Citizens' Independent Transportation Trust (CITT)
Metrorail Maintenance Assessment

Final Report prepared by

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1 EXECUTIVE SUMMARY

IMG Rebel (hereafter referred to as "the Team") was engaged by the Citizens' Independent Transportation Trust (CITT) to perform an assessment of maintenance and cleaning practices for the Department of Transportation and Public Works (DTPW) Metrorail system. This report outlines the Team's findings based upon analysis of data provided by DTPW, externally available data on cost and performance of other heavy rail systems, conversations over the phone and in person with DTPW staff and leaders, and site visits performed by the Team to Metrorail facilities.

Fleet Availability and Reliability

On-Time Performance/Vehicle Availability

Metrorail has struggled to meet its on-time performance and vehicle availability goals in recent years. It was not able to consistently meet its on-time performance goal of 95% and its peak vehicle requirement of 76 vehicles in 2018. The legacy Budd vehicles did not undergo the recommended mid-life overhaul and are now past their useful life. This drives some of the challenges that Metrorail has experienced, and the introduction of new Hitachi vehicles may only present a temporary solution due to issues affecting the way that maintenance is carried out at Metrorail. A substantial proportion of new vehicles are already experiencing maintenance issues preventing them from being utilized for service, partially due to a spare parts shortage for the new vehicles which must be addressed immediately.

Performance Metrics

Performance metrics are reported regularly by DTPW, but the Team found that such metrics are not closely tied to customer outcomes, some had errors in calculation, and reporting to CITT specifically did not reflect the comprehensive set of measures to which the Team would recommend CITT have access. This report makes recommendations on metrics that should be reported on regularly to ensure adequate oversight and proactive action to ensure Metrorail is performing to the satisfaction of customers and all other relevant stakeholders.

Fleet Maintenance

Preventive Maintenance versus Corrective Maintenance

While preventive (scheduled) maintenance schedules are generally adhered to, corrective (unscheduled) maintenance work orders still represent roughly 50% of all maintenance activity, indicating that preventive maintenance may not be adequately preventing failures. Although DTPW's target is 70% preventive maintenance and 30% corrective maintenance, this goal has not been achieved within the time period for which the Team had access to data.

Asset Management System

Maintenance activities are still recorded in paper forms, preventing the ability for maintenance technicians and supervisors to view past vehicle repair history, analyze trends, and adapt maintenance practices accordingly.

DTPW expects to deploy the Enterprise Asset Management System (EAMS) to Metrorail in the coming years, but the Team has not seen an implementation schedule nor a systematic approach to how EAMS will be used. The Team found in 2018 that EAMS was used essentially as a document management system for Metromover, without the ability to quantitatively analyze trends, hindering DTPW's ability to adequately maintain Metrorail's new vehicles given the complexity of the on-board electronics and various vehicle configurations currently in use. The Team therefore recommends a robust deployment of EAMS that enables trend analysis on failures to inform future preventive maintenance. The Team also recommends that DTPW plan for a mid-life overhaul for new vehicles today instead of closer to when such an overhaul would be required.

Labor Hiring Practices

The labor regulations and agreements currently governing hiring of maintenance employees severely restrict the ability for DTPW to recruit and retain qualified maintenance personnel. Rail maintenance technicians must be hired based upon seniority from the Transportation Workers Union of America (TWU), Local 291. In practice, this means that DTPW is largely limited to hiring maintenance technicians from the pool of bus operators, who generally do not have any experience in the necessary technical areas required for specialized maintenance activities. The Team understands from its conversations with DTPW staff that the majority of maintenance technicians cannot perform technical work independently of significant supervision. Many of the technicians considered "qualified" for the work will be retiring in the coming years, likely exacerbating the shortage of skilled maintenance technicians for Metrorail.

The shortage of qualified technicians may compromise the safety of the Metrorail system. This is especially true for technicians working on safety-critical systems such as train control, on which failures have not been uncommon in recent months. The Florida Department of Transportation (FDOT) triennial review voiced similar concerns based on irregularities in train control records and a lack of minimum qualifications for hiring technicians. Based on these observations, the Team strongly recommends that DTPW pursue the ability to recruit rail maintenance and other skilled positions based on minimum qualifications instead of through a strictly seniority-based method to ensure that skilled and capable technicians are working on mission-critical systems.

Vehicle Cleanliness

While Metrorail stations were found to be generally clean and comfortable, the Team found that vehicle cleanliness is below acceptable standards and is a frequent source of formal complaint to DTPW by customers. This may be driven, in part, by the hiring practices that govern cleaning staff, as vehicle cleaners are subject to the same TWU bargaining agreement as other rail maintenance staff. Cleaner attendance has been a frequent problem, with roughly 10% of scheduled staff showing up for the 8pm to 4am night shift in recent months, during which vehicles are cleaned for the following day's service. The Team recommends that DTPW outsource vehicle cleaning or vehicle cleaners be recruited externally to attract motivated employees who will consistently attend their scheduled shifts. More cleaners should also be assigned to mainline cleaning at terminals, given the Team's observation that vehicles frequently become unclean during service.

Budget/Cost:

Metrorail's O&M costs are generally in line with peers, which indicates that Metrorail's O&M spend is not unreasonable when compared with peers. However, the Team observed that actual spending has typically outstripped budget, occasionally by a substantial margin (e.g. $29 million actuals versus $16 million budget in FY17-18). Moving forward, the Team recommends setting realistic budgets that reflect prior years' actuals.

Summary

DTPW's Preventive Maintenance and Cleaning Program appears to be carried out as scheduled. However, the Team's assessment concludes that all four primary components (1. Fleet Availability & Reliability; 2, Fleet Maintenance, 3. Rolling Stock Comfort and 4. Cost of Operations & Maintenance) have room for improvement. The shortage of qualified staff for mission-critical systems (Train Control, Traction Power, and Vehicle Electronics) may compromise the safety of the Metrorail system. Additionally, current maintenance practices drive inefficiency in both long-term cost and system performance. The Team has offered several recommendations in this report to mitigate concerns raised.

2 METHODOLOGY

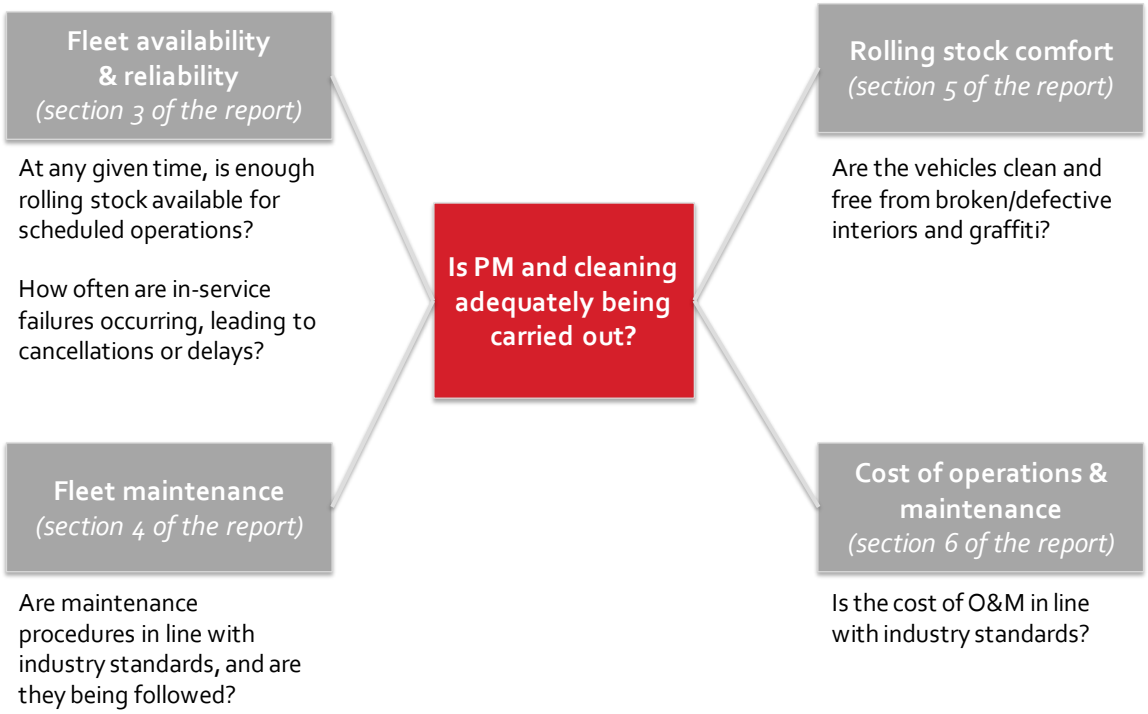
2.1 Scope of Work

The IMG Rebel Team (the Team) was engaged by the Citizens' Independent Transportation Trust (CITT) to review and analyze the Department of Transportation and Public Works (DTPW) Metrorail maintenance practices, answering one primary question:

Is preventive maintenance and cleaning of Metrorail vehicles being adequately carried out?

In answering this primary question, the Team has identified four main contributors and the supporting questions for each of these contributors in *Figure 1* below.

Figure 1: Primary question and supporting questions



In order to answer the above questions, the Team's scope of work was as follows:

1. Review vehicle and infrastructure maintenance best practices
    a. **Manuals and procedures**: The Team reviewed established manuals and practices for Metrorail's vehicles, including both its vintage Budd fleet and new Hitachi fleet

b. **Assess planning cycle for scheduled activities**: The Team looked at preventive maintenance inspection cycles and evaluated whether they were being adhered to as well as adequate for keeping vehicles, infrastructure, and systems in a state of good repair.
c. **Assess common repair activities and responses**: The Team reviewed common causes of failures and how frequently maintenance activities were scheduled versus corrective to determine the adequacy of preventive maintenance activities in mitigating against unforeseen maintenance issues
d. **Cleaning procedures**: The Team evaluated vehicle cleaning procedures and how cleaning is supervised / audited to ensure cleaning is being performed, in addition to reviewing customer complaint data for common cleaning issues

2. Review sample fleet and infrastructure

The Team randomly selected vehicles from both the Budd fleet and the new Hitachi fleet to review maintenance records and determine adherence to preventive maintenance protocols. The Team also assessed the ability of maintenance supervisors and Department of Transportation and Public Works (DTPW) leaders to analyze maintenance and parts failure trends using existing record-keeping practices.

3. Carry out peer analysis exercise

The Team performed a peer benchmarking exercise using data from the National Transit Database (NTD), prepared by the Federal Transit Administration (FTA), on a variety of performance benchmarks to evaluate fleet reliability, availability, maintenance cost, and maintenance staff productivity. The Team compared Metrorail to a group of 8 peers across the United States (Baltimore Metro, BART, GCRTA, LA Metro, MARTA, PATCO, and SEPTA) and one international city (Rotterdam, Netherlands) with a similar-sized system.

4. Prepare report and presentation

The Team is preparing this report to summarize findings from analysis of the documentation and data provided by DTPW, conversations (both in-person and over the phone) with DTPW staff, and observations from site visits to the Lehman Center, select stations across the Metrorail system, and riding Metrorail trains over the course of four days.

CITT and DTPW will review and comment upon this report, and the Team will incorporate this feedback into the final report.

2.2 Data gathering methods

The Team relied upon three primary methods of data gathering: 1) requesting documentation and data from DTPW 2) holding conversations with DTPW staff 3) observations through site visits to Metrorail facilities, stations, and trains.

Documentation and data from DTPW

The Team requested a variety of documentation and data from DTPW stakeholders in Performance Analysis, Rail Maintenance, and other relevant teams. The topics covered in this data request included budget, vehicle maintenance, fleet availability, service performance, spare parts availability, new vehicle deliveries, labor agreements and county regulations, customer complaints, and cleaning procedures, among others.

The Team reviewed this data and documentation in order to draw preliminary conclusions and to most productively utilize on-site time, as described in a subsequent paragraph.

Lastly, the Team supplemented the documentation and data provided by DTPW with data from the National Transit Database (NTD) to perform peer benchmarking analysis, comparing Metrorail's performance across key maintenance and cost metrics to relevant peers.

Conversations with DTPW staff

The Team held phone conversations with seven key DTPW stakeholders across relevant departments in February and early-March 2019. During these interviews, the Team discussed a variety of topics, including maintenance practices, hiring, and qualifications of maintenance and cleaning staff, disciplinary procedures, absenteeism, recent maintenance performance, commissioning of new vehicles, future plans for maintenance and asset management, security, and others.

The Team supplemented these phone conversations with in-person conversations on March 18th and March 19th, 2019 with the same DTPW stakeholders as well as others with whom the Team had not yet spoken. The Team used both phone and in-person conversations to draw new conclusions and validate previous conclusions drawn from initial documentation and data review.

Observations during site visits to Metrorail

The Team visited Metrorail's facilities and stations and rode on trains over the course of a four-day visit, with primary observations taking place on March 18-19, 2019.

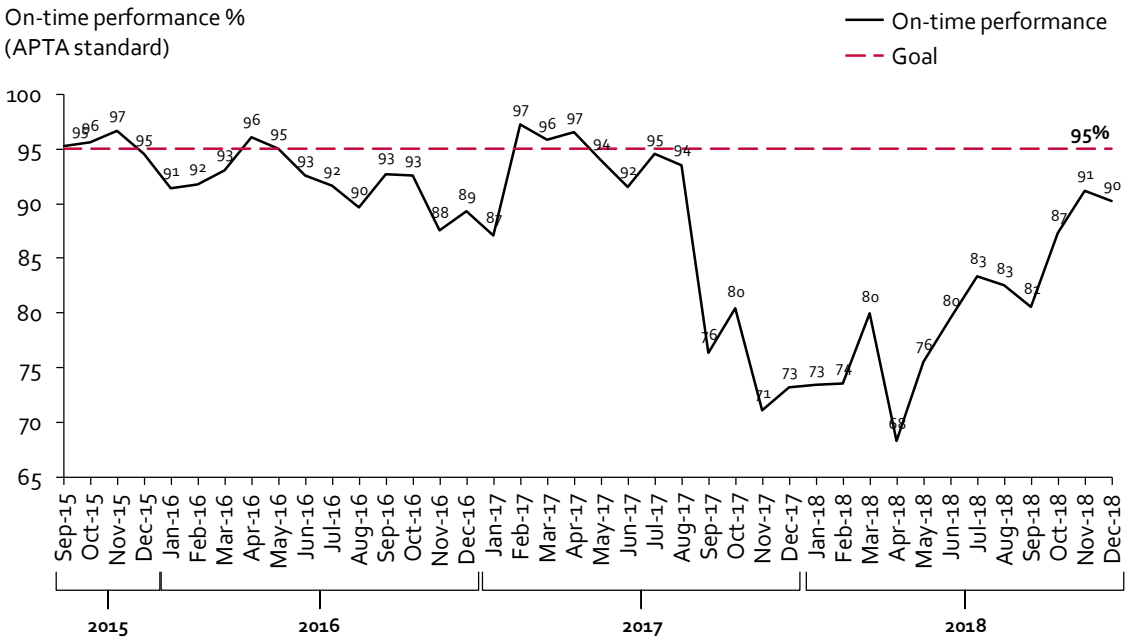
During the site visits, the Team inspected Lehman Center facilities, including the new vehicle commissioning area, the vehicle cleaning area, the maintenance garage, parts store, control tower, and other areas.

The Team also visited a variety of stations across the network and rode the system from beginning to end, inspecting stations and the interior of trains for cleanliness and maintenance.

3 CURRENT FLEET AVAILABILITY AND RELIABILITY

3.1 Service Availability

Figure 2: Metrorail on-time performance



Metrorail's on-time performance generally lagged behind its goal of 95% from late 2017 through 2018. *Figure 2* displays on-time performance at monthly intervals since September 2015.[1] Over the last three years, on-time performance was consistently above 90% but deteriorated in late 2017 and throughout 2018. This may be driven by mechanical issues affecting Metrorail's aging Budd vehicles, and the introduction of Hitachi vehicles throughout 2018 helped Metrorail increase on-time performance target later in the year, though Metrorail still failed to meet its 95% goal for any month in 2018. This data is based on the American Public Transportation Association (APTA) standard of counting a scheduled service as being "on time" if it arrives no more than 5 minutes later than its originally scheduled arrival time at the destination (or end-) station.[2]

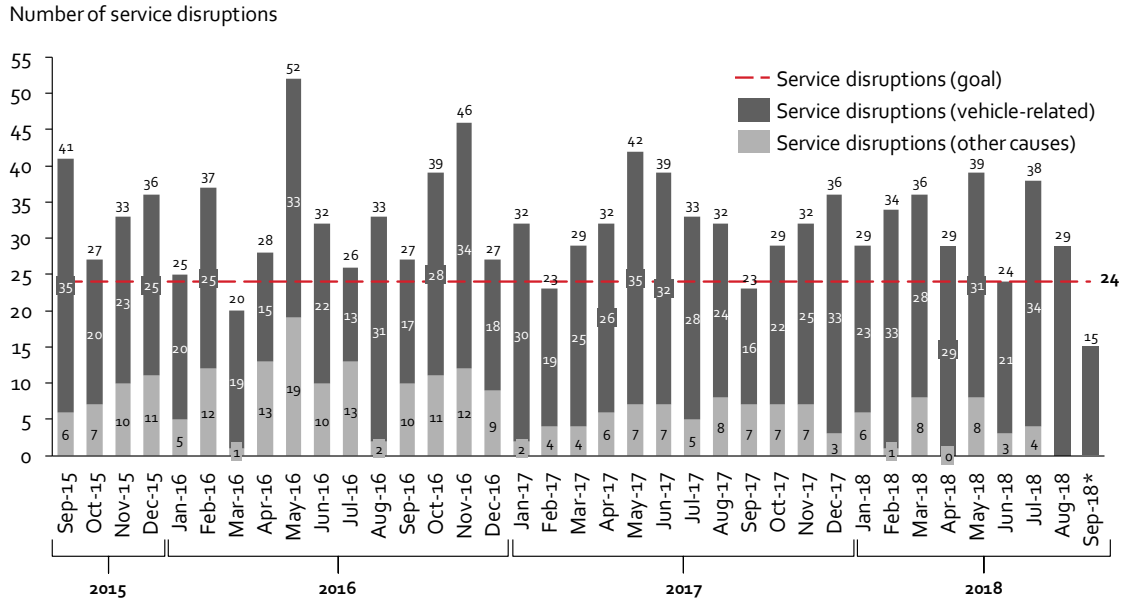
[1] Taken from "Metrorail Summary" pages of the Transit Service Monthly Report.

