. Budget – FY 2013, 2014, 2015	
a. Breakdown on "Overtime" by garage/facility category code	Received
b. Breakdown on "Vehicle Cleaning" by garage/facility	Received
c. Breakdown on "Material/Service" by garage/facility	Received
d. Monthly Expense Report: Regular and OT Labor Cost by garage	Received FY2015 only
e. Actual bus maintenance cost by garage and facility (labor & material classification)	Received
2. Maintenance	
a. Description of oil sampling program	NA (Program not set up. Sampling by request only.)
b. Labor hour and cost (labor, parts) by maintenance type for each garage and fleet type: FY 2013, 2014, 2015	Received
i. Code (E) - PM/ Defects : labor (regular & OT) and material cost of PM inspection and defects by fleet type	Received total labor & material cost. Did not receive breakdown/details on actual repair work performed and material used
ii. Code (F) - Failure in Service/road call: labor (regular & OT) and material cost by fleet type	Received total labor & total material cost.
iii. Code (R) - Running Repairs / Unscheduled maintenance: cost of labor (regular and OT) and parts by fleet type	Received total labor & material cost. Breakdown/details on actual repair work performed and material used unavailable
c. Monthly Dropped trips and vehicle availability Report by garage: FY 2013, 2014, 2015	Received
d. Rebuilt components at Everett Shop: List of each component and heavy repairs performed for last FY 2015, and the cost (labor & material) of rebuild.	Received engines & transmission data only; other subsystems available.
e. The list of components and repairs cost from South Hampton and North Cambridge where they were performing heavy repairs in the shop. Maybe it is included in the unscheduled maintenance?	Received total cost. Detailed breakdown not available.
f. RTA (Lowell, Worcester): Breakdown of their labor and parts used for one year for their fleet	Not available

Data Request Items (Red=priority item; FY = Jul 1st to Jun 30th)	Status
g. The current tire leasing contract	Received
h. Listing and the cost of rebuild items by outside vendor	Received
3. Bus Material Usage & Cost	
a. Material usage and cost by garage and by fleet: FY 2013, 2014, 2015	Received all locations, except Everett Main Shop & Cabot Tire Shop are unavailable
4. Fleet information	
a. Fleet roster with spare ratio by fleet type; reason for spare ratio	Received
b. Usage of contingency fleet (by miles per year) for inclement weather, bus bridge for rail, to substitute buses during campaigns and long term rehab, power disruptions (trolley buses) and various major interruptions i.e. fires, emergencies, and accidents	Received
5. Facility Maintenance & Information	
a. List of in-house and contracted maintenance work	Received
b. Last 10 years: annual operating cost by facility/garage (breakdown on subsystem, cost by labor & material)	Unavailable
c. General layout of each garage and facility	Received Facility Emergency Plan (except Charlestown, Everett, Lynn), & Construction Drawings.
6. Training	
a. Training program plan for bus maintenance staff	Received
7. Human Resource	
a. Workman's Comp: Provide information on type of injuries (shop slips, back etc.) by each location (maintenance garages) and the total workman's comp paid for bus maintenance each year from FY 2013 thru 2015	Received
b. # of days to fill Bus Maintenance Position Vacancy: FY 2013, 2014, 2015	Received
8. Service Planning	
a. Actual annual ridership by garage, fleet type, and/or bus route: FY 2013, 2014, 2015	Received

Data Request Items (Red=priority item; FY = Jul 1st to Jun 30th)	Status
9. Capital Planning	
a. FY 2013, 2014, 2015 Overhaul program by fleet type and garage; list of subsystems overhauled, # of bus, period of OH	Received high level information
b. Last 10 years: annual bus fleet capital spending by fleet type (breakdown on type of program and any cost details)	Received
c. Last 10 years: annual bus facility/garage capital spending by location (breakdown on type of program and any cost details)	Received partial information
10. MBTA has recently issued "formal" labor time standard for at least 10 maintenance tasks. Historical work orders showing the actual time for these tasks before and after time standards are issued.	Received
11. Service Failure Summary in past 5 fiscal year by fleet type	Received
12. Inventory On Hand by fleet per storage room location	Received
13. Others	
a. Monthly Performance Metric - FY 2013, 2014, 2015	Received Monthly MMBF by bus type and garage
b. Annual Performance Metric - FY 2011, 2012, 2013, 2014, 2015	Received FY MMBF by bus type

Appendix B
Detailed Bus Maintenance Facilities Review

Appendix B – Detailed Bus Maintenance Facility Review

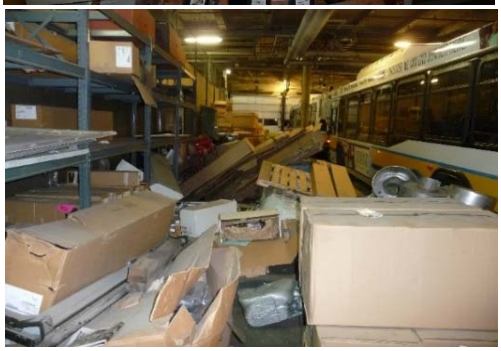
B.1 MBTA Bus Garage Findings

Albany Garage

General Condition

- Built approximately 1941
- Maintenance Area
  - Ceiling heights are high and allow full extension of lifts
  - Entrance door heights are not high enough to accommodate taller buses (including all new hybrid buses)
  - There seems to be adequate floor space for safe and efficient movement around buses in the maintenance bays
  - However, the area is dirty and unorganized with a lot of room consumed by discarded material and old, unserviceable equipment impeding efficiencies
- Parts Storeroom
  - Entire area appears to be completely unorganized with the shelves littered with trash and parts not in proper locations
  - Hardware bins in maintenance areas are fairly organized but some bins contain a mixture of miscellaneous incorrect parts
  - Floor area contains a lot of discarded, unlabeled parts
- Property and Bus Storage
  - The garage includes 2 bus storage bays but there exists a lot of old, discarded material, shelving and unserviceable equipment that consumes a lot of floor space and precludes maximizing the overnight storage capacity.
  - One of the storage bays has 10 contingency buses which supplement the daily fleet