[2] Definition from "Comparison of Rail Transit Vehicle Reliability Using On-Time Performance" - APTA. https://www.apta.com/resources/standards/Documents/APTA-RT-VIM-RP-024-12.pdf.

Metrorail is currently changing over from its legacy Budd cars to a new Hitachi fleet and, during this period, the usual ways of doing business and measuring results must be modified. As the new vehicles are delivered, tested, and accepted into service, Hitachi personnel are involved in maintenance as procedures are adjusted and standardized and Metrorail personnel trained. Old vehicles are either being refitted and maintained to compose a 40-car contingency fleet, given the minimum amount of attention to keep them in safe operation until they are removed from service, or immediately pulled from service for scrapping. As is always the case with the acceptance of new fleets, Metrorail and Hitachi are discovering and responding to novel issues, which creates the need to change designs for vehicles on the assembly line, update those already received, cope with spare parts shortages, update procedures, and work with multiple configurations of vehicles on the property while upgrades are made. Therefore, this period of changeover will also influence vehicle availability.

On-time performance can be driven by a variety of factors, but this report focuses on drivers related to maintenance adequacy and vehicle availability. For instance, higher vehicle availability can bolster on-time performance, as in-service vehicles that fail can quickly be replaced by other available vehicles. Vehicle availability is, in turn, driven by the adequacy of maintenance procedures, the execution of such procedures, and the availability of spare parts, among other factors.

Figure 3: Service disruptions, all causes versus target[3]



*All-cause disruptions reported for Aug-Sep. '18 are lower than vehicle-born disruptions, indicating miscalculation in reported data

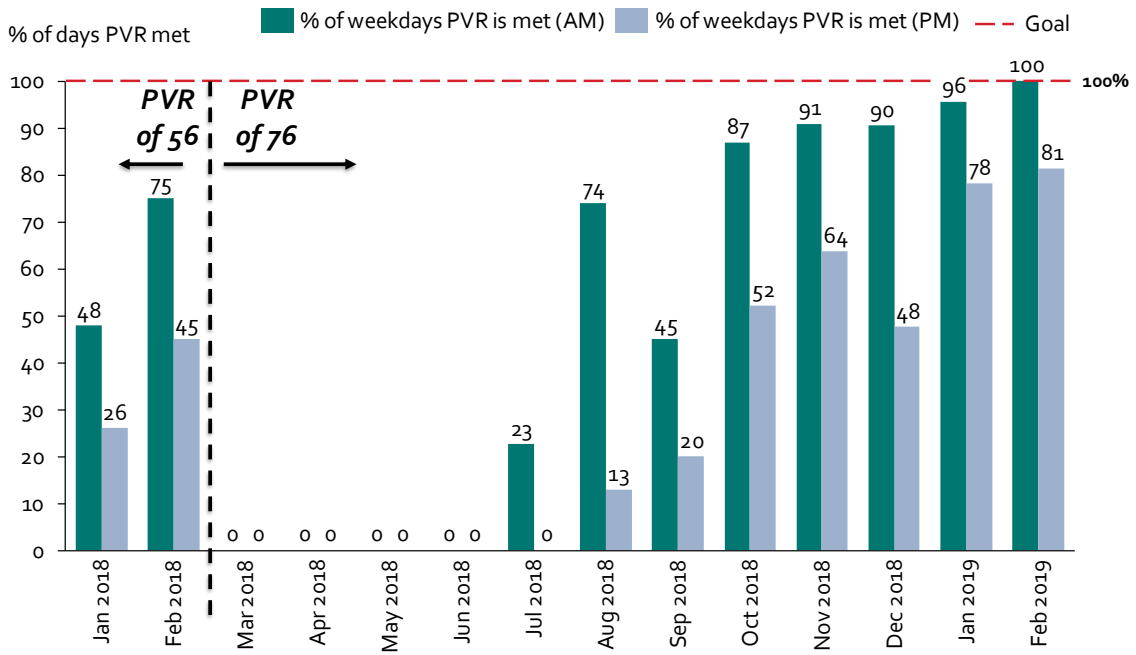
However, on-time performance may not be the best indicator for passenger experience in a system where passengers come to a station and take the first available train. In heavy rail systems, such as Metrorail's, most passengers do not check the timetable beforehand but instead arrive at a station and board the next train available; consistency of headway, the interval between trains, is more important. More relevant indicators would therefore be the actual headway between services and the number of service disruptions. For the first, relevant data was not available to the Team. For the latter, realized performance is shown in *Figure 3*.[4] Vehicle-related causes include mechanical failures on vehicles, while other causes can include passenger medical emergencies, police activity, and train control issues. Moving forward, the team recommends tracking additional service performance metrics, further described in section 7.

[3] The Team noticed two possible errors in monthly reporting. Firstly, service disruptions per 1,000 miles were sometimes reported higher than total service disruptions, indicating an error in calculation. This was corrected in an Excel spreadsheet provided to the team. However, the number of vehicle-born service disruptions reported has sometimes been higher than the number of all-cause service disruptions, for instance in August-September 2018, which would not be possible given vehicle-born disruptions are a sub-set of all-cause disruptions.

[4] Taken from "Metrorail Summary" pages of the Transit Service Monthly Report.

3.2 Vehicle Availability

Figure 4: Percentage of weekdays peak vehicle requirement (PVR) met[5]



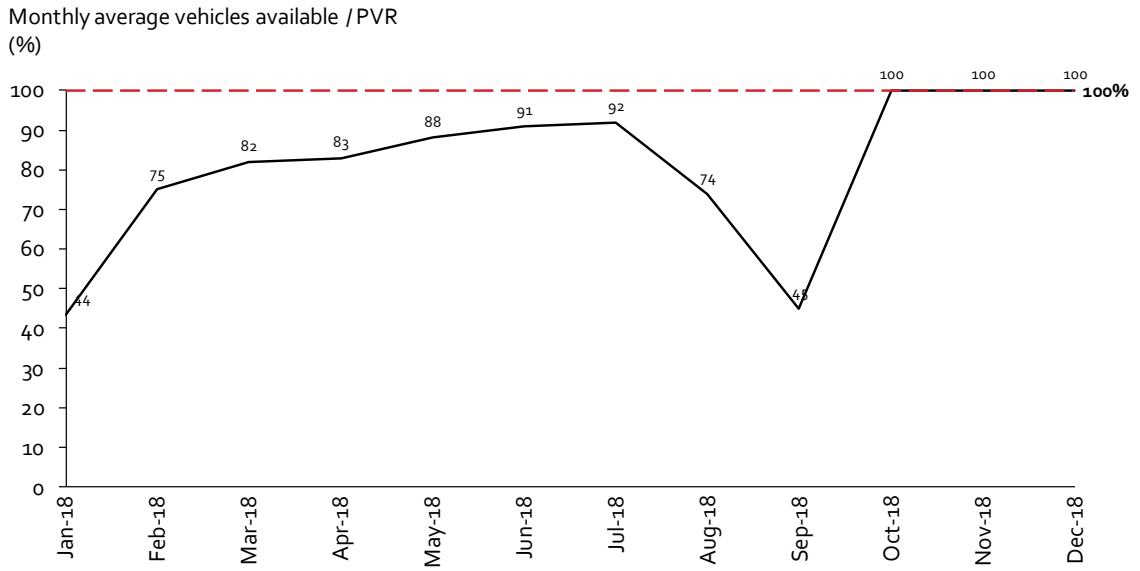
Metrorail has also struggled to maintain enough vehicle availability to meet peak vehicle requirement (PVR) over the last 14 months. In early 2018, Metrorail ran reduced service of 14 peak hour trains on working weekdays (4 cars per train set), requiring 56 vehicles. As seen in *Figure 4*, even with this reduced standard, Metrorail was only able to deliver enough vehicles to meet PVR between 48% and 75% of weekdays for AM service in January-February 2018.[6] It was able to meet this standard less than half of the time for PM weekday service. Moreover, peak vehicle requirement increased to 19 trains (76 vehicles) in March 2018. For four straight months (March through July 2018), Metrorail was not able to deliver 76 vehicles for weekday revenue service (either AM or PM) even once. The Team believes that the goal for "% of days PVR met" should be 100%, meaning that enough vehicles are available to meet PVR on every weekday in a given month. Looking at vehicle availability another way in *Figure 5*, Metrorail has delivered for service an inconsistent number of vehicles in 2018, with mean vehicle availability as a percentage

[5] Calculated by identifying the number of weekdays in each month that PVR is met (separately for AM and PM service) and dividing that number by the total weekdays in that month.

[6] Derived from "Metrorail Availability 2018" Excel workbook provided by DTPW.

of PVR ranging from 44% to 100% during AM peak weekday service.[7] This does not appear to be driven by a shortage of total vehicles, as Metrorail has aimed to keep a fleet of 136 vehicles on-property throughout 2018, according to data provided to the Team.[8]

Figure 5: Mean vehicle availability (AM peak weekday)[9]



The delivery of new vehicles has increased Metrorail's ability to meet PVR in recent months, but this may be a temporary solution. Starting in August 2018, vehicle availability has steadily increased to meet PVR more frequently during weekdays, both for AM and PM peak service. In the most recent month for which data is available (February 2019, through 2/22/2019), Metrorail was able to run at least 76 vehicles for 100% of weekday AM service, but it still lags in PM peak service. Also, as seen in *Figure 6*, a substantial proportion of new vehicles are already unavailable for service due to a variety of maintenance issues, including wheels wearing prematurely on many new vehicles.[10] The Team heard anecdotal evidence that wheels were wearing down within six months instead of the six years expected in the recommended preventive maintenance

[7] Taken from "Metrorail Summary" pages of the Transit Service Monthly Report.

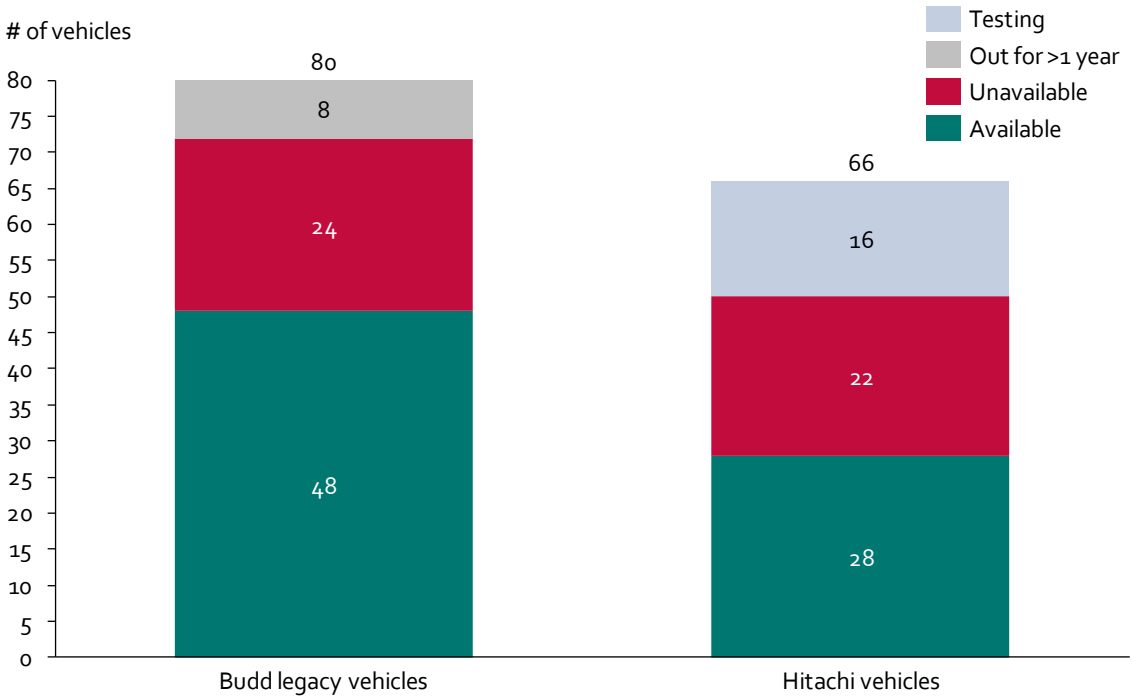
[8] Taken from "Metrorail Availability 2018" Excel workbook provided by DTPW.

[9] Calculated by taking the average number of vehicles available on a daily basis for AM service within a given month and dividing it by the PVR for that month. Reporting for mean vehicle availability was changed in FY18-19 to "Average Trains Available at Peak" (separately for A.M. and P.M.). DTPW reported at least 19 trains available out of 19 trains required for peak service in October-December 2018.

[10] Derived from "Metrorail Fleet Status Report" sent on March 18, 2019.

schedule (though this is expected to be addressed in software updates controlling braking).[11] Therefore, it is possible that, with the eventual phasing out of the old fleet, there will eventually be similar vehicle availability challenges within the new fleet. A recent shortage of spare parts for new vehicles, discussed later, may contribute to future vehicle unavailability.

Figure 6: Fleet availability on March 18, 2019



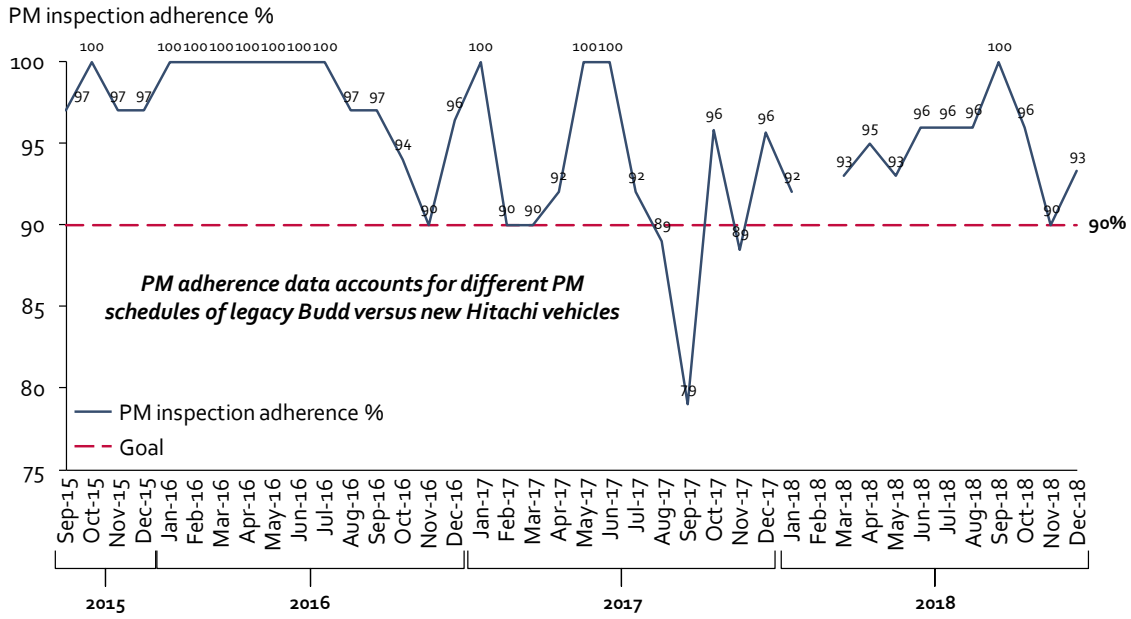
[11] Hitachi Friction Braking System Running Maintenance and Service Manual (M654-10-RMSM rev. 01) – page 82.

4 FLEET MAINTENANCE

4.1 Adherence to manuals and preventive maintenance schedule

PM schedules and inspection checklists are generally adhered to. For the preventative maintenance of the fleet, Metrorail defined a set of periodic inspections, in line with common practice in the industry. Four inspection types were defined: A, B, C and D, with overlapping frequencies resulting in the old fleet receiving an inspection every 60 days.

Figure 7: Rail vehicle PM inspection adherence[12]



The scheduling of these inspections is time-based, with a do not exceed mileage. This method is used to prevent scheduling of PM work for many vehicles simultaneously, and the do not exceed mileage is rarely reached according to DTPW. Review of the inspection reports confirms that, in general, the PM schedules are adhered to. *Figure 7* displays PM adherence.[13] As displayed, DTPW generally meets its target of completing 90% of preventive maintenance work orders on rail vehicles and it is currently reviewing how to address "deferred" PMs in a codified manner.

[12] The data point for February 2018 was not available in the "Metrorail Summary" page of the Transit Service Monthly Report for that month.

[13] Taken from "Metrorail Summary" pages of the Transit Service Monthly Report.

For the new fleet, the inspection terms during the warranty period are shorter, resulting in the Hitachi fleet receiving an inspection every 45 days. All inspections are carried out using fixed checklists with clearly defined requirements per type of inspection. The inspection checklists are linked to the maintenance manual (see section 4.2 for new fleet). The forms are completed in hardcopy by the maintenance team and signed off by the superintendent.

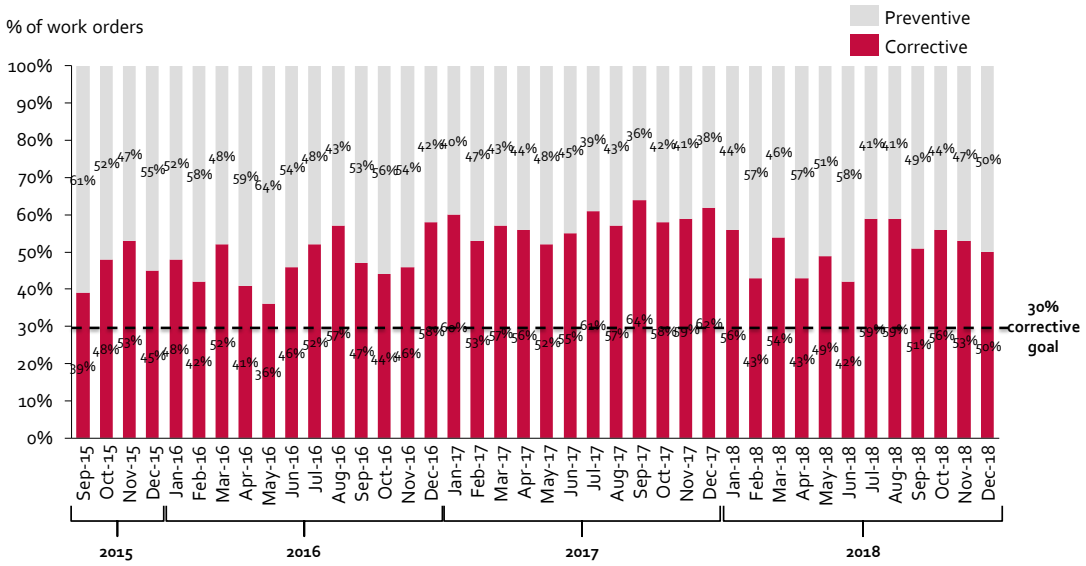
During the inspection, small repair activities are carried out, and if a repair is too lengthy or spare parts are missing, a vehicle maintenance request (VMR) is made. The severity of the issues in the VMR determines if a vehicle can be returned into service with the repairs being carried out later or if the vehicle is put out of service until repair can be completed. DTPW staff indicated that the possible conditions keeping a railcar from entering service are many, and the supervisor and the Chief Supervisor in Rail Maintenance make the final determination, based on their experience.