Figure 1 - Albany Garage Material Storage



Maintenance Capabilities & Capacity

- Fleet: 116 ECD Neoplan 40FT
- Pullouts: 92 am, 86 pm (26 spares)
- Employees: 1 Supervisor, 1 Garage Foreperson, 4 Forepersons, 24 Machinists, 4 Fuelers, 2 Car Cleaners
- Work Hours: 3 overlapping shifts, 24 hours per day, 5 days per week
- Maintenance Area: 6 bays, 1 drive on lift ,20 portable mobile column lifts (5 bus sets)
- Bus storage: 2 indoor bays with an undetermined amount of capacity and lot storage
- Bus Washing: Single lane bus washer, chassis wash
- Service Lane: Single fuel lane with 2 diesel nozzles

Improvement Opportunities

- Conducting a Lean 5S event to sort and remove old broken or unneeded materials, a general cleaning and conduct a study on how work is done to reorganize the maintenance area and storeroom improving operational efficiencies and overall site safety
- It was mentioned during the visit that the garage did not have enough lifts to support their maintenance operation. Develop an operational plan embedded with efficiency improvements and determine what additional equipment, if any, is needed to execute that plan. Then conduct a financial analysis to justify any capital expenses with resulting efficiency improvements.

Arborway Garage

General Condition

Figure 2 - Arborway Material Storage

- Built: Approximately 2000
- Built as a temporary facility but there has not been funding to build a permanent facility
- Maintenance Area
  - The maintenance area is well lit, orderly and clean
  - The ceiling heights are high and allow full extension of lifts
  - The 2 maintenance bays in Building 1 are narrow and have very limited room around buses in the bay impacting efficiencies and potentially safety
  - There were no visible posted performance metrics
  - Supervisor office is in a trailer and not inside the shop where all the maintenance works are performed.
- Parts Storeroom
  - The storeroom is housed in a temporary prefab building away from the maintenance garage making it necessary to leave the garage and walk across the drive area to retrieve parts
  - The storeroom is very clean and very well organized
  - Space seems adequate for the parts on hand
  - Many parts have a reorder quantity of 0 and a replenish quantity of 1 causing part shortages
- Property and Bus Storage
  - The property is large and well maintained with plenty of room for bus flow
  - Since the property was built as a temporary facility, there is no inside storage for buses and buses are stored in marked lanes on the outside pavement
  - CNG Fueling stations and equipment are outside resulting in complications in the fueling operation during cold weather making it necessary to take the buses to Southampton or Cabot (estimated 20-30 minutes one way) when the system does not operate properly. This happened 5 or 6 times last winter.

Maintenance Capabilities & Capacity

- Fleet: 118 CNG NABI 40 ft.
- Pullout: 97 am, 97 pm (21 spares)
- Employees: 1 Superintendent, 1 Supervisor, 3 Forepersons, 32 Machinists, 10 Fuelers, 1 Car Cleaner, 5 Vault Agents
- Work Hours: 4 overlapping shifts, 24 hours per day, 7 days per week
- Maintenance Area: 6 bays, 5 portable mobile column lift positions, 1 4-post lift position
- Bus storage: No enclosed storage, marked pavement for 108 buses outside
- Bus Washing: Single lane bus washer, no chassis wash capability
- Service Lane: 2 CNG fuel lanes with 1 CNG nozzle and 2 CNG dispensers

Improvement Opportunities

Figure 3 - Arborway Garage Maintenance Bay

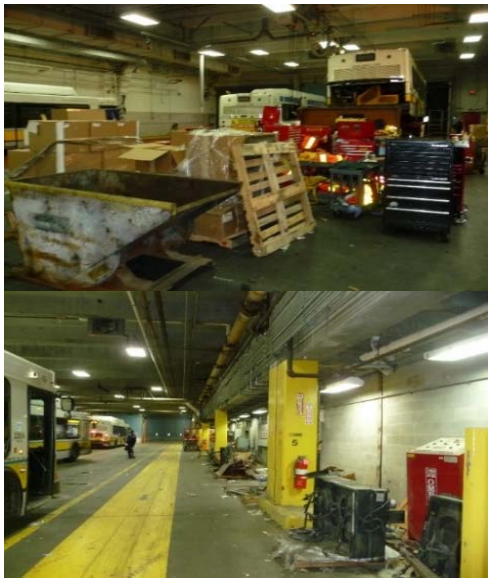
- Determine if more circulation space can be gained around the buses in the 2 maintenance bays in Building 1 by reorganizing the area
- Consider moving the parts storeroom building and supervisor office closer to the maintenance bays
- Investigate ways of protecting the CNG Fueling area and equipment from the weather to improve the equipment reliability
- Investigate adding chassis wash capability
- Revisit spare part min/max levels

Cabot Garage

General Condition

- Built in 1970's
- Maintenance Area
  - The maintenance area is well lite, clean and fairly orderly. However, there are a couple of areas where material and trash consume floor space and look disorderly. This was stated to be a temporary situation.
  - The ceiling heights are high and allow full extension of lifts
  - It was mentioned that the lifts are old and are becoming unreliable
- Parts Storeroom
  - The storeroom does not appear to be well organized particularly the shelves where a variety of parts seemed to be just thrown together where the shelf is designated for 1 part. It would be difficult to determine what inventory is currently on hand.
  - Cabot facility will continue to operate a mixed fuel fleet (CNG and diesel) which will require storage capability for both types of buses. Due to its current state, it is difficult to determine if there is adequate space to support both types of buses in the current storeroom. There is however a mezzanine about the storeroom that does not current appear to be fully utilized. There is also a lot of floor space in the bus storage area that is currently taken up by discarded material and old, unusable equipment.
- Property and Bus Storage
  - The property is large and well maintained
  - Indoors storage capacity for approximately 134 buses
  - This is also the central location for MBTA's tow trucks
  - The bus washers have stationary brushes that do not cover the fronts or rears of the buses making it necessary to wash those areas of the buses by hand
  - This is where many non-revenue vehicles are washed, sometimes interfering with bus washing operations and circulation around the property

Figure 4- Cabot Garage Storage/ Staging Area



Maintenance Capabilities & Capacity

- Fleet: 197 buses (180 CNG NABI 40FT).
- Pullout: 153 am, 140 pm (27 spares)
- Employees: 1 Superintendent, 2 Supervisors, 7 Forepersons, 54 Machinists, 16 Fuelers, 2 Car Cleaner, 2 Vault Agents
- Work Hours: 3 shifts per day, 24 hours per day, 7 days per week
- Maintenance Area: 14 bays, 4 portable mobile column lift positions, 1 pit, 2 additional bays at the south end
- Bus storage: Building to the west of bays is used for indoor bus storage
- Bus Washing: Hot water washer in service lanes and a relatively new 2-lane bus washer
- Service Lane: 4-lane CNG fueling and service, dual lanes diesel buses service