Completed PM inspection forms are still stored in hardcopy paper form, with only a high-level summary of the inspection stored in an electronic database. The consequence is that there is only limited capability to perform data and trend analysis on maintenance activities. It also means that when vehicles come in for preventive maintenance, the maintenance history of a given vehicle is not readily available and that this history is not taken into consideration when doing inspections, for instance to check if previous failures on the vehicle are recurring again. The Team's understanding is that most major transit agencies in the United States have already begun using electronic-based work orders for maintenance.

DTPW staff informed the Team that the FTA Triennial Review contractor suggested the FTA requires all maintenance tasks to be documented on signed paper documents. The Team had never heard of this requirement and, upon checking with FTA officials, in the FTA Region IV Office of Oversight & Program Management, we were informed that, "Our guidance is not specific on the format for the records".[14] The Team suggests that Metrorail personnel confer with this office to confirm FTA maintenance record keeping requirements prior to revising the design of Metrorail's maintenance system.

[14] Telephone and e-mail exchanges with John Giorgis, FTA official responsible for Transit Asset Management, and Ms. Sandberg, March 25-26, 2019.

Figure 8: Preventive maintenance vs. corrective maintenance repair work orders[15]



A substantial proportion of maintenance work is corrective maintenance, meaning preventive maintenance may not be preventing a variety of failures. Metrorail targets 70% of work orders to be preventive, but as *Figure 8* demonstrates, roughly half of maintenance work orders are corrective.[16] This does not appear to have reduced significantly after new vehicles delivery began in late-2017, though data to determine more recent trends was not available to the Team. DTPW must actively strive to meet its 70% goal, which will reduce in-service failures that cause a negative passenger experience. An ideal target would be to aim for 80% preventive and 20% corrective maintenance, as best practice guidelines from research referenced by the Transportation Research Board (TRB) suggest, given the finding that every $1 in preventive maintenance costs today prevents $3 in later corrective maintenance costs.[17] Therefore, investing in PMs may increase spending today but will reduce longer-term maintenance costs and may result in improved ridership.

[15] The FTA's "2018 Triennial Review – Miami-Dade DTPW" states that "campaign" maintenance work is currently classified under corrective (unscheduled) maintenance, which would be better classified as preventive (scheduled) maintenance. Such a reclassification could present a more accurate picture of the split between preventive vs. corrective maintenance.

[16] Taken from "Metrorail Summary" pages of the Transit Service Monthly Report.

[17] Preventive and corrective maintenance – cost comparison and cost–benefit analysis. *Structure and Infrastructure Engineering*, Vol. 12, Issue 5. May 2016. https://trid.trb.org/view/1398000.

4.2 Vehicle mid-life overhaul

Mid-life vehicle overhauls form an important component of ensuring that vehicles achieve their maximum useful life. DTPW made the decision in the early 2000s to forego a mid-life overhaul for its Budd vehicles after performing a lifecycle cost analysis to compare the cost of overhauling old vehicles versus procuring new vehicles.[18] However, while the Team has not seen the results of this analysis, the Team has observed the reliability issues that have significantly affected availability of Budd vehicles today. While the financial cost of such reliability issues is not quantified in this report, the Team does note that the unavailability of many Budd vehicles has reduced Metrorail's service reliability. Therefore, there is a "cost" to system performance due to the absence of a mid-life overhaul program for the Budd vehicles.

Moving forward, DTPW should consider designing a mid-life overhaul program for new vehicles at the beginning of the vehicles' lifecycle. This would help to ensure lower effort required in 15 years when the time comes to develop an RFP and other relevant elements of an overhaul program. The FTA's Triennial Review also notes that the benefits of a mid-life overhaul program should be evaluated, in conjunction with development of an asset management plan that utilizes life cycle engineering techniques.[19]

4.3 Manuals for new fleet

Inspection forms for the new fleet are based on draft maintenance manuals, which are not in line with actual vehicle configurations. While inspection forms for the old fleet make clear references to the respective chapters in the Budd vehicle maintenance manuals, such references do not currently appear on the inspection forms for the new Hitachi fleet. This makes it more difficult for the maintenance team to link inspection requirements as indicated on their forms to the detailed description in manuals, potentially limiting the effectiveness of maintenance activities on new vehicles. The explanation given for this omission is that new vehicle manuals are still in draft form, even though the first new Metrorail vehicles were delivered to DTPW in 2017. DTPW has indicated that, while the manuals currently being used are the latest revisions, they will be revised and approved every 180 days until issuance of the Acceptance Certificate

[18] "FTA Research – Managing Railcar Maintenance". September 2013. https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Report_No._0043.pdf

[19] FTA 2018 Triennial Review.

indicating all new vehicles have been accepted and all associated work, including 5-year warranty work, has been completed.[20]

Of particular concern is the fact that the manuals and inspection forms do not account for the different vehicle configurations currently in use. Differences in vehicle configurations are common practice; when a new vehicle is being tested, results may prompt changes in vehicle design, which may then lead to manufacturing and assembly changes for subsequent units. The goal in the delivery process is that configuration changes are confined to a limited number of vehicles in a "test fleet", though the size of the test fleet is usually greater if the vehicles are new to the industry without prior use at other transit agencies, as is the case with Metrorail's Hitachi vehicles. It is not uncommon to have multiple versions of the new vehicles on hand for a period of time until upgrades can be made to all the vehicles that were produced at different points in the production schedule. Given that Metrorail continued taking delivery of new vehicles throughout its test program, configuration changes were made more gradually, resulting in a large proportion of vehicles having different configurations from each other. It is currently unclear how each specific vehicle is configured, and the Team's understanding is that each vehicle's modified configuration is mainly tracked on an Excel spreadsheet maintained by external contractors, accessible to DTPW, in addition to a car-specific "Car History Book". However, as draft manuals and inspection forms may not account for each vehicle's specific configuration, effective preventive maintenance is difficult, and the risk of vehicle failure increases. This means that, today, it is difficult to assess if Metrorail is maintaining its new vehicles according to one, final maintenance protocol.

4.4 Asset management practices

With the passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21), each FTA grantee transportation agency must develop a risk-based Transit Asset Management Plan. This plan must "report on the condition of the system of the recipient and provide a description of any change in condition since the last report; establish an analytical process or decision support tool for use by public transportation systems that allows for the estimation of capital investment needs of such systems over time and assists with asset investment prioritization by such systems".[21]

[20] The Team confirmed this in the agreement between Miami-Dade County and AnsaldoBreda (Hitachi) for delivery of the new Metrorail vehicles.

[21] https://www.govinfo.gov/content/pkg/BILLS-112hr4348enr/pdf/BILLS-112hr4348enr.pdf.

DTPW has recently developed its first Transit Asset Management (TAM) Plan, which appears to be well structured.[22] DTPW's TAM includes an explanation of the system layout, life-cycle management, risk management, performance targets, and a robust gap analysis. It contains the parts required in a strategic asset management plan in compliance with international standards on asset management, although identification of specific individuals responsible for implementation and mapping of activities to broader organizational objectives is missing – currently, the "recommended implementation team" for each activity is vague, identifying stakeholders such as "Asset Program Team" and "Asset Owners". Prior to the MAP-21 legislation, DTPW had been in the process of introducing its Enterprise Asset Management System (EAMS) to additional parts of its operations.

However, the current plan for EAMS does not appear to include asset management best practices that will be required for proper maintenance of the new vehicle fleet. DTPW is starting EAMS implementation for Metrorail this year, although a realistic implementation schedule is missing. The Team has noted that this implementation is driven by the desire to improve record keeping rather than to improve asset management and maintenance capabilities. The lack of stakeholder analysis and connection with organizational objectives in the TAM plan makes it unclear for both IT and maintenance staff what EAMS implementation should look like, and who should be leading design of EAMS for Metrorail specifically. Current plans call for similar EAMS capabilities to what is used for Metromover. However, in reviewing preventive maintenance for Metromover in 2018, the Team found that EAMS is essentially used as an electronic document management system. Inspection forms are stored in PDF form, with limited ability to analyze trends, such as parts failure history for a specific vehicle, which would enable supervisors to verify the effectiveness of past maintenance. Such data would help to inform future preventive maintenance activities and prevent failures. Simple electronic document filing is inadequate for best practice asset management, especially in light of the complex electronic systems inside Metrorail's new vehicles, which may require more frequent inspection and analysis of failure trends to ensure preventive maintenance activities continue to be effective in the future.

DTPW should clarify with the FTA if hard copy retention can be replaced with electronic retention. As mentioned in section 4.1, Metrorail was told by FTA that it must retain hard copies of all maintenance records, which makes electronic data storage — beyond storing PDFs — difficult. In the Team's experience and its FTA officials, it did not find any official policies requiring such retention requirements. The Team recommends that DTPW clarify this, possibly with the respective FTA regional office with whom it coordinates. DTPW could enter the maintenance

[22] https://www.miamidade.gov/transit/library/mdt-tam-july-2018.pdf.

reports into an electronic system and, in parallel, continue to produce hard copy reports and scan them into the EAMS system. This is redundant and not cost-effective for the long-term. However, in the short-term it will help DTPW to establish electronic data for the new vehicles at the beginning of their lifecycle, creating a strong foundation for their maintenance history.

4.5 Availability of spare parts

Spare parts availability has been a recurrent problem for the old fleet, and there are only limited spare parts available for the new fleet currently. Obsolescence is a common problem in the industry for aging assets. Metrorail's experience with its nearly 40-year old Budd vehicle fleet is no different, and availability of spare parts for these vehicles is increasingly low, although cannibalization of retiring vehicles and last-chance ("close-out") orders of certain parts is helping to alleviate a parts shortage currently. The FTA's Triennial Review also highlights the issue of parts for the Budd vehicles, suggesting the "lack of availability of parts no longer produced by equipment suppliers delays corrective maintenance (repair) work and holds vehicles out of service for longer periods, further impacting vehicle availability".[23] For the Hitachi fleet, spare parts are yet to be delivered by the manufacturer, though the Team's discussions with DTPW indicate that Hitachi is obligated to deliver $18 million in spare parts as part of its contract. In recent instances where parts have been urgently needed, Hitachi has taken parts from its manufacturing line to keep delivered vehicles operating, but it is possible that such a practice could delay manufacturing of future vehicles, and once all vehicles are delivered, this will no longer be feasible. Overall, the parts shortage for Hitachi vehicles is a major concern for the maintenance team, as performing maintenance is not possible without having adequate spare parts.

4.6 Maintenance labor practices

DTPW has great difficulty in filling Metrorail vehicle maintenance positions with properly-qualified long-term employees. This is due, in large part, to one of the most restrictive bargaining unit agreements and recruitment practices that members of the Team have encountered in their experience with a variety of transit operators. The availability of qualified maintenance staff will likely grow worse in the years to come, given upcoming retirements of veteran technicians and mechanics. Metrorail skilled maintenance positions require years of training and experience for incumbents to develop the skills and experience necessary to perform work independently. The traditional electromechanical skill set is still required on Metrorail's new fleet, but knowledge of computer electronics/software/firmware will become more important.

[23] FTA 2018 Triennial Review – Miami-Dade DTPW.

Metrorail is currently in a key changeover period as its new rail vehicles are being delivered and placed into service.

The bargaining unit agreement with Transportation Workers Union of America, Local 291, AFL-CIO (TWU), as it is currently interpreted, controls the hiring process. Every labor bargaining agreement requires the agreement of both labor and management to come into existence and to be changed, subject to requirements of federal law, state statutes, and case law developed by courts and through arbitration.

An ideal situation for rail transit maintenance positions (also applicable to those of other transit modes) would include:

- Detailed job descriptions and minimum qualifications for applying for employment
- A well-designed and executed testing, interview, and reference checking process for applicants
- Competitive compensation and benefits package
- A career path that builds from entry-level positions through training and experience to higher levels of responsibility, first-line supervisor positions, and on to higher levels of management
- Close monitoring of individual performance through a well-designed and properly utilized maintenance information system, preferably real-time and readily accessible to both staff and supervisors at all levels, displaying everything from component status on individual vehicles through to fleet-wide summaries
- Working with technical training institutions to include Metrorail's specific requirements in their training programs, both to develop a pipeline of qualified applicants and for existing Metrorail employees to attend such institutions to gain the skills that are needed to apply for skilled maintenance positions.

While no agency has all of the above, DTPW currently has none of them. It must currently recruit for skilled maintenance positions from existing TWU members, with applications considered strictly based on seniority. The Team's understanding from conversations with DTPW is that most applicants for Metrorail skilled maintenance positions are long-term bus operators who generally do not have any experience in the necessary technical areas required for specialized maintenance activities, which are becoming increasingly complex on the electronics systems present in the Hitachi vehicles. The current TWU bargaining agreement prohibits hiring from the outside for these positions, and there are no minimum qualifications. While it is common for bargaining units to have contract provisions that provide paths for their members for upward mobility, having no minimum qualifications for such positions is uncommon. DTPW has one bargaining unit for both its vehicle operators and maintenance employees, while many other transit operators have separate bargaining units for these skills. This generally means, for

those agencies with maintenance position-specific bargaining units, that even the represented employees applying for skilled maintenance roles have at least the basic necessary skills to maintain vehicles and systems as well as an interest in the field.

Metrorail's need to hire from TWU membership by seniority also creates unpredictability in keeping maintenance worker and other positions filled. At Metrorail, it is common for candidates to begin the training for maintenance positions and either drop out to return to their former position or fail the test upon training completion (although many are ultimately successful on retesting after remedial training). Almost all of these high-seniority applicants are relatively close to retirement, and it is very common for them to stay as maintenance employees for only five years, which also means that DTPW has fewer first-line and mid-level managers who begin internally as mechanics and gain detailed hands-on knowledge before applying for promotion to management positions. Consequently, DTPW is repeatedly recruiting and training new mechanics, most of whom never achieve the desired level of proficiency to allow them to work independently on difficult maintenance tasks. While DTPW waits for months to determine if employees-in-training will fill permanent positions, it is unable to backfill bus operator or other positions that employees left behind because many maintenance candidates later elect to return to their former positions. There are cases where an employee has changed positions multiple times over a period of years, which can further complicate trying to keep each function fully staffed, leading to large amounts of overtime and budget requests for additional staff positions in order to maintain minimum levels of staffing. The pattern of DTPW only employing senior TWU members in Metrorail positions also increases the costs of maintenance. TWU positions have a multi-step salary scale, and Metrorail maintenance positions are concentrated at the high end of this scale. When these high-step maintenance employees leave, they are replaced with those who are also at or near the top end of the scale.

One of the most important aspects of current DTPW labor practices can be traced to what is commonly known as "Section 13(c)". This refers to the relevant section of the Urban Mass Transportation Act of 1964, as amended, when it first became law. Although this has since been recodified as 49 USC 5333(b) Labor Standards[24], the section is still most commonly called "13(c)". Section 13(c) came into existence at the beginning of the federal transit grant program as national and local transit bargaining units were concerned about both loss of jobs and loss of legal protection related to wages, benefits, and working rules. DTPW's current 13(c) agreement was developed in connection with federal capital grants that were made for buses and for

[24] http://uscode.house.gov/view.xhtml?req=(title:49 section:5333 edition:prelim) OR (granuleid:USC-prelim-title49-section5333)&f=treesort&edition=prelim&num=0&jumpTo=true

construction of Metrorail and Metromover. This was followed by updates to the original 13(c) agreement, bargaining unit agreements, and arbitration.[25]

The ability for senior bus operators to shift to higher-paid rail maintenance positions toward the end of their career is, in part, due to the 13(c) agreements made with TWU. This is not likely to be changed as, barring major changes in federal law and/or case law, changes can only occur through the labor negotiation process.

Due to current labor arrangements, the current capability of Metrorail maintenance staff to perform their responsibilities is already limited, but it is likely to worsen over the coming years. DTPW still has a limited number of senior maintenance employees who were hired into maintenance positions within a few years of Metrorail's inception and now have decades of experience and the ability to work on complex maintenance tasks. This is thanks to a roughly 12-year period during which DTPW was able to hire rail maintenance staff from outside TWU. In the February 28, 1978 MDT 13(c) agreement with TWU, the governing language became, "All other jobs were to be filled by employees who were represented by the union, *wherever possible*" (*emphasis* added), which meant, "In essence, first opportunity for new jobs was restricted to comparable jobs."[26] However, in a 1990 arbitration, "The arbitrator also found that bargaining unit members who are qualified *or can become qualified* (*emphasis* added) get the jobs. They do not have to be the 'best' qualified."[27] Between these two events, DTPW had the opportunity to hire from outside TWU for new positions after TWU members were given their first opportunity to apply; after, DTPW was restricted to recruiting from the TWU ranks. The last of these pre-1990 hires, made going on thirty years ago, are nearing normal retirement age. Most of these employees will retire in the next 5-10 years.

4.7 Safety and reliability implications

As a result of current labor practices, Metrorail is short of qualified maintenance employees, compromising the safety of the system. Passenger rail systems are generally considered safer than driving, walking, or cycling in US cities. They are protected by multiple layers of safety devices and systems, interacting electromechanical, electronic, software, and human safety protocols. If there is a failure in one system, there are generally others that will operate to prevent safety incidents. However, when such systems are not constantly kept in working order by skilled

[25] For a history of this topic and its details through 2001, see Miami-Dade Transit, "13(c) Strategic Task Force Final Report," June 29, 2001.

[26] Miami-Dade Transit, 13(c) Strategic Task Force Final Report, June 29, 2001, pp. 6-7.

[27] Miami-Dade Transit, 13(c) Strategic Task Force Final Report, June 29, 2001, p. 9.

and well-trained maintenance employees, safety is compromised, and the reliability of the system can be negatively impacted.