Improvement Opportunities

- The debris and old, unusable equipment need to be removed from the maintenance and the bus storage areas. Six more bus spots could be gained by moving trash dumpers outside
- Conducting a Lean 5S event to sort and remove old broken or unneeded materials, conduct a general cleaning and reorganize the storeroom improving operational efficiencies and overall site safety.
- Once the debris is removed and the storeroom is reorganized a determination can be made as to what will be needed to support the new diesel buses.
- To eliminate the interference of bus operations , develop rules as to when non-revenue fleet vehicles can use the bus washer facility
- Repair or replace bus lifts to improve reliability

Charlestown Garage

General Condition

- Built in 1970's
- Maintenance Area
  - Fairly clean and most areas, particularly areas around buses, organized and free of clutter with some areas in the parameter of the garage more congested with equipment
  - Facility maintenance is a concern, particularly the reliability of lifts and overhead doors
- Parts Storeroom
  - Clean and fairly well organized
  - Maintenance personnel mentioned that there are daily parts shortages that impact efficiencies. Car cleaners are used to chase down parts. Although there are complaints about space availability, there are numerous empty drawers in the storeroom
- Property and Bus Storage
  - The seawall on the east side of the property has deteriorated to the point that the buses and other vehicles cannot circulate around the property causing two-way traffic and congestion

Figure 5 - Charlestown Storage Cabinets

Figure 6 - Charlestown Facility

Maintenance Capabilities & Capacity

- Fleet: 60 New Flyer Hybrid, , 60 Diesel NOVA, 134 New Flyer Diesel 40 ft., 254 Total
- Pullout: 191 am, 194 pm (60spares)
- Employees: 1 Superintendent, 2 Supervisors, 1 Garage Foreperson, 7 Forepersons, 61 Machinists, 17 Fuelers, 6 Car Cleaners, 2 Vault Agents, 1 Garage Clerk
- Work Hours: 4 overlapping shifts, 24 hours per day, 7 days per week
- Maintenance Area: 14 repair bays, 12 lift positions, 2 inspection pits, 1 touch-up and body work bay
- Bus storage: Inside storage for approximately 230 buses
- Bus Washing: 2 bus wash alleys, steam bay with bus hoist
- Service Lane: 2 diesel fueling islands

Improvement Opportunities

- Conduct a Lean 5S event to reorganize the equipment along the garage perimeter to improve operational efficiencies and overall safety
- Resolve the spare parts shortage issues
- Address the capital and facility maintenance issues with overhead doors and lifts to improve efficiencies

Fellsway Garage

General Condition

- Built in 1925
- Maintenance Area
  - Very clean and orderly
  - Adequate circulation space in service bays around buses
  - Lifts are currently all operable
  - Capital issues such as maintaining the lifts are a challenge
- Parts Storeroom
  - Clean and well organized
  - Part availability was stated to be pretty good
- Property and Bus Storage
  - There is no enclosed storage for buses
  - The pavement around the facilities has a lot of pot holes

Figure 7 - Fellsway Maintenance Area

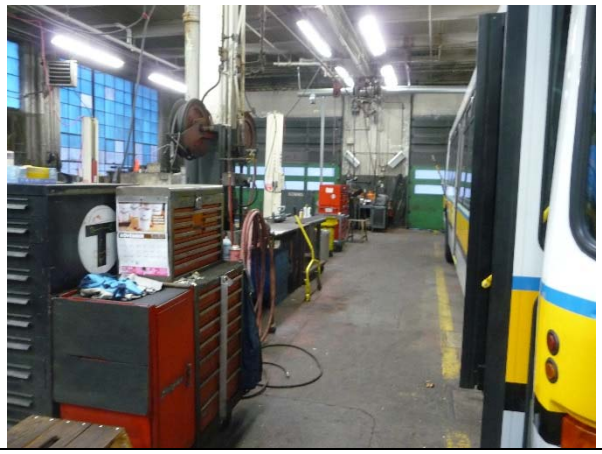


Figure 8 - Fellsway Garage Storage

Maintenance Capabilities & Capacity

- Fleet: 76 ECD Neoplan 40 ft.
- Pullout: 55 am, 49 pm (21 spares)
- Employees: 1 Supervisors, 1 Garage Foreperson, 3 Forepersons, 21 Machinists, 4 Fuelers, 1 Car Cleaners, 2 Vault Agents
- Work Hours: 4 overlapping shifts, 24 hours per day, 5 days per week
- Maintenance Area: 6 repair bays, 3 sets of portable lifts, 1 parallelogram lift, 1 2-post lift, 1 flat floor bay
- Bus storage: No enclosed indoors storage
- Bus Washing: 1 bus wash lane
- Service Lane: 1 diesel fueling nozzle

Improvement Opportunities

- Condition of the outside pavement should be addressed
- This seems to be the only garage that washes buses twice a day. This could be reduced to once per day
- Address the capital and facility maintenance issues with lifts to improve efficiencies

Lynn Garage

General Condition

- Built in 1936
- Maintenance Area
  - Entire maintenance area is poorly lighted
  - Although the facility is quite old, it is clean and fairly well organized
  - Bus maneuvering within maintenance area is congested
- Parts Storage
  - Area is well organized which has been done by the foremen and machinists
- Property and Bus Storage
  - Indoor bus storage is clean
  - Not a good flow through in the storage area making it necessary to pull in and back up to park buses risking damage to the buses
  - Property in small making it necessary to use street for circulation