Only properly qualified maintenance staff should be allowed to work on safety critical systems, such as the ATO/ATP systems both in vehicle and on wayside, and in three important skilled maintenance positions, only a fraction is considered "qualified" to work independently. ***Error! Reference source not found.*** shows a breakdown of staff in important rail aintenance roles, as identified through discussions with Rail Services and Rail Maintenance management. In train control, traction power, and vehicle electronics positions, only 12 of 99 positions (12%) are considered qualified to perform independent work on complex tasks, without the assistance of supervisors or other staff.

Figure 9: Overview of employees in skilled maintenance positions

	Train Control	Traction Power	Vehicle Electronics	Total
Authorized positions	**34**	**27**	**38**	**99**
Unfilled (vacant) positions	11 (32%)	9 (33%)	3 (8%)	23 (23%)
Filled positions qualified to perform independent work	4 (12%)	3 (11%)	5 (13%)	12 (12%)
Filled positions unqualified to perform independent work	19 (56%)	15 (56%)	30 (79%)	64 (65%)

The impact of having too few qualified maintenance technicians could result in prolonged shutdowns and/or safety events, as illustrated in the following examples:

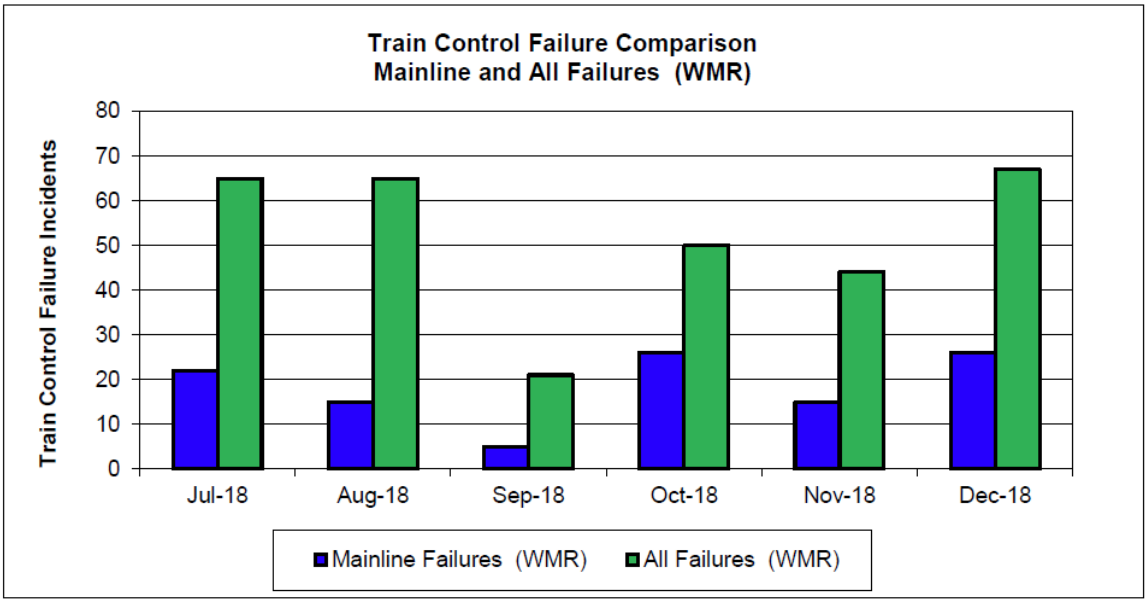
- On June 22, 2009, Washington Metropolitan Area Transportation Authority train 112 struck the rear of stopped train 214 at the Fort Totten Metrorail station, causing nine fatalities, at least 52 injuries, and $12 million in damages. The cause was the failure of a track circuit module, which caused the automatic train control system to lose detection of the struck train 214 and thus transmit speed commands to train 112 up to the point of contact. The NTSB found that the crash was caused by the failure of a track circuit module but also by "WMATA's failure to ensure that the enhanced track circuit verification test (developed following the 2005 Rosslyn near-collisions) was

institutionalized and used systemwide, which would have identified the faulty track circuit before the accident".[28] DTPW cannot allow its vital systems to become degraded to the point where a similar type of incident could occur, and having qualified and capable maintenance staff is imperative to ensuring the functioning of vital systems.

- Miami-Dade County is at high risk for hurricanes and, though hurricane survival was a key consideration in the design of Metrorail, it is not difficult to imagine a hurricane doing significant damage to multiple sections of Metrorail right-of-way and associated systems, including traction power and automatic train control. Such an event may also require detailed examination of all Metrorail vehicles, including significant repair activities for many vehicles, given that vehicles are stored in outdoor conditions at the Lehman Center and at terminal stations. It is common that, following such events, there are staff shortages as employees must attend to personal family and property issues. Many of the problems that spring up in such times are complex, often previously unknown, and require highly skilled and experienced maintenance staff that can work through what are often multiple additive problems. Even if DTPW staff were augmented with trained personnel from other agencies, without well-qualified DTPW maintenance staff, full recovery could take much longer than would be expected or acceptable to the riding public.
- Propulsion power stations are subject to failure; fires are not infrequent and generally take several days to weeks to fully recover from. Procedures exist to mitigate impact of such failures, but this requires careful train operations to avoid putting extra strain on power systems at adjacent stations, which can lead to cascading failures and make train operations more difficult and inconsistent. Adequate maintenance of propulsion power systems is therefore critical to preventing major disruption to operations.
- Automatic train control (ATC) and associated systems, such as signaling, are highly complex and must be carefully integrated. If there are major ATC failures – Metrorail's system is over three decades old, and DTPW is attempting to find approximately $250 million dollars to replace and upgrade it. The worst-case outcome can be a retreat to line-of-sight (LOS) operations. This requires multiple safety adjustments that significantly reduce speed of travel and require a high level of close attention by Metrorail train operators, who are typically only responsible for ensuring that the platform is clear to close vehicle doors.

[28] National Transportation Safety Board, "Collision of Two Washington Metropolitan Area Transit Authority Metrorail Trains Near Fort Totten Station," NTSD Number RAR-10-12, adopted July 27, 2010.

Figure 10: Train Control Failure Incidents, Jul. '18 - Dec. '18

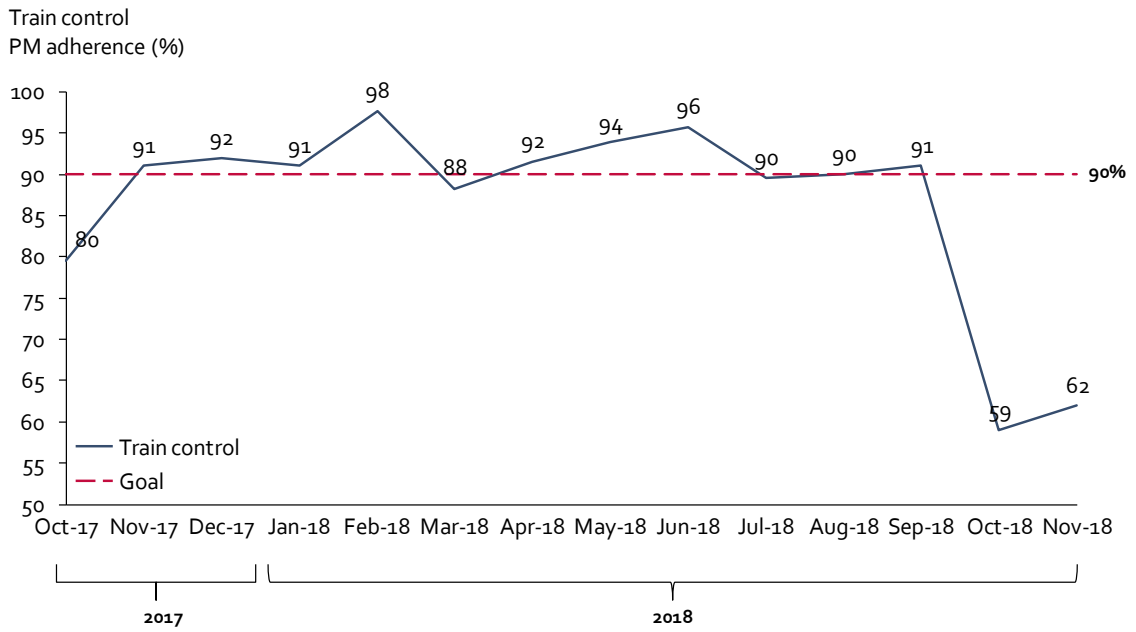


As *Figure 10* demonstrates, train control failures are not uncommon.[29] While the trend through September 2018 was downward, train control failures increased once again through the end of 2018. While no service failures occurred as a result of train control failure during the July – December 2018 time period, there were five service failures caused by train control in April – June 2018, and it is likely service failures related to train control may begin occurring again given the recent uptick in train control failures more generally.[30]

[29] Taken from December 2018 Transit Service Monthly Report. The Team was not clear on the definition of the "WMR" term used in this chart, as it is a direct screenshot of a page from the report.

[30] DTPW indicates that there is currently a 5-year program to replace certain train control components such as mini-bonds, coupling units, and circuit boards. However, the Team has observed that the most common reason for train control mainline failures is "adjust track circuit" as opposed to "repair track circuit" (second-most common reason) in November-December 2018, indicating replacement of components may only address a sub-set of causes of train control failures.

Figure 11: Train control preventive maintenance adherence, Oct. '17 - Nov. '18



Furthermore, preventive maintenance adherence for train control is inconsistent. As *Figure 11* displays, DTPW typically met its goal of 90% adherence for train control PMs, but it dropped significantly in October-November 2018. This is especially significant relative to general PM adherence, which was 90% and above in the same months, as shown in *Figure 7*. DTPW indicated that the drop is due to a misclassification of relay PM work orders as "late" even though they were on-schedule. Nevertheless, the recorded drop in adherence is also cause for concern, as the Team would expect such a drop to trigger an immediate investigation into root causes and a subsequent correction of the data.

The team found irregularities in the inspection forms for a set of randomly selected vehicles, specifically with the wheel diameter measurements for train control settings. Issues with inspection and maintenance were also raised in the Florida Department of Transportation (FDOT) Triennial Safety and Security Audit of DTPW:

- AOC-10-2: Some ATP equipment inspection records are completed incorrectly for Item 2.1 – Wheel Diameter Measurement.
- D-14-1: Train Control preventive maintenance checklists use inaccurate descriptions in the nomenclature of the procedures and have no references to provide acceptable values for various measurements.

Metrorail should develop the ability to attract highly skilled new employees directly into maintenance positions. Such actions could include implementing minimum qualifications and, if there are insufficient TWU members that can meet such requirements, recruiting from outside or making improvements to the existing staffing process, such as limiting the number of transfers between positions that TWU members can make in a given time period, preventing uncommitted employees from beginning maintenance training only to drop out and transfer back to previous positions.

DTPW difficulties in hiring and retaining sufficient numbers of qualified maintenance personnel have also come to the attention of the Federal Transit Administration and FDOT. We outline a number of relevant excerpts from both reports. The following are direct quotes from the Federal Transit Administration Fiscal Year 2018 Triennial Review – Final Report, June 8, 2018, page 13, Maintenance Budget and Resources:

- "For at least the past three years, the maintenance budgets for Rail, Metromover, and Bus have been inadequate to fund the personnel resources needed to provide the level of supervision, hourly staffing, and training needed."
- "The situation is worst in Rail and Metromover because union requirements mandate that they accept bus operating personnel based on their seniority to fill maintenance vacancies and train and retrain them. As reported, there are no means of rejecting any applicant for lack of competency, even after multiple efforts to train an applicant does not result in a capable maintenance worker."
- "The DTPW executive should work with the union to gain the ability for rail and Metromover to use competency standards and reject applicants who do not possess the ability, or will, to perform required maintenance tasks."

The following are from the FDOT Triennial Safety and Security Audit of DTPW:

- "Currently, the Train Control Division does not have a minimum qualification for hiring technicians."
- "The attrition rates for students over the period of the training appears to be high, with some classes graduating fewer than half of the students. FDOT is concerned that DTPW staff are entering training without the requisite skills to succeed in the training and that the lack of minimum technical qualifications results in underqualified candidates who are not equipped to succeed with the complex material of the current courses."
- "County Testing and Qualification is disconnected from DTPW and the process regarding how it aligns with Rail Services is not clear, hindering DTPW Rail Services' ability to provide additional training and supervision to people who do not perform optimally in certain exam areas."

Regarding the first bullet of the above list, the report says:

- "Area of Concern 14-1: Currently, the Train Control Division does not have a minimum qualification for hiring technicians. This may lead to underqualified personnel performing maintenance on Train Control components on Metrorail. Additionally, the Division has at least two Senior Technicians approaching retirement and as a result, under current qualification standards for hiring technicians, Metrorail may not have enough trained experienced technicians to safely and correctly maintain the train control systems."
- "At a minimum, DTPW should consider the following recommendations when developing a formal CAP to address this finding:
    - Define minimum qualifications for employees transferring into the Maintenance Technician position for Train Control.
    - Provide complete training for the new hires and some on the job training with the retiring technicians."

Similar comments are made in the report for Track & Guideway and Facilities Maintenance.

The Team believes that the FTA and FDOT comments above are valid and important, having made similar observations, and the Team concurs with these recommendations.

5 CLEANING PRACTICES

DTPW's Standard Operating Procedures outline primary responsibilities for Maintenance Cleaners at William Lehman Center Facility. Regular cleaning is supposed to be performed on a daily basis, seven days week. Rail vehicle cleaners are assigned to specific vehicles, and regular cleaning is expected to be performed on all vehicles going into revenue service before leaving the Lehman Center. Staff consists of 11 scheduled cleaners at the Lehman Center, plus two cleaners at terminal stations in the morning (one each Dadeland South and the MIC) and two in the afternoon (one each at Dadeland South and Palmetto). Random inspections for cleanliness are performed on vehicles by the Supervisor at the Lehman Center before vehicles go into service. The Team's understanding is that no cleaners work mid-day at terminal stations. *Figure 12* shows the schedule for rail vehicle cleaners effective as of June 2019.[31]

Figure 12: Number of scheduled rail vehicle cleaners by day effective as of June 16th, 2019

	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Total
1st shift: 6AM – 2PM	0	4	5	5	5	5	1	25
2nd shift: 1PM – 9PM	0	3	3	3	3	3	0	15
3rd shift: 8PM – 4AM	7	7	12	12	11	5	5	59
Total	7	14	20	20	19	13	6	99

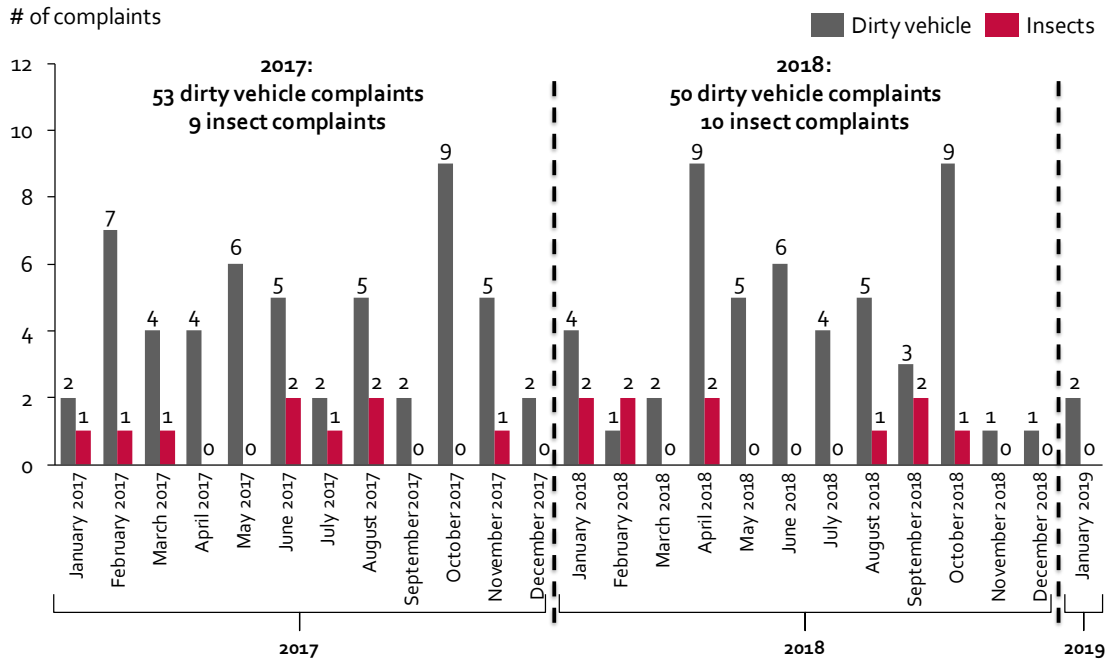
Detail cleaning is done on weekends, and fumigation of cars is done every quarter. DTPW's goal is to clean 20% of the PVR of 76 cars each month or 14 cars (rounded down from 15 as cars are paired). This comprehensive cleaning procedure includes all aspects of the interior rail car – ceilings, floors, seats backs, metal stanchions, seat railing, liners, windows, interior doors, operator cabs, and gum removal. Vehicles with graffiti, a substantial amount of food and garbage, or that are otherwise unusually dirty are selected for detail cleaning outside of rotation. Detail cleaning is also done after cars are out of service for long periods of time for repair or waiting for parts. It is important to note that an increase in the number of cars receiving detail cleaning does not necessarily mean that the vehicle is immediately seen or enjoyed by the riding public. The

[31] Taken from feedback provided by DTPW on this report.

Team also notes that the information provided to CITT indicates that, on average, 12 vehicles are detail cleaned every month (seen later in this report in *Figure 26*), indicating the goal of detail cleaning 14 vehicles per month is not consistently met. DTPW indicates the goal cannot be met if high absenteeism or high levels of vandalism (such as graffiti) prevent detail cleaning from occurring on-schedule.