Figure 9 - Lynn Garage Bus Staging Area

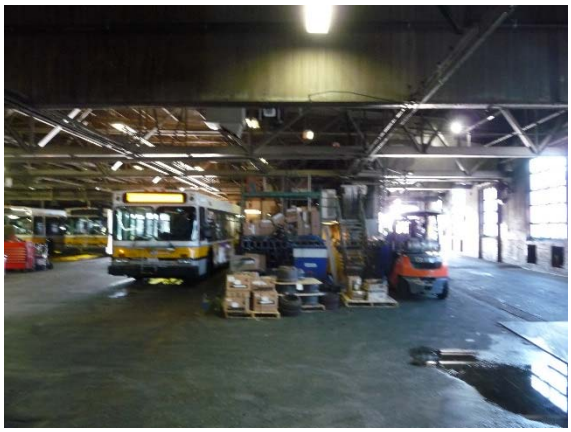


Figure 10 - Lynn Garage Material Storage

Maintenance Capabilities & Capacity

- Fleet: 89 New Flyer Diesel 40 ft.
- Pullout: 75 am except 74 am on Friday (12 spares), 71 pm (14 spares)
- Employees: 1 Garage Foreman, 4 Forepersons, 22 Machinists, 7 Fuelers, 2 Car Cleaners, 1 Vault Agent
- Work Hours: 3 shifts per day, 24 hours per day, 7 days per week
- Maintenance Area: 10 bays total, 6 inspection bays with pits, 3 bays with hoist, 1 bay with portable lifts
- Bus storage: in house storage for 60 buses, all others are parked outside
- Bus Washing: 1 bus wash lane
- Service Lane: Single 2 diesel fueling pumps

Improvement Opportunities

- Due to its age, construction and layout, this garage has many challenges. However, the foremen and staff seem to be working well together to determine what works best with the conditions they have. Although the garage and storeroom are well organized, the garage could benefit from a Lean 5S (Organization) event to improve organization even more and increase efficiencies.

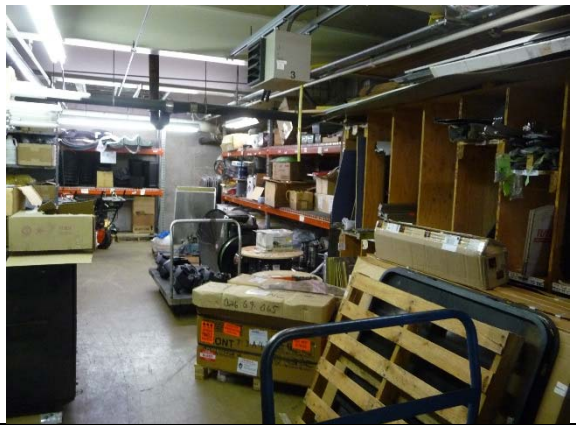
North Cambridge Garage

General Condition

- Built approximately 1979
- Only garage equipped to maintain ETB fleet
- Maintenance Area
  - Garage is clean and fairly well organized
  - Fairly narrow space between bus and garage sidewalls
  - Good room between buses in bays
  - Electronics repair lab in basement
- Parts Storage
  - Storeroom is in a basement under offices
  - Organization and condition is fair
  - Drawers are in good order, shelves are in fair order
- Property and Bus Storage
  - Property is very clean and orderly

Figure 11 - North Cambridge Maintenance Area

Figure 12 - North Cambridge Material Storage



Maintenance Capabilities & Capacity

- Fleet: 28 Electric Trolleys Buses, 3 NF 40FT ECD, 3 TMC/Nova 40FT
- Pullout: 22 am, 23 pm (5 spares) (Now in temporary service: 10 am, 8 pm-18 Spares)
- Employees: 3 Forepersons, 7 Rail Repairers, 1 Car Cleaners
- Work Hours: 2 shifts per day, 6 days per week
- Maintenance Area: 4 bays, 1 pit, 1 with portable lifts, 2 with piston lifts
- Bus storage: all outside storage
- Bus Washing: 1 bus wash lane
- Service Lane: none

Improvement Opportunities

- Conducting a Lean 5S event to reorganize the storeroom improving operational efficiencies.

Quincy Garage

General Condition

- Built in 1930
- Maintenance Garage
  - Facility is old (1930's) with pits that are being barely maintained structurally
  - Entrance door heights are not high enough to accommodate taller buses (including all new hybrid buses)
  - Ceiling height is low and does not allow full lift height jacking for brake change-outs. Due to ceiling height and construction, lifting is done on one end of the bus only
  - Bays with pits are close together impeding circulation around the buses during maintenance
  - Perimeter is not organized well
- Parts Storage
  - Storeroom area appears to be not well organized with the shelves littered with trash and parts not in proper locations
  - Storeroom floor area contains discarded, unlabeled parts
  - Hardware bins in maintenance areas are fairly well maintained but the top shelf is littered with discarded parts
  - Routine maintenance shelves in garage area are well organized
- Property and Bus Storage
  - One-way traffic flow necessitates use of adjacent surface street to access bays with pits
  - Fixed washer brushes do not wash fronts and rears of buses. This is accomplished manually or not at all. Buses in storage ready for services were seen to have unwashed rears
  - Garage personnel and stock clerk indicated problems with part availability. If stock clerk is not available, car cleaner or machinist must travel to another location to retrieve part.

Figure 13 - Quincy Garage Pit Structure

Figure 15 - Quincy Garage Storage Room

Figure 14 - Quincy Garage Foreperson Office

Maintenance Capabilities & Capacity

- Fleet: 86 New Flyer Diesel 40 ft.
- Pullout: 59 am, 52 pm (27 spares)
- Employees: 1 Supervisor, 1 Garage Foreperson, 4 Forepersons, 19 Machinists, 5 Fuelers, 3 Car Cleaners, 1 Vault Agent
- Work Hours: 3 shifts on weekday and 5 shifts on weekend, 24 hours per day, 7 days per week
- Maintenance Area: 5 repair bays with pits, 2 floor bays with portable lifts
- Bus storage: 26 bus capacity inside, remaining outside storage
- Bus Washing: 1 bus wash lane, no undercarriage washing capability
- Service Lane: Single lane with 1 diesel fueling nozzle

Improvement Opportunities

- The physical constraints of this facility (tight areas around buses in pit bays, unable to lift both ends of buses in floor bays or to a comfortable working height, physical conditions of pits, poor circulation around property) impedes its operational efficiencies
- Conduct a Lean 5S event to reorganize the maintenance area and storeroom to improve efficiencies and overall site safety
- Conduct analysis to determine required parts holding and method for replenishment that results in most efficient operations.