5.1 Cleanliness of vehicles

Figure 13: Complaints related to vehicle cleanliness and insects[32]

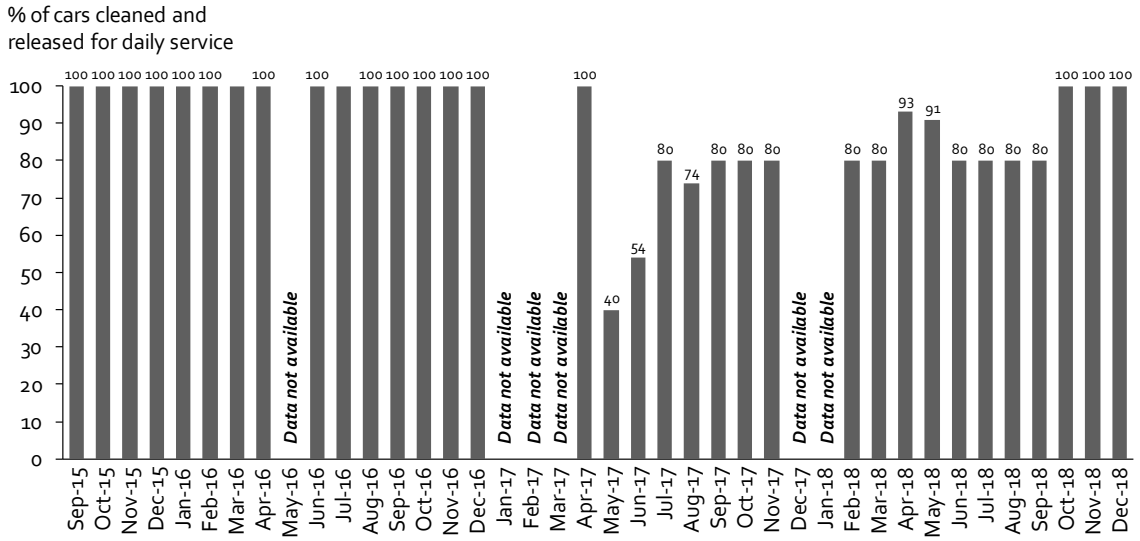


Vehicle cleanliness is below acceptable standards and detracts from the riding experience. From January 2017 through January 2019, a total of 5,191 complaints for all reasons were received by Metrorail. Complaints were received online, via Twitter, the 311 Line, vehicle operators, security officers, and letters to the Department. About 124 were comments directly regarding dirty vehicles and insects, including the presence of cockroaches, rats, leaks rendering seats unusable, and excessive trash and debris inside vehicles. *Figure 13* shows a breakdown of these 124 complaints by month and year. However, dirty vehicles were mentioned in a variety of other complaints about Metrorail more broadly. Complaints on lack of, or insufficient, air conditioning

[32] Feedback subtypes: "EM-DirtyVeh" and "EM-Insects".

constituted the most frequent cause of complaint – nearly 10% of total – which also speaks to the frequency of failing HVAC equipment on board rail vehicles. Lastly, data from Transit Service Monthly Reports, shown in *Figure 14*, demonstrates that adherence to the daily cleaning schedule may be variable.[33] However, DTPW claims that every vehicle leaving the Lehman yard prior to service is cleaned. Variability in cleaning data was explained as an error in methodology, as the number of vehicles cleaned and released for service is affected by the number of vehicles available to meet PVR (i.e. if a vehicle is not available to meet PVR, it counts against both the number of vehicles cleaned as well as the number of vehicles available for service). As discussed earlier, detail cleaning schedule adherence must also be verified based on data provided to CITT on number of cleanings, assuming detail cleaning is scheduled on a quarterly cycle for every vehicle.

Figure 14: Daily cleaning schedule adherence on rail vehicles released for service

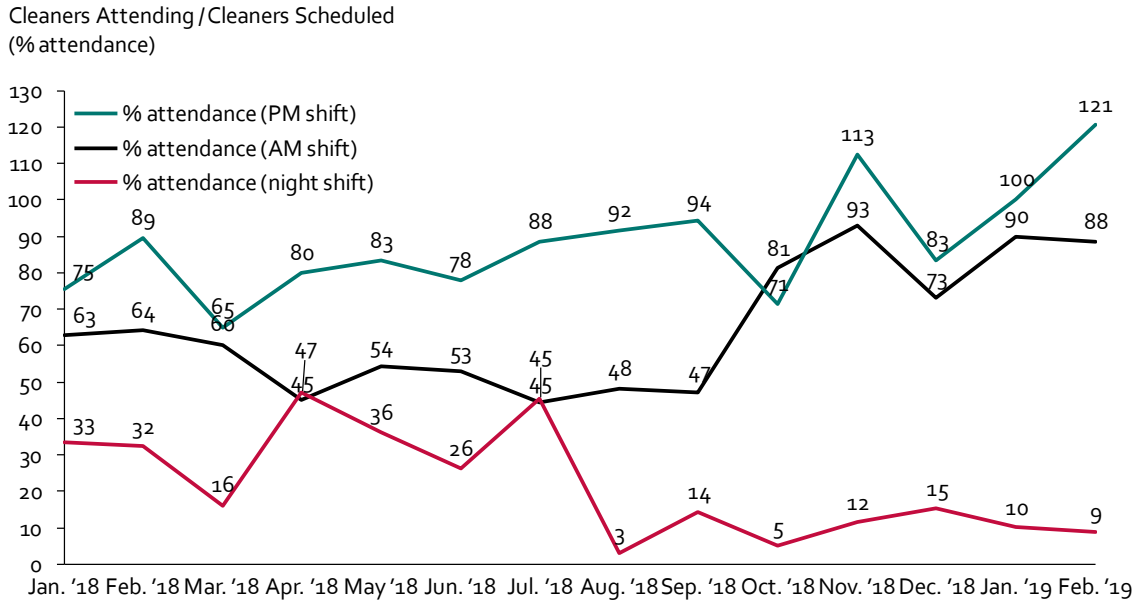


Cleanliness and general appearance of vehicles likely contribute to riders continuing to use Metrorail. The Metrorail Fleet Management Plan outlines factors influencing ridership – escalating fuel prices, fuel shortages, and large migrations, among others – but fails to highlight the importance of cleanliness and amenities to riders as factors influencing ridership. Cleanliness and reliability are especially important in light of other transportation options available such as ridesharing services. It is also important to address issues associated with cleanliness before new

[33] Taken from "Metrorail Summary" page of Transit Service Monthly Report.

vehicles are impacted and begin to deteriorate. Visual appearance of vehicles also raises questions about the appropriateness of maintenance of parts and systems that cannot be seen.

Figure 15: Cleaner attendance percentage, Jan. 18 through Feb. 19



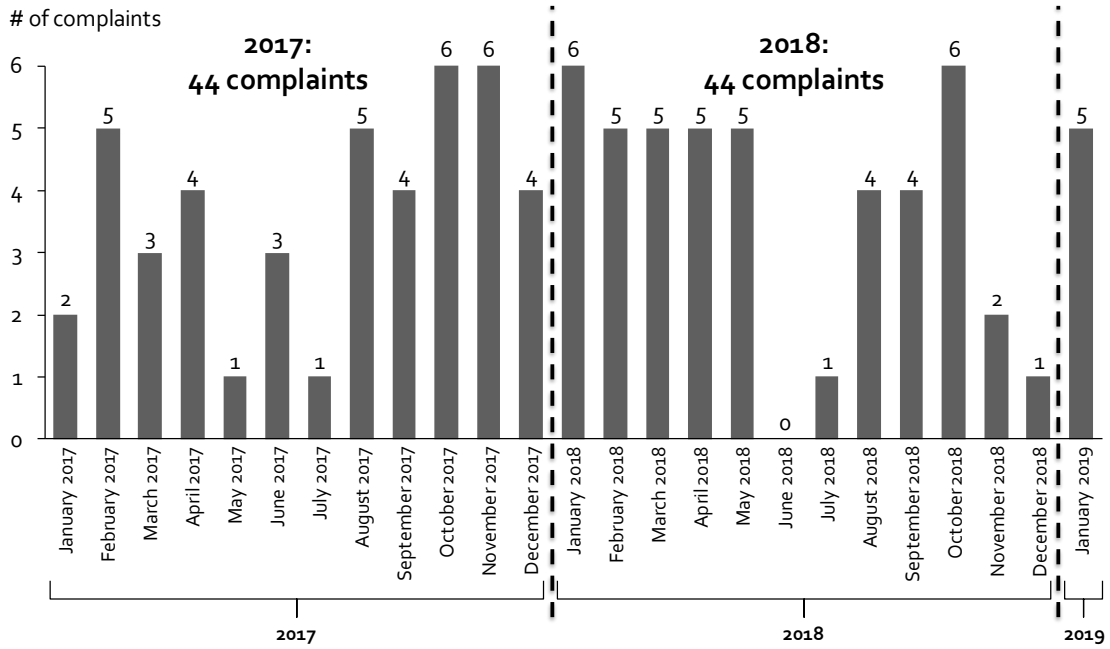
The number of staff available for performing cleaning greatly impacts cleanliness of vehicles. Absenteeism is a problem with cleaning staff. High levels of absenteeism are common, including some shifts when no scheduled cleaners reported for duty. This is evident through analysis of cleaner availability in *Figure 15*.[34] It is particularly important to note the low availability (only 9% in February 2019) during the 8pm to 4am night shift, as that is the time during which vehicles are cleaned for the next day's service. Many individuals become cleaners as result of nonperformance in other positions. There are anecdotal accounts of evenings where supervisors and even technicians and/or mechanics were pulled from their regular assignments to help with vehicle cleaning as a result of cleaner absences, including shifts when not a single scheduled cleaner showed up for work. This leads to an unproductive use of maintenance staff time, especially significant given that this practice may sometimes exacerbate the shortage of qualified maintenance staff discussed earlier in this report. The Rail Maintenance Division requested additional personnel in last year's budget – 15 additional cleaner positions and one supervisor – and was not granted any. With the number of cars needing daily cleaning (76 to meet

[34] Derived from "Metrorail Availability 2018" Excel workbook provided by DTPW. Cleaner attendance above 100% reflects days when additional cleaners are scheduled to address graffiti, shop clean-up projects, and special events that may increase ridership.

peak vehicle requirement) and the few individuals available for the job, it is easy to understand the difficulty in keeping a high standard of vehicle cleanliness. Cleaning procedures for all vehicles – legacy or new – are approximately the same, and regular cleaning is currently easier on the new cars, given easier-to-clean surfaces, but unless the quantity and quality of the cleaning crew is addressed, new cars may become as difficult to clean as older vehicles over time. The Team's observations while riding Metrorail during service hours also indicate that more cleaners are necessary during the day at route terminals – Palmetto, Miami Intermodal Center (MIC), and Dadeland South stations – to clean vehicles of trash and debris accumulated during service and to maintain an overall standard of cleanliness on cars. DTPW has confirmed that it needs additional support for mainline cleaning, given patrons may board trains with items such as construction supplies and food. Rail Maintenance requested 15 additional cleaners and one supervisor in the most recent budget but has not yet received any additional cleaning positions, discussed further in section 6.2.

5.2 Cleanliness of stations

Figure 16: Cleaning complaints routed to Facilities Maintenance[35]



Metrorail stations are generally clean and mostly present a safe and comfortable environment for customers. While there were 93 complaints between January 2017 through

[35] Feedback subtype: "FM-NeedsClean".

January 2019 classified as requests for cleaning routed to facilities maintenance, many of these complaints related to rail vehicle cleanliness instead. A substantial proportion of complaints (11 of 93) were also related to restroom cleanliness, which is expected to subside as all station restrooms have recently been overhauled with institutional-grade equipment that is easier to clean. *Figure 16* shows a breakdown of these 93 complaints by month and year. The Team's observations while walking through a number of stations at random confirm the general cleanliness of station entrances, platforms, elevators, etc. Therefore, the overall cleanliness of stations appears to be maintained, and complaints regarding spills, bad smells, etc. appear to be addressed quickly by cleaning staff at stations.

Facilities maintenance procedures and contracts appear to be well designed. Objectives and an action plan for keeping Metrorail stations clean are included in the Miami-Dade Facilities Equipment and Maintenance Plan dated January 2019. The Facilities Maintenance Division is responsible for this activity and performs its duties through a variety of in-house and contracted services. Janitorial services and extermination services are provided through two janitorial service contracts under the supervision of DTPW Facilities Property Managers. Daily, weekly, bi-monthly, and semi-annual work activities for each Metrorail station are specified in the Janitorial Services for Metrorail Systems Stations Contract. Extermination services are provided at each transit facility and station on a monthly basis. The Facilities Maintenance Division ensures that the contractor's work efforts are effective by establishing detail work programs and monitoring performance.

Elevators and escalators at Metrorail stations are undergoing a replacement plan, and funding has been identified in the Five-Year Capital Plan. DTPW maintains and operates ninety-nine elevators and ninety-one escalators in its facilities, which include Metrorail, Metromover, and Metrobus. Maintenance of elevators and escalators is performed by contract personnel. The contractors are responsible for completing and performing preventive maintenance and all repairs in order to meet various unit operating goals. Performance is based on a monthly percentage of unit availability of 95 percent for escalators and 96 percent for elevators. Availability is exclusive of shutdowns due to vandalism, overloading, activation of safety devices by external causes, and routine maintenance shutdowns. DTPW also pays its contractor for an additional Team of mechanics to perform repairs, likely due to the frequency of repairs required. The replacement of elevators and escalators included in the Five-Year Capital Plan should effectively address lack of availability experienced in years past.

5.3 Security at Lehman Center and vandalism issues / implications on cleaning

Vandalism at Lehman Center demands additional cleaning efforts of an already challenged cleaning staff. New and more frequent graffiti occurrences during the evening at the Lehman

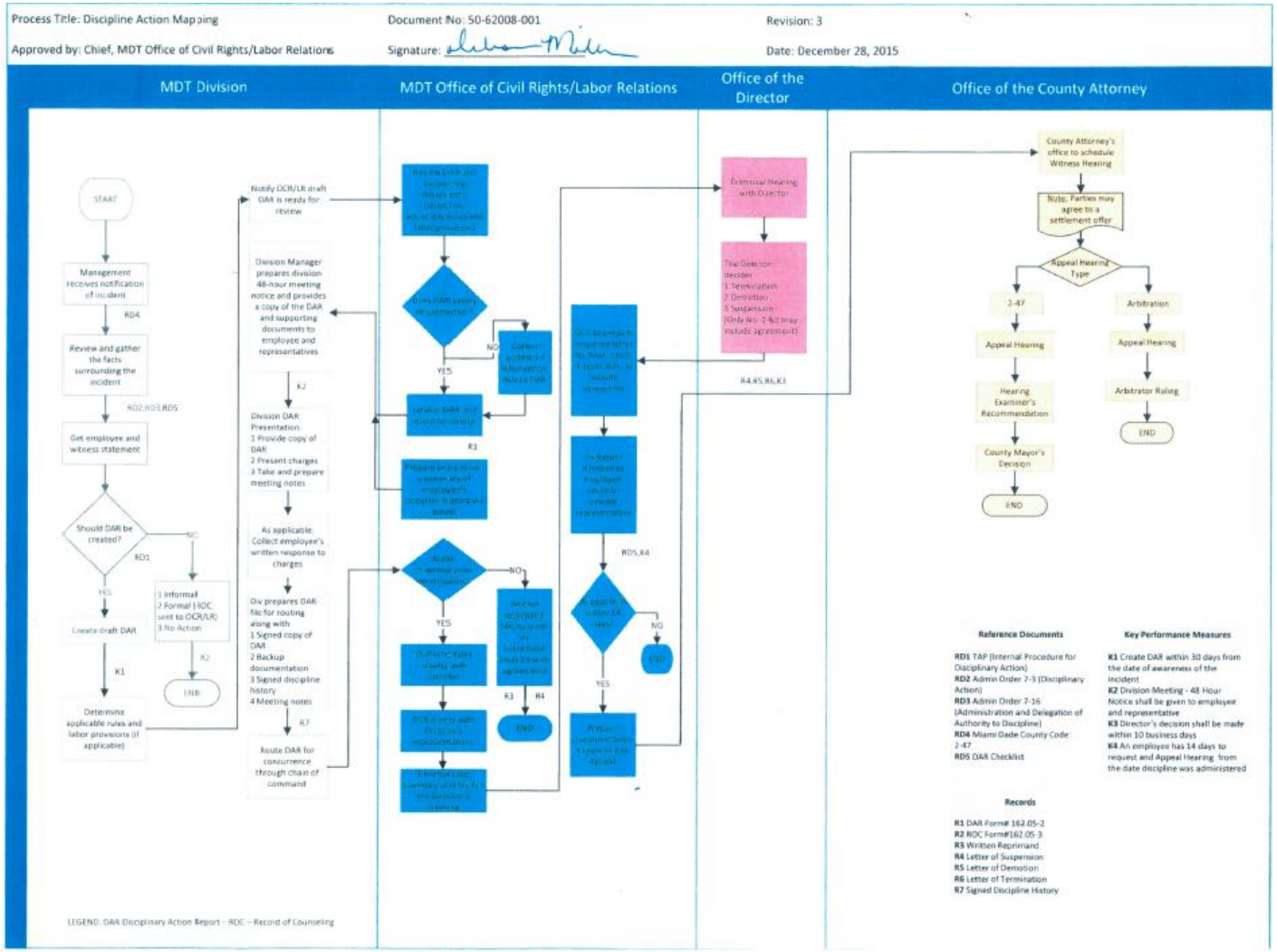
Center add effort and work for cleaning crews. Vehicles with graffiti require additional staff time, which interrupts scheduled rotations for detail cleaning. It also prevents the vehicle from being available for service. Nevertheless, given general vehicle availability challenges for Metrorail, the Team has heard anecdotal evidence of occasions when vehicles with graffiti were put into service before they could be cleaned, adding to the dissatisfaction of riders. Between January 2017 through January 2019, there have been at least 12 complaints lodged about graffiti either on the inside or outside of rail vehicles. Vandalism is being addressed by security, and the upcoming perimeter fence project around Lehman Center should help to deter it, but in a large open area with many vehicles, it has proven hard to control for Lehman Center staff.

5.4 Staff disciplinary process for cleaners

Hiring procedures and the disciplinary process are inadequate to achieve effective vehicle cleaning. Hiring practices are based solely on seniority with no minimum qualifications for most positions. Most hires in the maintenance teams, including in the cleaning group, are transfers from other positions in DTPW and union agreements constrain the ability to hire from outside. Technically, cleaners can be hired externally, but the Team's conversations suggest that this has seldom (if ever) happened. Instead, many rail vehicle cleaning staff appear to have been placed in their roles after infractions in prior roles. The existing disciplinary review process and other factors, such as the Family and Medical Leave Act (FMLA), make it difficult to for supervisors to enforce attendance and job performance requirements.[36] *Figure 15* on cleaner availability demonstrates this point. The Office of Civil Rights and Labor Relations, which is part of the DTPW, takes the lead in disciplinary actions and must follow procedures outlined in Progressive Disciplinary Administrative Order 7-3, County policies on leave, and the TWU contract. An overview of the disciplinary process is in *Figure 17*, which illustrates the numerous steps and stakeholders that are currently involved in disciplinary action. DTPW Human Resources participates only when the disciplines process results in a reduction in pay or suspension. There are ongoing talks with TWU to address conditions that present enormous challenges for the Department to perform reasonably. Until the Department can create a discipline process that is effective, the cleanliness of vehicles will likely remain in its existing state.

[36] DTPW has indicated that 43% of vehicle cleaners currently have FMLA (as of June 2019).

Figure 17: DTPW Discipline Action Map (as of December 2015)



The key position of Chief, Office of Civil Rights and Labor Relations was vacant for over a year, but it was filled last November. The Team's interaction with new leadership demonstrates that the office is being led by an experienced and capable individual familiar with the complex and difficult Miami-Dade County/DTPW disciplinary process. The Team was informed that the office has been diligently working to reduce the discipline case backlog. A complaint that the Team heard during conversations with DTPW supervisors is that disciplinary cases previously could not be "stacked", whereby an employee with multiple pending disciplinary actions could not have the second one processed until the first action had been completed, which could take many months prior to the recent backlog cleanout process began. The Team heard from the Office of Civil Rights and Labor Relations that it has now instituted procedures to "stack" higher-level disciplinary complaints, eliminating the wait time for lower-level complaints to be processed before the next level of complaints can be addressed. The Team sees these as positive indicators of change in the disciplinary process, though it is too soon to conclude that no additional changes will be required.

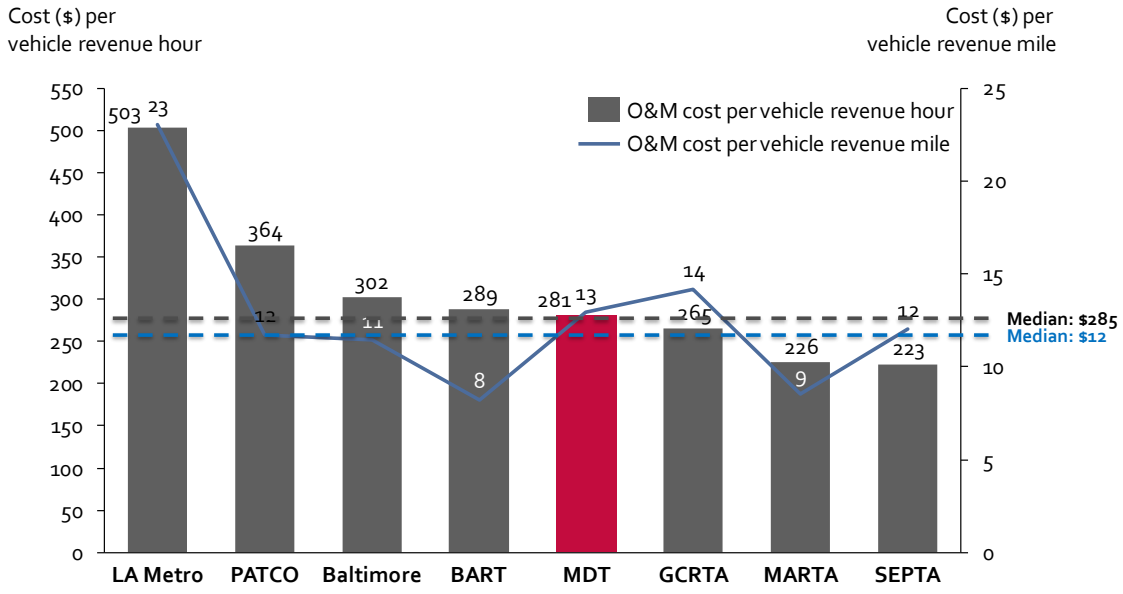
6 COST ANALYSIS

Metrorail spending on O&M is comparable to peer systems, and while spending on maintenance specifically is higher than median among peers, there is room to increase budget to adequately perform maintenance activities. O&M cost is roughly at the median of peer systems when standardized to the number of vehicle revenue hours. While both vehicle and non-vehicle maintenance costs are higher than peers, they are not exceptionally so, at 17% and 6% higher than median respectively. Given that Rail Maintenance is currently operating with an inadequate number of qualified staff, it may be advisable for an increased Rail Maintenance budget to provide for the staff and resources necessary to perform adequate maintenance on vehicles and systems.[37] However, the Team's discussions with DTPW's leadership and review of historic cost data suggest that a significant amount of overtime, which increases actual costs versus budget, is currently used in lieu of hiring qualified personnel. Therefore, this report does not make a definitive recommendation on budget except to recognize that Metrorail is currently a "mid-cost" system versus peers.

[37] While Rotterdam, Netherlands is included in peer comparisons in the appendix of this report, it is not included in cost comparisons due to labor cost, currency, and accounting differences.

6.1 Peer benchmarking[38]

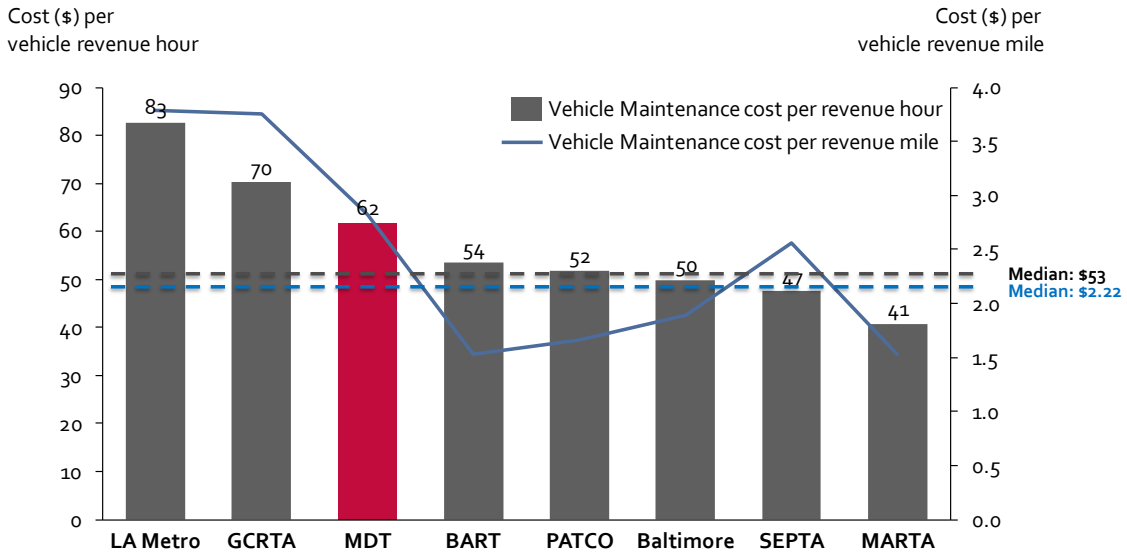
Figure 18: O&M cost (2017) across peer systems



Metrorail's overall O&M cost is comparable to peer systems, with roughly median O&M cost per vehicle revenue hour, though it trails cost leaders such as MARTA and SEPTA. As *Figure 18* shows, in 2017, Metrorail's O&M cost was $281 per vehicle revenue hour compared with $289 at BART and $302 at Baltimore. Nevertheless, this is nearly 25% higher cost than MARTA and SEPTA, which had O&M costs of roughly $225 per vehicle revenue hour, as reported to NTD.

[38] All peer benchmarking data comes from the National Transit Database (NTD) maintained by the Federal Transit Administration (FTA).

Figure 19: Vehicle maintenance cost (2017) across peer systems



While Metrorail does appear to control overall O&M costs relatively well, maintenance cost is higher than most peers. As shown in *Figure 19*, vehicle maintenance cost per vehicle revenue hour and per revenue mile was 3rd highest among peers and roughly 50% higher than the lowest-cost system in this cost category, MARTA. The Team's research through conversations with Metrorail and other DTPW stakeholders suggests that labor practices may contribute to higher maintenance cost. While NTD data in *Figure 20* appears to indicate that higher labor cost is not a driver of higher maintenance cost at Metrorail, an analysis of Metrorail budget indicates that labor cost data reported to NTD ($30) may be underestimating true cost, as the Team's estimate indicates an average labor cost per hour may be closer to $63 for the Rail Maintenance division, as explained in the footnote.[39] Nevertheless, non-labor maintenance cost at Metrorail is the highest among all peer systems, as seen in *Figure 21*, indicating there may also be room for increasing the productivity of Metrorail's spend in categories such as service costs and materials & supplies, though further analysis of this is beyond the scope of this report.

[39] Total spend in FY16-17 on labor-related costs, including fringe benefits (accounts 110 through 197 and accounts 1010 through 1116) was $19,587,643 according to Rail Maintenance - Division 82 cost data provided to the Team. Assuming that the 170 actual Rail Maintenance positions for FY16-17 worked, on average, 1,840 hours per year, the per hour labor cost is $62.62.

Figure 20: Labor cost per hour worked (2017) by peer system

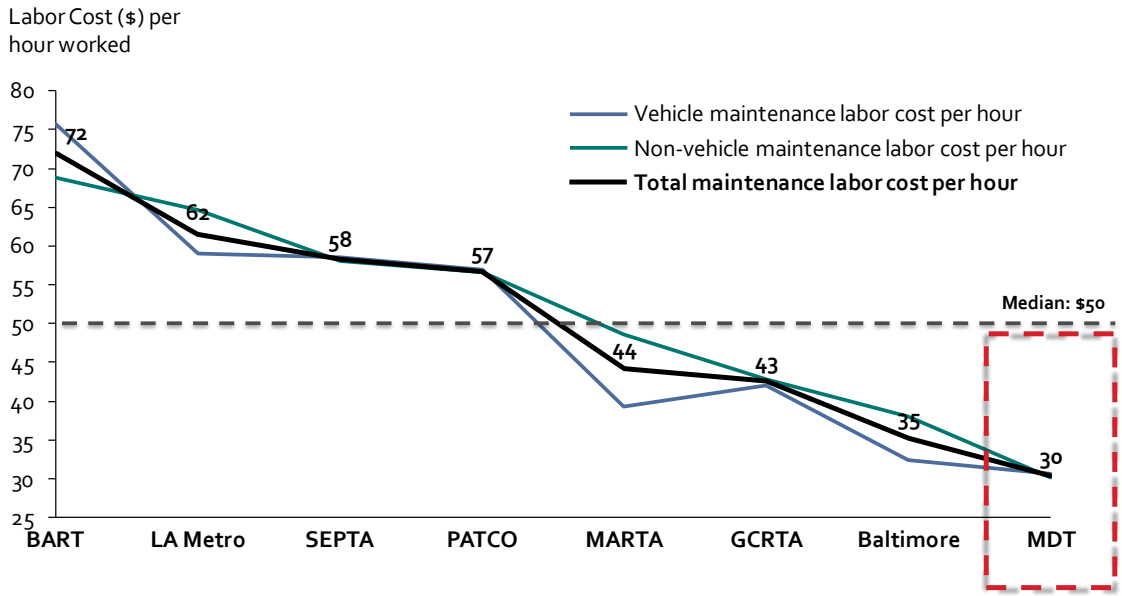


Figure 21: Non-labor maintenance cost per vehicle revenue hour (2017) by peer system

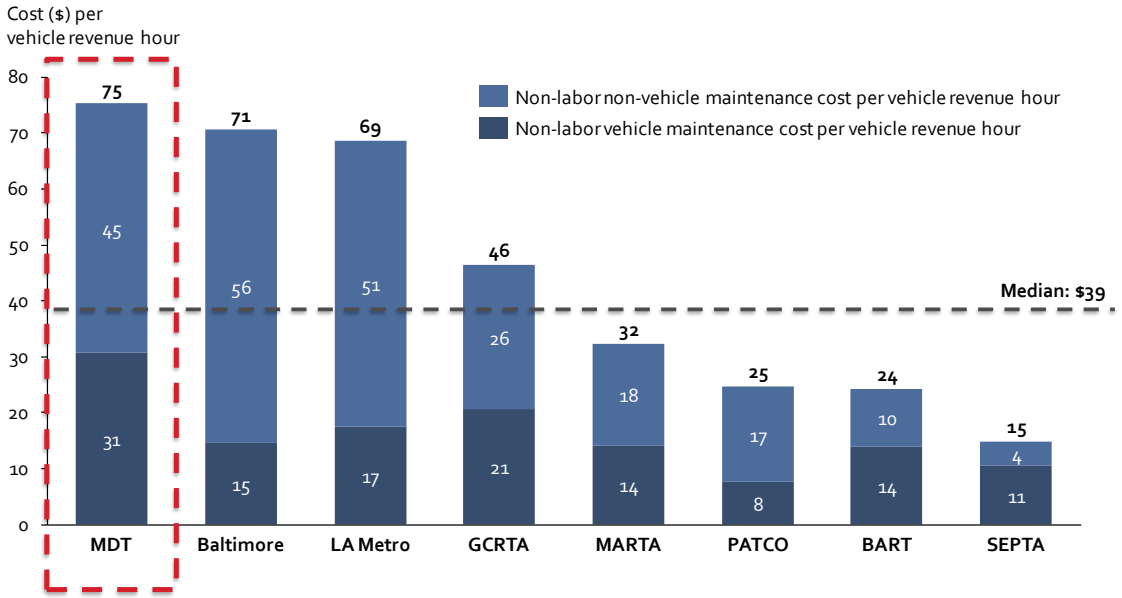
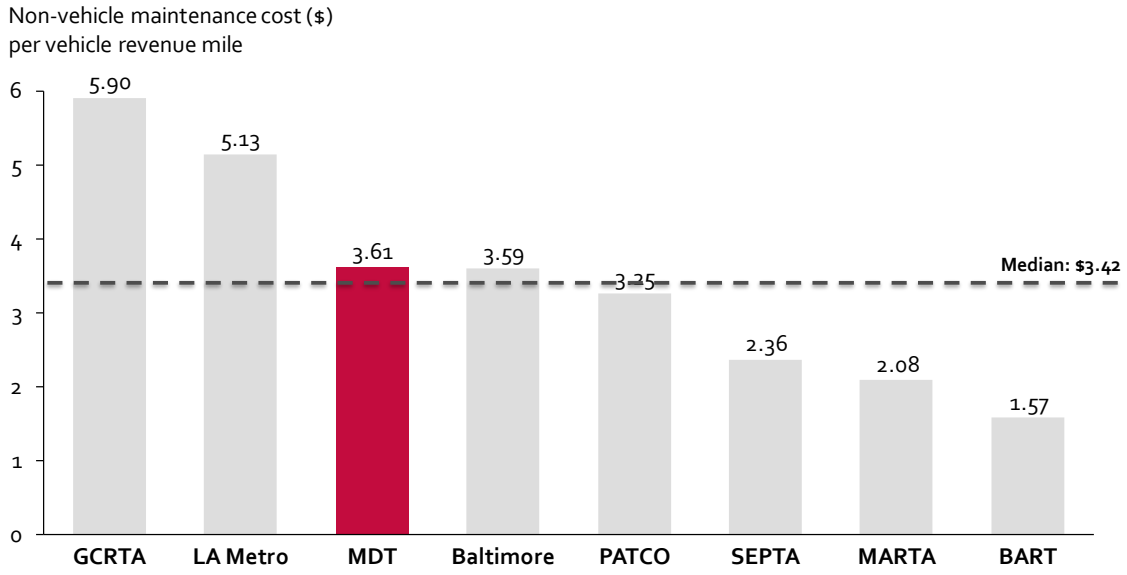


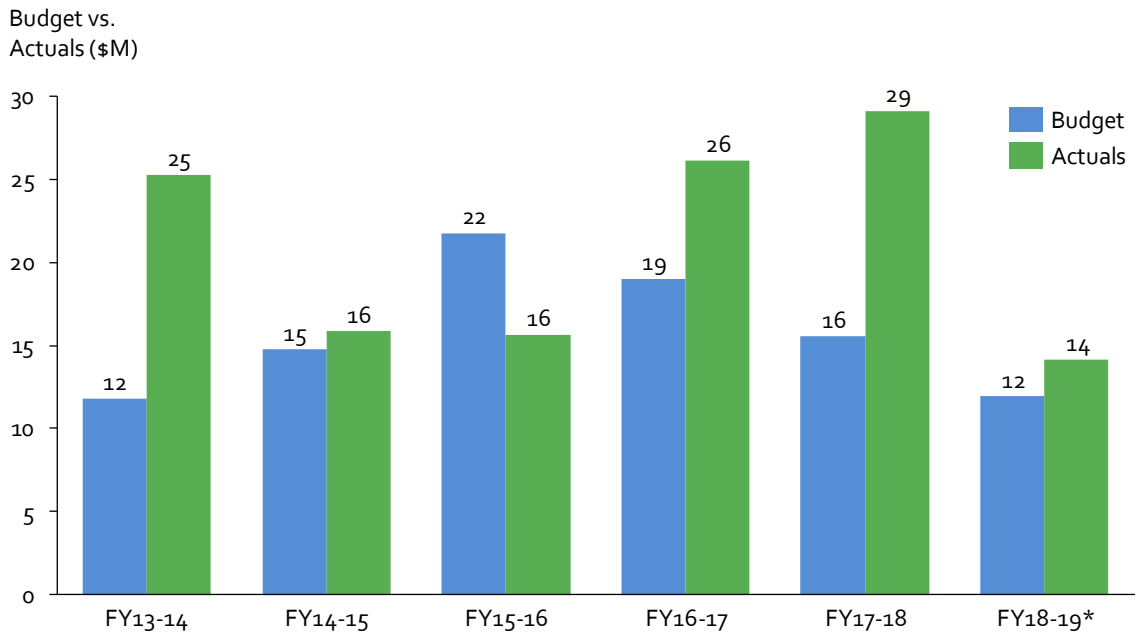
Figure 22: Non-vehicle maintenance cost (2017) among peer systems



For non-vehicle maintenance cost specifically, Metrorail also trails most peers. On a per vehicle revenue mile basis – likely a stronger driver of non-vehicle maintenance activities on track and guideway – Metrorail has the 3rd highest cost among peers, comparable to peer systems such as Baltimore's but significantly higher than SEPTA, MARTA, and BART. *Figure 22* displays this data.