Southampton Garage

General Condition

- Built in 2002
- Only garage equipped to maintain DMA fleet
- Only garage capable of maintaining 60' buses
- Maintenance Garage
  - Garage is clean and fairly organized
  - Tool boxes around the garage perimeter causes close quarters with buses in adjacent maintenance bays
- Part Storeroom
  - Shelves are appear messy and not well organized containing what appears to be discarded parts and packaging materials
- Property and Bus Storage
  - Facility was built in 2002 and seems clean and not congested
  - Most buses are parked under an open-air parking garage with additional outside parking

Figure 16 - Southampton Garage Maintenance Bay

Figure 17 - Southampton Garage Material Storage

Maintenance Capabilities & Capacity

- Fleet: 25 New Flyer HYBRID 60 ft., 41 Neoplan CNG 60 ft., 32 Neoplan DMA 60 ft., (98 Total)
- Pullout: 56 am, 60 pm (38 spares)
- Employees: 1 Superintendent, 2 Garage Forepersons, 5 Forepersons, 26 Machinists, 22 Rail Repairers, 7 Fuelers, 3 Car Cleaners, 1 Vault Agent
- Work Hours: Multiple overlapping shifts, 24 hours per day, 7 days per week
- Maintenance Area: 10 repair bays (1 dynamometer bay, 1 drive-on pit, 4 drive-on lifts, 2 3-post lifts, 3 bays with portable lifts)
- Bus storage: Most buses are stored under an open air parking garage
- Bus Washing: 1 bus wash lane with chassis washing capability
- Service Lane: 2 service lanes with CNG and diesel fueling nozzles

Improvement Opportunities

- Conduct a Lean 5S event to reorganize and clean up the storeroom to improve efficiencies
- Determine if there is a way better organize the machinists' tool boxes to improve circulation around buses in the maintenance bays, primarily those against the outside walls

B.2 Regional Transit Authority Facilities Visit Findings

Lowell RTA Facility

General Condition

- Maintenance Garage
  - Fairly clean but no very orderly
  - Plenty of room which allows for more efficient operations even though the garage was not very organized
- Storeroom
  - Clean and well organized
- Property and Bus Storage
  - There is plenty of room on the property for bus circulation
  - All buses and vans are stored inside which helps with property circulation and morning bus startups during inclement weather

Figure 19 - Lowell RTA Maintenance

Figure 18 - Lowell RTA Bus Staging Area

Maintenance Capabilities & Capacity

- Fleet: 23 35-ft bus, 18 29-ft bus, 9 vans (Total 50 vehicles, which both type of buses are shorter than the 40 ft. standard)
- Pullout: 34 am, 42 pm (Buses) 8 spares
- Employees: 1 Superintendent, 5 full time Machinists, 3 Fuelers/Cleaners, 1 Facility Maintenance
- Work Hours: 2 shifts Monday through Saturday
- Maintenance Area: 6 maintenance bays with scissor lifts
- Bus storage: All inside
- Bus Washing: 1 bus wash lane

Comparison with MBTA Facilities and Operations

- This garage and property are newer than most MBTA garages with fewer facility maintenance issues
- There is more room in this garage allowing more efficient operations without being very orderly
- All vehicles are stored inside keeping snow off them in the winter and enabling easier startups in inclement weather
- Garage has responsibility for all replacement parts (quantities on hand, reorder quantities, storage organization)
- Garage has responsibility for facility capital plan and maintenance to keep facility in good condition
- All buses are the same make by Gillig and purchased over several years, limiting spare part quantity requirements
- Bus fleet has a much lower average life requiring less maintenance per bus per year
- Government capital funding seems much different than that of MBTA
- Garage employees are within 1 union (Local 589) making operating rules simpler
- Machinists' wages are approximately $20 per hour
- Road breakdown tows are accomplished through an outside contractor
- Overtime has been less than 16 hour per month total year to date
- The service lane operators accomplish fueling, bus cleaning and vaulting
- They have found it very efficient to adopt the rule "once on a lift, the bus stays there until everything is complete". In other words, when they accomplish inspections, all maintenance issues identified are corrected before the bus leaves the garage
- 9 vans are used on light routes, vans are easier to maintain than buses

Worcester RTA Facility

General Condition

- Maintenance Garage
  - Although the facility is quite old, the garage is clean, organized and very well maintained
  - There is plenty of room in the garage
- Parts Storeroom
  - Extremely clean and orderly
  - No complaints about missing or a shortage of parts
- Facility and Bus Storage
  - Plenty of room on the property for bus circulation
  - All bus can be stored inside when necessary

Figure 20 - Worcester RTA Material Storeroom

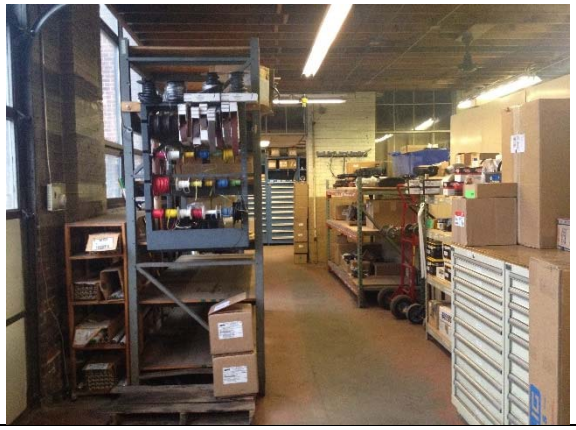


Figure 21 - Worcester RTA Work Bench

Maintenance Capabilities & Capacity

- Fleet: 52 buses (6 electrics, 17 Hybrids, 29 diesel, oldest being 2008), 40 vans
- Pullout: 43 buses, 9 spares
- Employees: 15 strictly bus maintenance (4 mechanic A/B, 10 specialists, 1 foreperson) and 37 other personnel for a total force of 52 in facility
- Work Hours: 3 shifts per day, 7 days per week
- Maintenance Area: 8 bays: 5 in-ground, 2 drive-on, 1 with portable lifts
- Bus storage: All inside when necessary
- Bus steam room
- Service Lane: 1 Wash/Service Lane

Comparison with MBTA Facilities and Operations

- Although this garage and property are as old as many of the MBTA garages, it is in excellent condition and very well maintained
- There is more room in this garage allowing more efficient operations, however, it is very well organized
- All vehicles are stored inside keeping snow off them in the winter and enabling easier startups in inclement weather
- Garage has responsibility for all replacement parts (quantities on hand, reorder quantities, storage organization)
- Garage has responsibility for facility capital plan and maintenance to keep facility in good condition
- Bus fleet has a much lower average life requiring less maintenance per bus per year
- Government capital funding seems much different than that of MBTA
- Garage employees are within 1 union making operating rules simpler
- Machinists' wages are approximately $30 per hour
- The service lane operators accomplish fueling, bus cleaning and vaulting
- They have found it very efficient to adopt the rule "No bus leaves the garage with a defect".
- 40 vans are used on light routes, vans are easier to maintain than buses.