6.2 Budget

Figure 23: Rail Maintenance (Division 82) Budget vs. Actuals FY13-14 through FY18-19

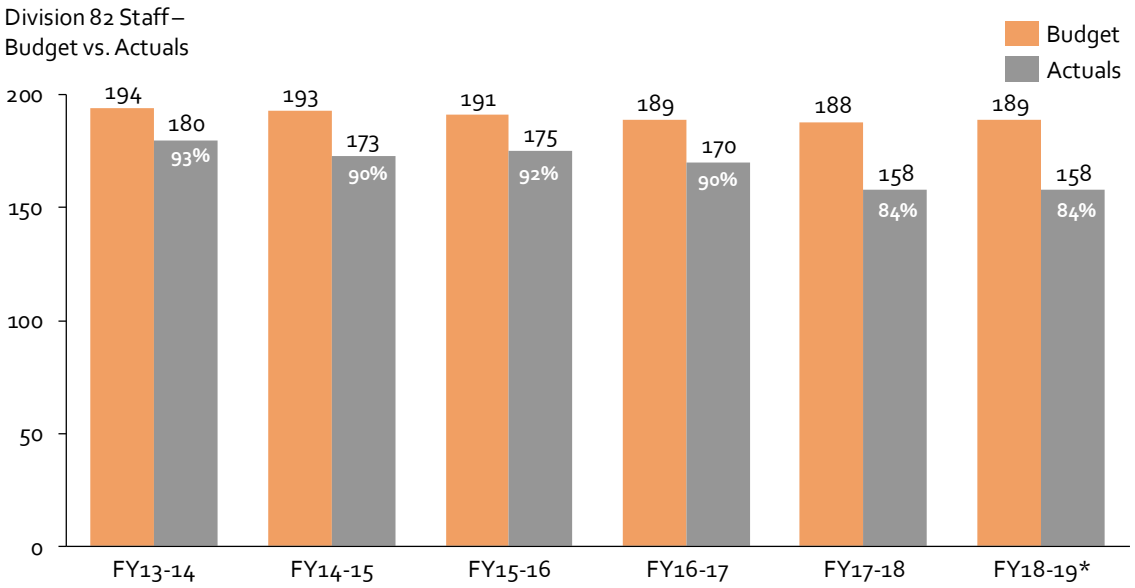


*FY18-19 full-year actuals estimated based upon year-to-date spending

Rail Maintenance spending fluctuates widely from year to year, and actuals have typically outstripped budget, especially in light of consistent decreases in annual budget. An overview of Rail Maintenance budget versus actuals is seen in *Figure 23*. The decreases in budget are especially surprising given that a prior reduction in service to 56 vehicles was increased once again to 76 vehicles in March 2018, requiring greater maintenance activities to keep a higher number of vehicles operating, though the increase in service was requested in the middle of a fiscal year after budgeting was already complete.

There are a number of reasons why actuals are typically higher than budget, though all of these should be foreseen and factored into budgets. For instance in FY16-17, some of the variance in actuals vs. budget may be explained by the purchase of motor control boxes and motor reactors through operating budget, which were used for the 40-car contingency fleet of Budd vehicles that are to remain available for a short period of time after service is fully operated using Hitachi vehicles. Budgets also have not consistently included termination pay, though such payments are included in actuals. Lastly, difficulty in hiring qualified technical staff results in overtime. Nevertheless, annual budgeting exercises should generally account for one-time and recurring costs such as these, which can typically be foreseen. A better starting point for future budgets may be actuals from the prior year, especially given that actual spending has not been constrained by County-approved budget in past years.

Figure 24: Rail Maintenance (Division 82) Staff - Budget vs. Actuals



*) FY18-19 full year actuals estimated based on first half year

Rail Maintenance also consistently operates with vacant positions, which impedes effective maintenance operations both for vehicles and for supporting systems such as train control. As seen in *Figure 24*, vacant positions have increased over time, from 14 vacancies in FY13-14 to an expected 31 vacancies in FY18-19. As discussed elsewhere in this report, one driver of the high number of vacancies is that hiring practices do not allow for recruitment outside of the bargaining unit, and anecdotal evidence suggests that supervisors are leaving positions open in the hope that minimum qualifications will be introduced for vacant positions in their division in the future.

While certain positions remain vacant, Rail Maintenance has requested budget for additional FTEs for other functions such as cleaning, which have been rejected. Both Rail Maintenance and Infrastructure & Maintenance (Division 34) have requested additional budget for cleaning staff and contractors for vehicles and stations. Prior budget requests for Division 34 have been approved (back to 2014-2015), but the most recent budget request for additional cleaning staff made by Rail Maintenance (Division 82) has not yet been approved and, according to DTPW, is not likely to be approved. As discussed in the cleaning section, vehicle cleaning staff in particular must be strengthened, either through enforcement of higher staff attendance or through additional outside hiring or contracting, to adequately clean vehicles both before and during service. Moving forward, the Team also recommends more realistic budgets based on prior year actuals, discussed further in our recommendations in section 8.

7 PERFORMANCE METRICS

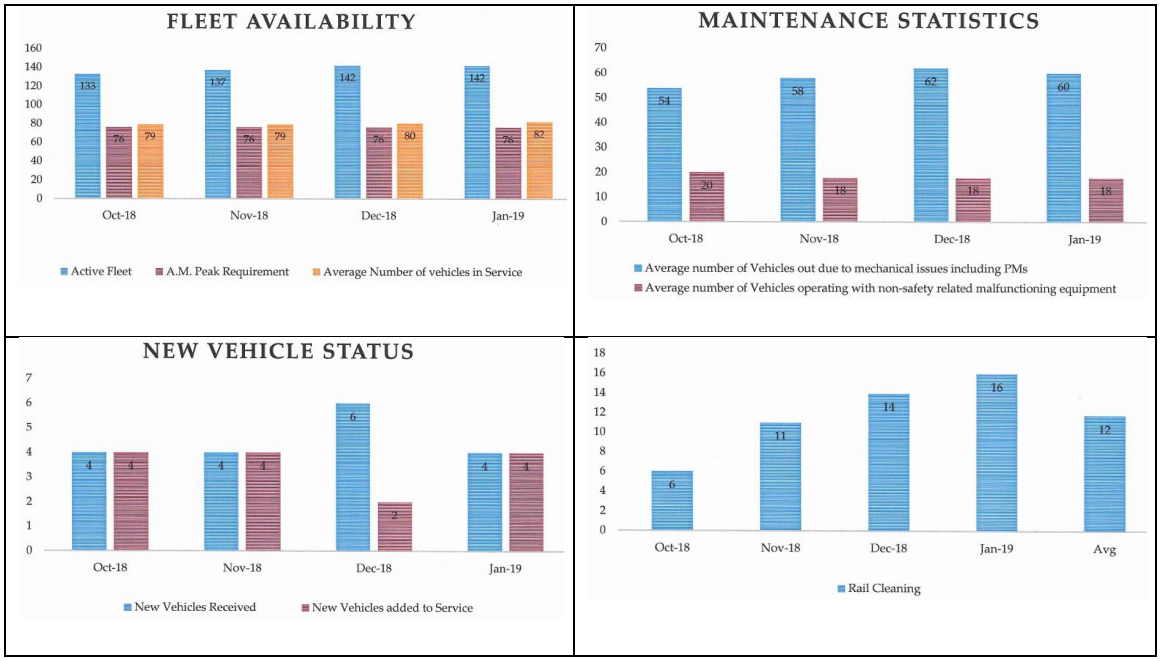
DTPW consistently reports on Metrorail performance in monthly status reports, but these reports do not typically appear to be acted upon. The Transit Service Monthly Report is produced on a monthly basis for all of DTPW's transit systems, including Metrorail. A typical report is shown in *Figure 25* below, which is for September 2018.

Figure 25: Example Transit Service Monthly Report

CATEGORY		GOAL	SEPT
Metrorail			*2018*
On-Time Performance	APTA Std.	95%	80.6%
On-Time Performance	Station to Station (Wkdy)	95%	
Percentage of Stations Serviced		96%	87.3%
	Annulled Trips	-	998
	By-passed Trips	-	495
	Late Trips	-	37
Train Operator Absenteeism (unanticipated)		16%	10.6%
Service Disruptions per 1000 Pair Miles (all causes)		6.9	3.6
Service Disruptions (All Causes)		24	12
Service Disruptions (All Vehicle Born)			15
Mean Vehicle Availability (Week Day) *(Avg Car Count 68-88% of PVR Met)*	A.M.	100%	45.0%
Mean Vehicle Availability (Week Day) *(Avg Car Count 64-83% of PVR Met)*	P.M.	100%	20.0%
Mean Vehicle Availability (Week End)		100%	100.0%
Rail Vehicle PM Inspection Adherence		90%	100%
Scheduled vs. Unscheduled Maintenance	Scheduled	70%	49%
	Unscheduled	30%	51%
Operating Miles (Budd Cars)		-	436,723
Operating Miles (Hitachi Cars)			71,523
Total Operating Miles			508,246
Mean Distance Between Disruptions (Vehicle) In service hard failures		39,000	54,590
Mean Distance Between Mainline Failures		3,000	3,054
MDBSD & MDBF numbers do not include Hitachi Fleet			
Failures:	Service Failures (Hard Failures)	16	8
	Mainline Failures	-	143
	Mainline - Reset Conditions	-	24
	Mainline - Tested No Trouble Found		129
	All Failures	600	315
Percentage of Vehicles Down for Parts			0.0%
Stockouts Issued (part unavailable at time of request)			20
Open Vehicle Repair Orders	Priority 1		10
Open Vehicle Repair Orders	Priority 2		343
Cars Cleaned and Released For Service		100%	80%

One reason such reports may not be acted upon is because of their lack of clarity and lack of review by external observers. First, the definitions for metrics in the left column are not defined in the document. Therefore, for a new reader of this report, it is difficult to decipher what each metric represents. During discussions with staff responsible for producing the report, clear definitions of the metrics were not easily understood without internal consultation. Secondly, it is not clear how goals for each metric were agreed upon, nor why they represent a "good" quality system. Lastly, the Team was informed that this report is not shared with CITT as an official document, meaning that these metrics may not be independently reviewed outside of DTPW on a regular basis.

Figure 26: Metrorail report presented to CITT (February 2019)



For external audiences, a different report is prepared. During the CITT monthly meetings, the report in *Figure 26* is presented for Metrorail. These performance metrics, while easier to comprehend than those in the monthly report, also do not provide a representative view of realized performance and its relationship to customer experience. The Team found it unclear what the bottom right graph represents (later informed that this is the raw number of detail cleanings performed each month), and the overview lacks additional information to understand system performance from a customer perspective. On-time performance and customer complaint data are notably absent.

A new set of key performance indicators (KPIs) should be developed that provide better insight into actual performance and customer experience. At minimum, the KPIs reported to CITT should include relevant performance metrics that represent system quality. They should also be well-defined, and the calculation of each metric should be transparent. A more robust reporting system would also include easier access to real-time data outside of the Performance Analysis group, providing the ability for additional DTPW stakeholders and the riding public more broadly to view system performance. Such tools area already being created outside of County offices[40], and both CITT and DTPW would be well-served to develop performance metrics and standard reports that provide deeper insight into the drivers of customer experience.

The Team recommends that CITT lead the redevelopment of KPIs that DTPW must report upon, tying such metrics more closely to passenger outcomes. The following should be included at minimum in monthly reporting to CITT:

- **On-time performance for AM and PM peaks on weekdays and during full day on weekends**: On-time performance in aggregate is currently reported in DTPW's Transit Service Monthly Report, but it does not appear in the report presented to CITT. Firstly, on-time performance should be reported separately for three distinct time periods: AM peak, PM peak, and off-peak periods. Reporting on AM and PM peak periods would provide better insight into customer experience. Data on these three metrics should be displayed on a rolling 12-month basis to determine trends over time.
- **Average realized headway during AM and PM peaks on weekdays and during full day on weekends**: Customer experience is driven partly by reliability of the Metrorail service, which in turn is driven by average waiting time. Average headway is a strong proxy for the average wait time that a passenger may experience to board a train, and it should be displayed separately for AM and PM peak periods on a rolling 12-month basis to view trend over time.
- **Percentage of days that peak vehicle requirement (PVR) is met**: Average fleet availability is currently reported, but this does not clearly illustrate the frequency of days when PVR is not achieved; the ability of Metrorail to meet PVR is a driver of both on-time performance and average headway. This should be reported on a monthly basis and displayed on a rolling 12-month basis to view trend over time.
- **Percentage of maintenance positions filled**: The number of vacancies in skilled technical maintenance positions is not currently reported upon, and it is a driver of DTPW's ability to adequately maintain Metrorail vehicles and systems. The vacancy rate for key positions such as train control (position 8060), traction power (position

[40] https://transitalliance.miami/campaigns/transit-audit.

8061), and Vehicle Electronics (position 8068) should be reported upon on a rolling 12-month basis to view trend over time.

- **Train control failures over time**: The Transit Service Monthly Reports show data on train control failures and train control disruption incidents over time, but these are not reported to CITT. Given how critical the train control system is to the safety and effective functioning of Metrorail, it is important that external stakeholders have access to data on train control failures and train control-related disruptions, which should be displayed on a rolling 12-month basis to view trend over time.
- **Breakdown of service disruptions**: The Transit Service Monthly Reports display service disruptions due to all causes and vehicle-specific causes. This should be reported to CITT on a rolling 12-month basis to view trend over time, and it should be broken down by source of cause to determine whether disruptions are being caused by vehicle maintenance, maintenance of train control, maintenance of track & guideway, etc.
- **Number of stockouts issued**: The number of stockouts issued for spare parts is reported in the Transit Service Monthly Report, but it is not reported to CITT. Given the current shortage of spare parts for new vehicles, it is important that leadership and management attention is given to spare parts availability. It is also critical that maintenance staff are encouraged to file requests even if parts are known to be unavailable, to ensure visibility of unmet demand for spare parts, especially for new vehicles. This should be displayed on a rolling 12-month basis to view trend over time.
- **Number of customer complaints related to vehicle cleanliness per month:** Customer complaint data is collected and categorized by DTPW, but it is not reported upon to CITT. The number of complaints by category, focused on cleanliness of vehicles and stations, should be reported to CITT on a monthly basis and displayed on a rolling 12-month basis to view trend over time.
- **Rail vehicle cleaning staff attendance rate by shift:** Vehicle cleaner staff (position 8069) attendance rate, defined as number of staff available divided by the number of staff scheduled, has not been reported upon in either Transit Service Monthly Reports or in reporting to CITT. It is a major driver of DTPW's ability to clean vehicles on a regular basis and should be reported upon by shift to CITT on a rolling 12-month basis to view trend over time (as in *Figure 15* of this report).

A sample table showing the recommended metrics to include in a revamped monthly report is displayed below:

Metric	Monthly value	12-month average
Service performance		
On-time performance (AM peak)		
On-time performance (PM peak)		
On-time performance (weekends)		
Average actual headway (AM peak)		
Average actual headway (PM peak)		
Average actual headway (weekends)		
Percentage of days that PVR is met		
Service disruptions by cause		
Train control failures		
Number of train control mainline failures		
Number of train control overall failures		
Number of train control service disruption incidents		
Vacancy rate		
Vacancy rate for train control (position 8060)		
Vacancy rate for traction power (position 8061)		
Vacancy rate for vehicle electronics (position 8068)		
Parts stockouts		
Number of parts stockouts issued		
Percentage of all work orders for which there was a parts stockout		
Cleaning performance		
Number of customer complaints by feedback (FB) subtype for "EM-DirtyVeh" and "EM-Insects"		
Vehicle cleaner attendance rate by shift		

8 RECOMMENDATIONS

The Team has formulated its recommendations based upon the observations and analysis outlined in this report, which fall into three major categories: labor practices, maintenance practices, and budgeting:

Labor practices

1. DTPW should have the ability to recruit rail maintenance and other skilled positions based on minimum qualifications instead of through a strictly seniority-based method to ensure that skilled and capable technicians are working on mission-critical systems such as train control, traction power, and vehicle electronics systems.
    a. DTPW should try to negotiate changes to the bargaining unit agreement with TWU to allow for the recruitment of technical maintenance positions outside of the union if there are not qualified TWU members that can meet the minimum qualifications.
    b. Failing a more holistic renegotiation of the bargaining unit agreement, DTPW should at least push to include a cap on the number of transfers that an employee can make within a given time-frame, subject to feasibility under existing labor laws and arrangements, to dissuade uncommitted employees from beginning maintenance training programs.
2. Unfilled rail maintenance positions, including supervisory positions that are not bound by the TWU contract, must be promptly filled with qualified staff.
3. DTPW should consider whether vehicle cleaning should either be outsourced or vehicle cleaners should be recruited externally to attract motivated employees who will consistently attend their scheduled shifts.
4. Additional cleaners should be hired, especially at terminal stations, given the deterioration of cleanliness that is observed during service.

Maintenance practices

5. Key performance indicators (KPIs) should better define and be more closely linked to critical outcomes, including safety and passenger experience; specific recommendations on important KPIs to track are made in the Performance Metrics section of this report.
6. EAMS implementation should be prioritized and executed as soon as possible for new Metrorail vehicles. It should include the ability for maintenance supervisors, DTPW leadership, and other relevant stakeholders to perform quantitative analysis on common maintenance characteristics such as time-series measurements and readings and parts failure history on individual vehicles.

a. In general, Metrorail should move away from paper-based inspection forms to electronic entry of data directly from the technician and provide for technicians and their supervisors to have real-time data on vehicle and right-of-way maintenance and status for individual vehicles up to the entire fleet.
b. DTPW should clarify that maintenance records can be maintained in electronic format with the FTA.
c. As an interim step, DTPW could enter the maintenance reports into an electronic system and, in parallel, continue to produce hard copy reports and scan them into the EAMS system.
d. Individual vehicle configurations should be tracked and continuously updated in EAMS to ensure version control of parts, design modifications, software/firmware, and other relevant attributes of new vehicles.

7. Hitachi vehicle manuals should be finalized as soon as possible, and preventive maintenance inspection forms should be clearly linked to relevant sections in such manuals, which should also be kept in electronic format. The procedures applicable to previous vehicle or assembly configurations should also be discussed in the manuals, as long as such prior configurations continue to exist.
8. There should be adequate spare parts available for new vehicles and Metrorail systems more broadly, especially train control, to ensure vehicle availability and system safety and reliability, and multiple suppliers should be used to ensure that parts remain available for the foreseeable future in the event that individual suppliers stop making compatible parts.
9. A mid-life overhaul plan for Hitachi vehicles should already be part of the long-term maintenance and funding plans to prevent new vehicles from eventually deteriorating to the condition in which Metrorail's Budd vehicles are currently. This is consistent with the FTA's recommendation in their Triennial Review.[41] This recommendation also applies to other critical support systems, such as, but not limited to, train control, to ensure continued safety and reliability of Metrorail service.