Appendix C
Proposed MBTA Bus Maintenance Lean Program

Appendix C – Proposed MBTA Bus Maintenance Lean Program

C.1 Overview of Lean Program

Improvement Opportunity Alternative F3 states "Apply lean methodology at garages: lean training, 5S reorganization, and form lean councils". Lean is defined as "a customer centric methodology used to improve any process through the elimination of waste in everything you do. It is based on the principles of continuous improvement and the respect and engagement of all employees." Simply put in MBTA Bus Maintenance terms, turning the wrench and installing the new parts on a bus are value-added activities while locating and retrieving the wrench and the new parts are among non-value-added activities or waste. Lean is about eliminating as much waste or non-value-added activities from our work as possible so that we have more time to conduct value-added activities which improve our efficiencies and lower overall cost of operations.

CH2M has over 30 years of experience in providing Lean program planning, training and implementation services to its clients across many industries. Through this experience, we have identified the elements that are required for a Lean Program to have the best chance of success in achieving the goal of sustained efficiency improvements. These elements include:

- The program must be embraced and led from the top of the organization
- It needs to carry the same importance to management and all employees as Safety and Quality
- Just like Safety and Quality, all employees are trained in Lean principles and techniques and are responsible to actively identify and implement improvement opportunities
- Just like Safety and Quality it is a program that never ends

The best way to build a Lean Program that includes these elements of success is to place a structure around the program. This is accomplished through the establishment of a Lean Council at each MBTA Garage and at the Charlestown Bus Maintenance Headquarters. Due to their ages, configurations and fleet models, each garage has its own unique challenges and, therefore, needs its own Lean Program focused on its operation. However, there is a need for effective communications and sharing of ideas and best practices across the garages. There are numerous ways of accomplishing that: periodic Lean Leadership meetings, forming of an Executive Lean Council headed by the Director of Bus Maintenance, a Lean Communications Team made up of Lean Leaders from each garage and the Charlestown Headquarters, etc.

C.2 Lean Program Structure for MBTA Bus Maintenance

This subsection discussed a proposed Lean Program structure for MBTA Bus Maintenance.

Lean Program Purpose

To establish a program across all MBTA Bus Maintenance that creates a culture of continuous improvement by engaging and encouraging all employees to identify and implement improvements that will make their jobs easier and more efficient to perform. This will result in a better work environment for all employees and reduced overall cost of operations for the organization.

Program Organization (each Garage and at Charlestown Headquarters)

Each garage and at Charlestown Headquarters will have its own lean program organization composed of a lean council and a team of lean leaders. The general make-up and responsibilities of the program organization is provided in the table as follow.

Lean Council

Organization per Location

Council Chairperson (1 person per location)	• Garage – Location Leader (Superintendent or Supervisor) Charlestown Headquarters - Director of Bus Maintenance or his/hers designee
Council Members (4 -5 person per location)	• Direct reports to Chairperson • 1 Union Representative • Membership can rotate annually (similar to a board of directors to keep all employees engaged)

Responsibilities

- Responsible for overall location Lean Program
- Coordinate location communications
  - Establish metrics to monitor obtained benefits from program
  - Coordinate program communications to MBTA Bus Maintenance Leadership
  - Hold Lean Council Meetings
  - No less than once per month (usually more frequent at the start of the Lean Program)
  - No longer than 1 hour per meeting
  - Not held in conjunction with any other meeting
  - Set topics for Lean Council Meetings
  - Review progress of ongoing improvement implementations and make any needed adjustments
  - Review and make determinations on new improvement opportunities
    - Approve, disapprove, need of more information
    - Identify resource requirements
    - Establish priorities and schedules
  - Coordinate program communications
  - Review Program Metrics

Lean Leaders

Organization per Location

Total # of leaders per location depends on garage size	• Garage - 1 leader per shift minimum • Charlestown Headquarter – 4 to 6 leaders from different functions

Responsibilities

- Receive improvement opportunities from employees
- Make initial evaluation of improvement opportunities and communicates outcome to submitting employees; evaluation result categories:
  - Not valid

  - Acceptable and can be implemented without Lean Council approval (meets all of following)
    - No expense or capital requirement
    - Low effort requirement
    - Low impact to overall garage operations
  - Good potential for improvement but needs Lean Council approval (includes any of following)
    - Expense or capital funding required
    - Medium or high effort requirement
    - Medium to high impact to overall garage operations
- Submit improvement opportunities to Lean Council for consideration
  - Prepare written submittal (usually on A3 sheet and developed with submitting employee) to include the following items:
    - Current State
    - Improvement opportunity
    - Anticipated benefit
    - Resource requirement for implementation
- Attend Lean Council meetings
  - Introduce new improvement opportunities
  - Report progress of improvement implementations
- Lead larger Improvement Team implementations

All Employees

Responsibilities

- Identify improvement opportunities
- Submit improvement opportunities to Lean Leaders for consideration
- Implement approved improvement opportunities as an individual or on an Improvement Team

C.3 Summary

The above outline of this program may seem overwhelming at first glance and it does require a significant effort to put the organization in place, train all employees in Lean Techniques and Principles and to get the program started, but it soon will become a normal way of operating and the benefits in increased employee involvement and quality of life and the improvement in efficiency and its resulting cost reduction can be significant. The estimated net reduction is approximately $500,000 in operating cost through reduced overtime, improved safety and maintainability, and better utilization of garage equipment which we believe to be the minimum benefit from the implementation of a Lean Program. The actual improvement can be much greater and depends on the emphasis and rigor MBTA Bus Maintenance Leadership places on the program.

Appendix D
Estimated Cost Saving Justifications

Appendix D - Estimated Cost Saving Justifications

Improvement Opportunity Alternative Item #	Increased cost per Year	Estimated Cost Assumptions	Estimated Net Operating Cost Savings per Year
G1 Delete 5 positions after filling in positions to reorganize for warranty, store room clerks and production coordinators. The total staff will reduce from 525 to 520.	None	5 positions @$120,000per position	+$600K
G2 Reduction in overtime after filling vacant positions and implementing work standards for repetitive repair jobs and controlling absenteeism. Annual overtime : $8.3 million budgeted	None	On an average, 70 to 80% of labor hours are recorded for the unscheduled repairs (reference garage report). These are repetitive jobs. Also, overtime is being utilized to cover absenteeism and coverage for vacant positions. Approx. 15 to 18% savings can be achieved by implementing work standards and controlling absenteeism and filling vacant positions	+$1.5M
G4 Reduction of 4% PMIs	None	**a**) 4% of pm inspection and defect expense or 4% of $3.89M/$156K (11/14-11/15) **b**) 4% increase in bay availability MBTA has 92 but should have 125 based on industry standards	**+$**156K TBD
F1 Outsource Cabot Tire shop. Four existing positions can be reassigned to fill the vacant positions.	TBD	Existing cost of tires and equipment = $1.8M (MBTA Budget) Labor cost of four positions = 4 x $120,000 = $480,000 Total Cost = $1.8M + $480K = $2,280,000 Outsourcing cost based on annual mileage and WMATA cost per mile contract with Good Year = $2,016,090	$2,280,000 - $2,016,090 = +$263,910
F3 Apply lean methodology at garages: lean training, 5S reorganization, and form lean counsels	None	$0.5 M in operating cost through reduced overtime, improved safety and maintainability, and better utilization of garage equipment.	$0.5M
B1	None	The phased replacement of this fleet will begin in July 2016. The replacement will initially reduce the unscheduled repairs by 30% in first few months due to	+$3M to 5M

Improvement Opportunity Alternative Item #	Increased cost per Year	Estimated Cost Assumptions	Estimated Net Operating Cost Savings per Year
Replacement of NABi CNG with 325 newly purchased New Flyer buses will reduce the unscheduled repairs and parts cost due to the high level of maintenance required for existing NABI buses and 44 articulated CNG. New articulated buses replacing the existing Neoplan buses.		partial delivery of buses. The savings will increase as the unscheduled repairs decrease by 50 to 60% when the entire fleet is delivered with no repairs required for structure and CNG tank replacement. Also, a condition based PM program will help reduce the maintenance cost. The 2015 running repair cost (from 2015 report) is approx. $10.5 million which includes labor and material costs.	
B2 Reduce contingency fleet from 75 to 60 buses	None	Based on avg. maintenance cost (includes fuel) of $98K for a conventional bus and assuming $40K for a contingency bus, a reduction of 15 buses would result in $600K	+$600K
B3 & B4 Planned replacement of 100 buses per year to control unscheduled repair costs and obsolete parts and standardization of fleet	Capital Budget to be funded	The strategic capital plan for 5 years should include the phased replacement to reduce and maintain the fleet age. This also helps to reduce the age of the contingency buses from 20 years to less than 15 years. The long term savings can be estimated by reduced unscheduled heavy repairs.	Long Term Plan +$8M to $10M
P1 Streamline materials management, reduce obsolete parts, appropriate min-max	None	Reduced $26M material inventory by 1%	**+**$260K
P5 Explore Vendor Managed Inventory (VMI) Program to outsource this function at MBTA. It will reduce inventory and eliminate obsolete parts and zero bus held out of service while awaiting parts.	None	Reduced $26M material inventory by 10% offset by contract cost for hiring vendor to provide management and supply of all materials.	+$2.6M - $1.3M = $1.3M
M1 Explore the potential savings in reducing daily bus washing frequency	None	The cost should include labor to wash and spot windows, alkaline cleaner diluted with water, electricity, wear and tear on washer equipment including brushes. In California due to water restrictions, some bus agencies have switched to wash every other day with no negative passenger perception.	TBD
M3	$120,000	The cost for rebuilding the failed transmissions and engines is quite high (Everett shop reports). A comprehensive oil program can help extend the life of	$1.2M - $120K = +$1M

Improvement Opportunity Alternative Item #	Increased cost per Year	Estimated Cost Assumptions	Estimated Net Operating Cost Savings per Year
Oil Analysis Program for engine, transmission, hydraulic fan drives and differentials		engine and transmissions help reduce the unscheduled repairs by monitoring the condition of oil and lubricants. This will require training and initial investment of an external contract with an oil lab to test the oil condition.	
M4 Reorganize daily servicing of buses	Add 10 service person 10*$120,000 =$1.2M	Modify cleaning service contract of $3.2M (FY15) to eliminate daily cleaning only ($1.6M savings). Net saving $1.6M-$1.2M=$400K.	$1.6M - $1.2M = +$400K
S1 Create a QC section to audit PMIs, CM, material inspection, and warranty recovery.	Create a QC section of 6 staff at $720K	a) Recover 1% of material inventory ($26M) by rejecting defective parts b) Reduce road call failures cost ($250K) by flagging defects in 25% of PMIs c) Reduce corrective maintenance cost ($31.9M) by flagging 5% of workmanship problems	$260K**+$**63K**+**$1,595K= $1,918K-$720K Net**=**$1.198M
S2 Improve warranty recover process by upgrading organization and implementing standard procedures	Add 3 QC Quota at $360K	Recover an additional 3-4% of contract value=$3M 3QC quota at $360K.	$3M - $360K = +$2.64M

Appendix E
Methodology to Estimate Number of Bus Maintenance Bays

Appendix E – Methodology to Estimate Number of Bus Maintenance Bays

E1. Description of methodology

For estimating the required number of standard work bays (pits, hoists, flat/portable lifts) for a bus garage to perform a maintenance program consisting of Preventive Maintenance/Inspections, Running Repairs and Program Maintenance/Campaigns, the following three main methods are available:

1. **The Fleet Management Operating Guide by the National Association of Fleet Administrators:**
   - The guide suggests using as a rule of thumb a ratio of 1.5-2 bays per bus technician/mechanic.
   - This method maximizes the number of bays based on the scenario that down time of actual work can be minimized by having a mechanic work on a second bus while awaiting for parts for the original assigned bus occupying another bay. Based on this rule of thumb an agency with 271 bus mechanics would need as many as 407-542 bays.
   - The CH2M team concluded that this method could produce at times some misleading results because it is mostly based on budgeted manpower. An agency with an old poor performing fleet or with a very low maintenance efficiency would require an extraordinary higher number of bays, an option which is not practical nor realistic.
2. **1994 TCRP Report "Synthesis 7 Regulatory Impact on Design and Retrofit of Bus Maintenance Facilities":**
   - The number of required bays is calculated by multiplying 2.34 bays per million mile of operation and adding a constant of 3.79 bays.
   - Using this method (first published in 1987), an agency operating 24.6 million miles annually would require a total of 61 bays.
   - The CH2M team concluded that this 29 year old method could be slightly flawed as the result is based on the size of the agency and does not accurately reflect the increased and more sophisticated maintenance requirements of today's new technology buses.
3. **Industry Maintenance Repair Units (MRUs):**
   - This third alternate method and the one used by the CH2M team is based on industry maintenance repair units (MRUs) showed in the table below:

	Maintenance Activity	Bay to Buses Ratio (# of buses per bay)	# of Bay per 10 Buses
a.	General Repair	1 bay : 20 buses	0.50
b.	PM / Inspection	1 bay : 50 buses	0.20
c.	Major Repair	1 bay : 60 buses	0.17
d.	Body Repair	1 bay : 75 buses	0.13
e.	Brake Repair	1 bay : 100 buses	0.10
f.	Tire Repair	1 bay : 200 buses	0.05
	Total	**1 bay : 8.7 buses**	**1.15**

- Based on the six maintenance activities and their bay to buses ratio, it yields a ratio of 1.15 bays per 10 buses or 1 bay for 8.7 buses. If we assume a MBTA fleet of 1047 buses (without consideration of various types of buses), a total of approximately 120 bays would be required.

E2. Industry comparison on bus maintenance bays

For validation of the estimated 8.7 ratio recommended by CH2M, we conducted an industry comparison survey on recent construction of various bus facilities with the results listed in the table below:

	Agency	Facility Built Year	Bus to Bay Ratio	# of buses per bay	Bus Fleet	# of Bus Models/Types	# of Bus Technology
a.	NYCT Mother Clara Hale	2014	150 buses / 14 bays	10.71	40’ & 60’; Hybrid	2	1
b.	SEPTA Philadelphia Allegheny	2000	119 buses / 14 bays	8.5	40’ & 60’; Diesel, Hybrid	4	2
c.	SEPTA Philadelphia Midvale	1996	306 buses / 41 bays	7.46	40’ & 60’; Diesel, Hybrid	4	2
d.	MTA Baltimore Kirk Ave	2014	178 buses /15 bays	11.87	40’ 60’; Hybrid	2	1
e.	North County Clarksville, MD		250 buses / 25 bays	10			
f.	WMATA Andrews Federal Center	2019-2020	175 buses / 19 bays	9.21	40’; Diesel , Hybrid	1	2
g.	WMATA Shepherd Parkway	2012	250 buses / 28 bays	8.93	CNG, Diesel, Hybrid	3	3
h.	West OX Fairfax, VA	2009	300 buses / 26 bays	11.54	40’ Diesel	1	1
i.	GRTA Georgia		120 buses / 12 bays	10			
j.	Santa Monica, CA		204 buses / 21 bays	9.71	40’ & 60’; LNG	2	1
k.	CTA 103rd Street, Chicago IL	1988	229 buses / 24 bays	9.54	40’ & 60’; Diesel, Hybrid	4	2
l.	LACMTA Division 13, Los Angeles, CA	2015	200 buses / 19 bays	10.5	CNG		1
			Average	**9.83**			

If calculating the # of buses per bay using the average between MRU ratio of 8.7 and the sampled agencies average ratio of 9.83, it generated a more conservative value of 9.27. This would dictate 113 (instead of 120) bays is required for MBTA bus fleet of 1046 buses (included ETBs), which is still significantly higher than the present 99 MBTA bays.

In conclusion, CH2M considers the number of buses per bay ratio of 9-10 as reasonable for general bus maintenance efficiency review. While other design factors, i.e. bay configuration (pit vs. hoist vs. flat/potable lifts), type of bus (diesel, CNG, hybrid, electric) and size of bus types (standard vs. articulated), are to be considered in the final analysis of the estimated number of work bays, the MRU ratio method is more reflective of actual maintenance activities performed on a generic bus. These other design considerations could also explain why the CH2M ratio is slightly higher than a previously cited MBTA industry average of 7.5 but lower than the sample (above) of 12 recent facilities at 9.83.

CH2M recommends this method as it is founded on valid standard repair times. However, this 8.7 ratio is higher than an industry standard of 7.5 cited in the March 2014 MBTA Bus Facility Analysis.

Appendix F
Glossary

Appendix F - Glossary

C	Completed
CBT	Computer Based Training
CNG	Compressed Natural Gas
CTA	Chicago Transit Authority
DMA	Dual Mode Articulating Buses
ECD	Emissions-Controlled Diesel
ETB	Electric Trolley Bus
FMIS	Financial and Material Information system
FTA	Federal Transit Authority
FY	Fiscal Year
IDCS	Inventory Data Control System
IP	In-Progress
KPIs	Key Performance Indicators
LACMTA	Los Angeles County Metropolitan Transportation Authority
LEED	Leadership in Energy and Environmental Design
MDBF	Mean Distance Between Failures
MBTA	Massachusetts Bay Transportation Authority
MCRS	Maintenance Control and Reporting System
MDT	Miami-Dade Transit
MMBF	Mean Miles Between Failures
MPH	Miles per Hour
MRB	Material Review Board
MRU	Maintenance Repair Units
MTA	Maryland Transit Administration
NABI	North American Bus Industries
NJT	New Jersey Transit
NFI	New Flyer Industries
NTD	National Transit Database
NYCT	New York City Transit
QA/AC	Quality Assurance/Quality Control
OCS	Overhead catenary system
OEM	Original Equipment Manufacturer
OT	Overtime
PM	Preventative Maintenance
RTA	Regional Transportation Authority
RTS	Rapid Transit Series
SEPTA	Southeastern Pennsylvania Transportation Authority

SRTs	Standard Repair Times
TBD	To be Determined
TCRP	Transit Cooperative Research Program
TTC	Toronto Transit Commission
UC	Under Consideration
VAMS	Vehicle Available for Maximum Service
VOMS	Vehicle Operated in Maximum Service
VMI	Vendor Managed Inventory
WMATA	Washington Metropolitan Area Transit Authority