Budgeting

10. Future year budgets should be realistic, include all foreseen costs, and give adequate resourcing to maintenance functions that require additional capacity; at minimum, budgets should use actual spending of the prior year as a starting point.

[41] DTPW has indicated that a Life Cycle Cost Analysis (LCCA) is a New Vehicle Contract Deliverable from Hitachi. The updated LCCA is due soon and will be provided for budgeting.

Next Steps

The Team recommends following an action plan that prioritizes addressing the most critical deficiencies in the near- to medium-term (within the next 30 days to 6 months) while continuing to address other issue areas in the longer term (within 1 year):

Address immediately (within 30 days)

- Minimum qualifications requirement for all new technical employees in rail maintenance, including vehicle electronics, traction power, and train control technicians
- Additional spare parts availability for train control system and new vehicles, in accordance with Hitachi contract terms
- Redefinition of key performance indicators (KPIs) to more closely align reports from DTPW with safety outcomes and passenger experience

Address in the medium term (within 3-6 months)

- Finalization of Hitachi vehicle manuals and linkage to PM inspection forms, including specific procedures for different vehicle configurations in use
- Vehicle cleaning practices (i.e. whether to outsource) and hiring of additional cleaning staff or contractors at terminal stations
- Realistic annual budgeting for rail maintenance, accounting for past actual spending

Address in the long term (within 1 year)

- Digitization of all maintenance records into quantifiable / analyzable modules within EAMS, fully moving away from paper-based inspection and maintenance forms
- Mid-life overhaul plan for Hitachi vehicles

DTPW has been relying on the People's Transportation Plan surtax to subsidize operations and maintenance expenses, replacement of rolling stock, and infrastructure renewal costs. While the Team did not analyze this issue in detail, there is concern about whether this historic reliance on surtax funds will lead to future budgetary shortfalls as surtax funds become increasingly tied to debt service payments associated with transit expansion, such as implementation of the SMART Plan. The Administration and Board of County Commissioners must be prepared to provide greater financial support from non-surtax funding sources to adequately maintain, operate, and upgrade the system over time.

The Team's most important takeaway is that, while Metrorail is attempting to adequately maintain its system in the short-term, it is not prepared to effectively maintain new vehicles and ensure safety of critical systems, such as train control, in the short, medium- and long-term. Our recommendations should provide DTPW with guidance on priorities in order to achieve Metrorail's safety and performance objectives for the foreseeable future.

9 APPENDIX - PEER COMPARISON

This section summarizes the results of our peer benchmarking exercise, comparing Metrorail's performance on key metrics to that of its peers. Metrorail is one of 15 systems operating a heavy rail transit network in the United States. While each system has unique characteristics, it is also possible to select similar systems based on qualitative factors, such as vehicle manufacturer (e.g. Baltimore's use of Budd vehicles), and quantitative factors, such as the number of unlinked passenger trips (UPTs), vehicle revenue miles and revenue hours, track length, etc. We are then able to compare Metrorail's performance on a variety of key metrics to relevant peers and determine areas for improvement in cost and productivity.

Taking Metrorail's input into account, the Team has identified seven relevant peers in the United States (using 2017 NTD data, the latest year available) and one relevant international peer – Rotterdam, Netherlands. These peers were chosen based on similar attributes as described above (e.g. vehicle type, trip volume, and network length). The Team generally omitted systems that were significantly larger than Metrorail, though we have included Bay Area Rapid Transit (BART) per DTPW's input into the process. We display and discuss the results of the peer benchmarking analysis by category of performance metric below. All bar and line charts are displayed in descending order of value; if there are two categories of data displayed on the same chart, the systems are ordered by the value of the first (left-most) category of data displayed.

9.1 Peer system characteristics

MDT's Metrorail is a relatively small heavy-rail system compared with major peers. At roughly 20 million unlinked passenger trips (UPTs) per year, Metrorail experiences about 30% of the traffic of MARTA and only about 15% of the traffic of BART. Data on UPTs is shown in *Figure 27*. Similarly, as shown in *Figure 28*, Metrorail's vehicles ran for about 8 million vehicle revenue miles in 2017 when compared with 22 million at MARTA and 75 million at BART.

Figure 27: Unlinked Passenger Trips (UPTs) in 2017

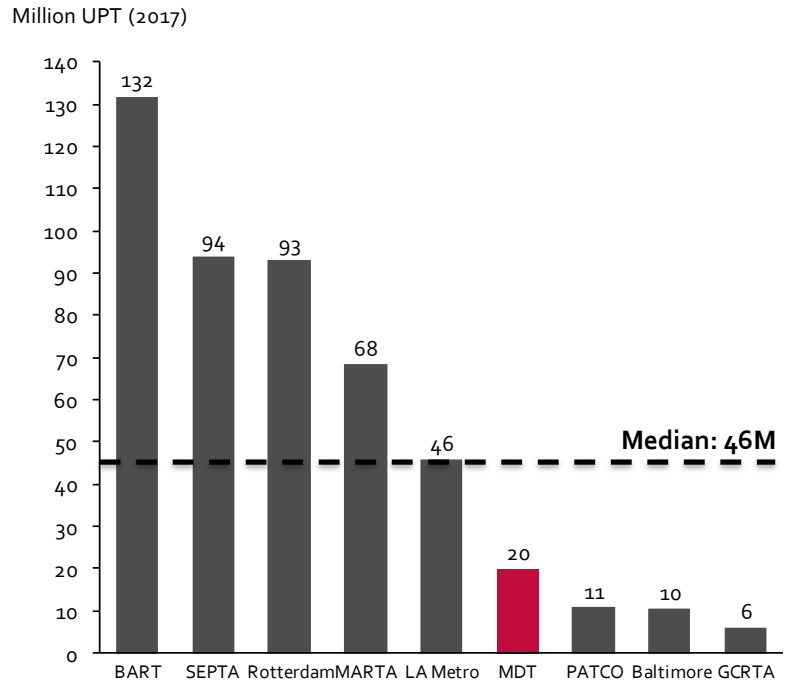


Figure 28: Vehicle Revenue Miles in 2017

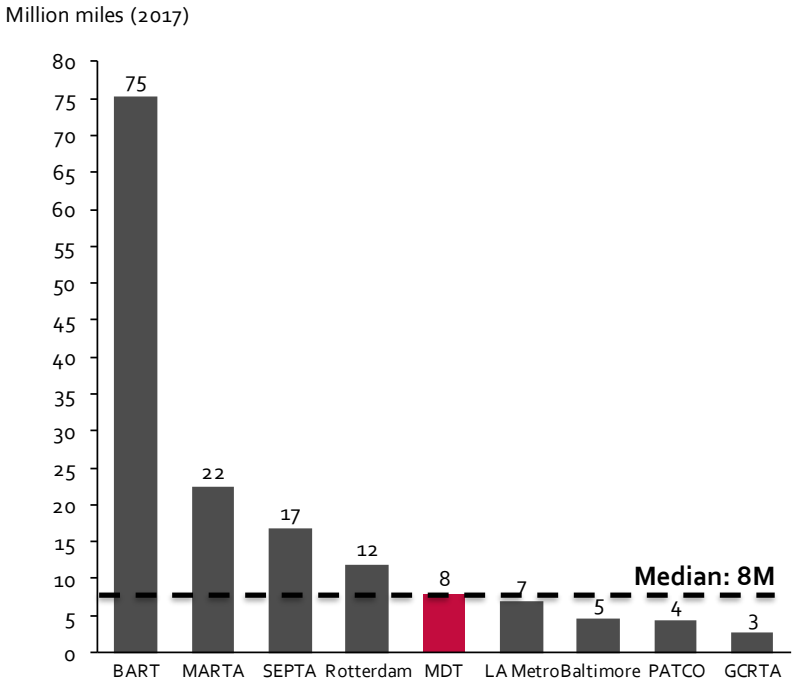
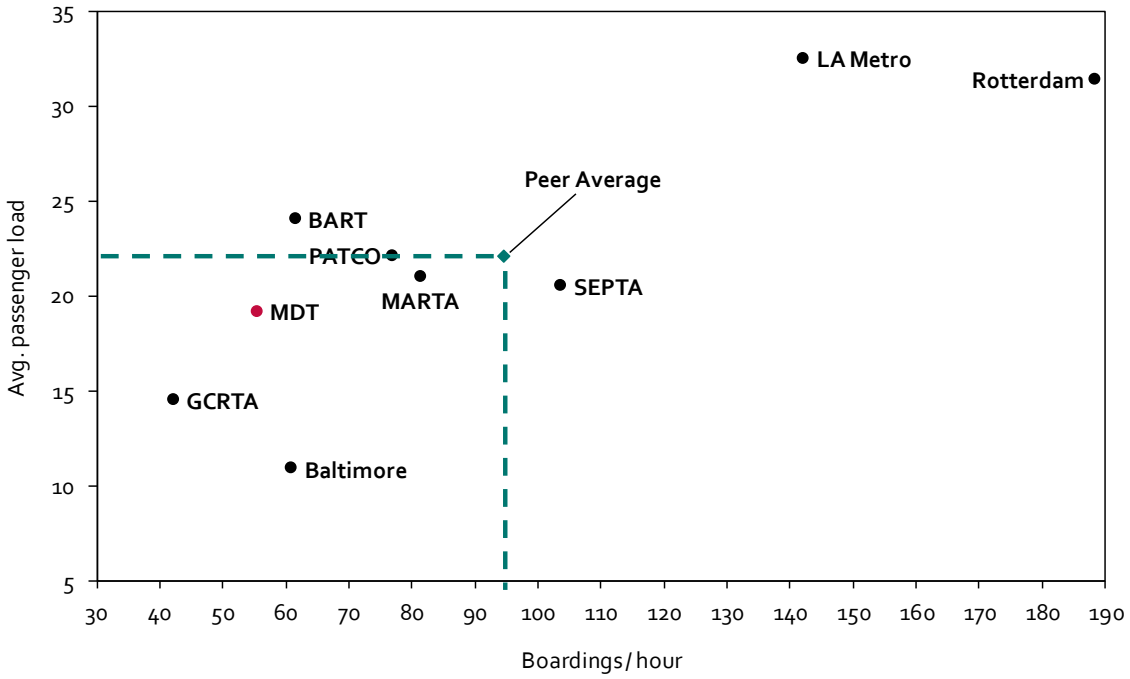


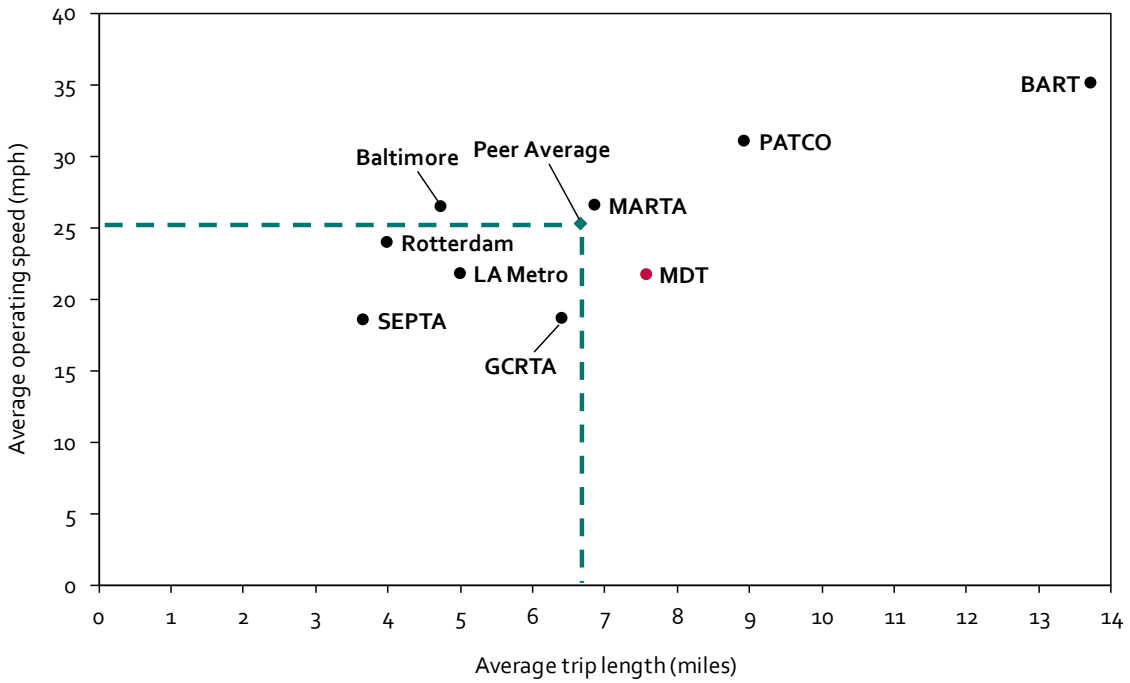
Figure 29: System Utilization of Peers in 2017[42]



Metrorail also experiences lower system utilization rates compared to peers. *Figure 29* displays system utilization. In 2017, Metrorail vehicles had an average passenger load of roughly 19, while peers such as MARTA, SEPTA, and BART all experienced higher average load. Similarly, Metrorail sees roughly 55 unlinked trips per revenue hour, while some peer systems see 100+ passengers boarding per hour.

[42] Average passenger load is calculated as follows: passenger miles / vehicle revenue miles. Boardings per hour is calculated as follows: unlinked passenger trips / vehicle revenue hours.

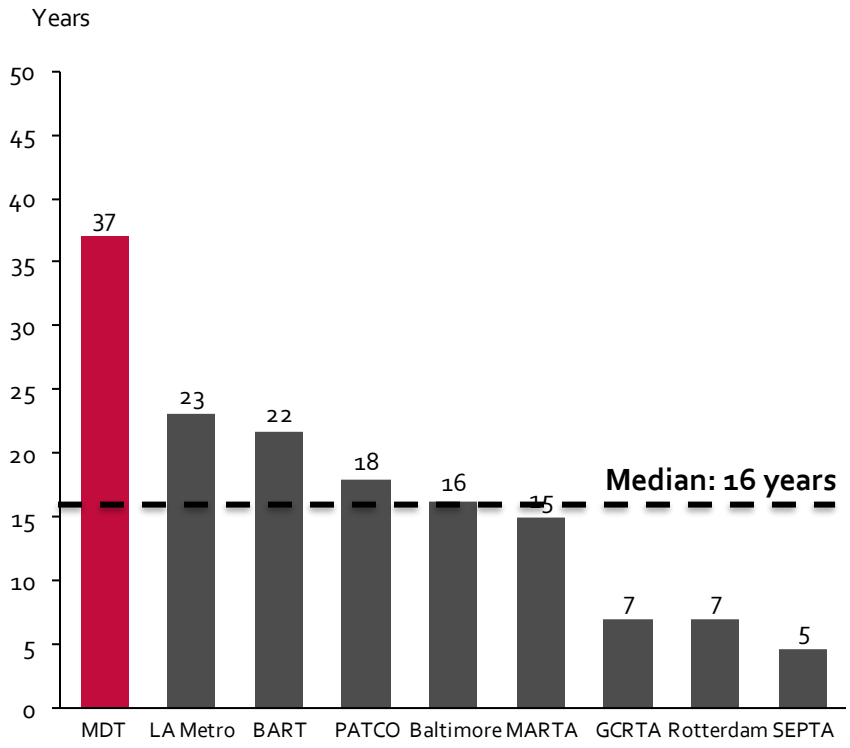
Figure 30: Average Operating Speed versus Average Trip Length in 2017[43]



Nevertheless, Metrorail's average trip length is higher than the peer average. The average trip length was 7.6 miles in 2017, while peer systems generally see lower trip lengths, as shown in *Figure 30*. This may reflect varying geographies and levels of urban concentration depending upon the peer system under consideration.

[43] Average operating speed is calculated as follows: vehicle revenue miles / vehicle revenue hours. Actual operating speeds may be higher. Average trip length is calculated as follows: passenger miles / unlinked passenger trips.

Figure 31: Average age of vehicles since last mid-life overhaul (as of 2019)*

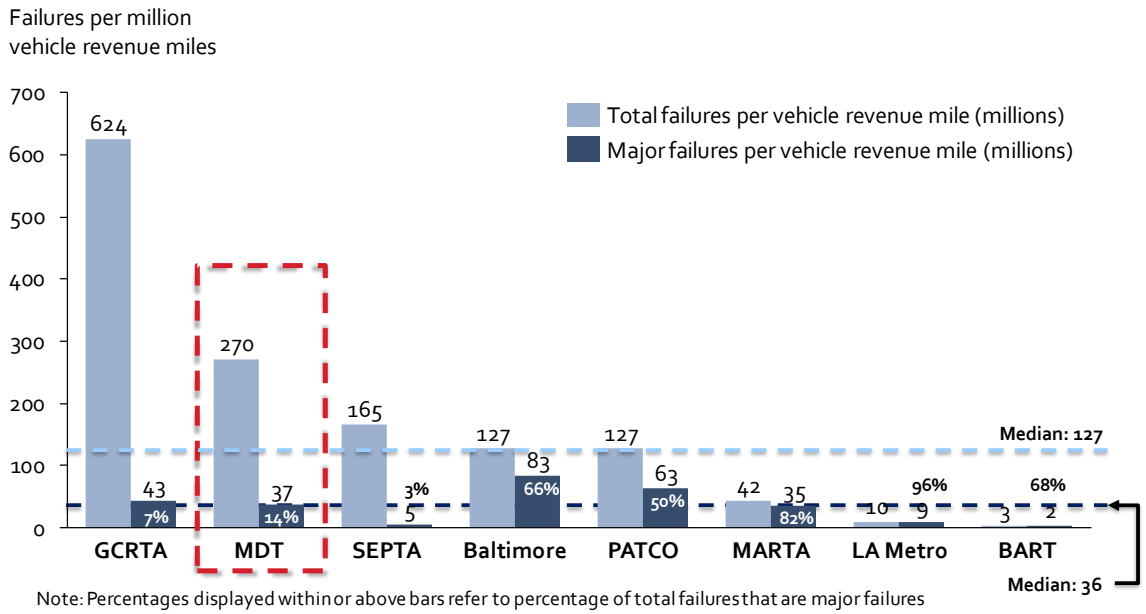


*Year of manufacture is used if there have been no mid-life overhauls

Lastly, Metrorail's vehicles in 2017 were significantly older than peer systems, largely due to the lack of any mid-life overhaul of Metrorail's Budd vehicles. *Figure 31* displays average vehicle age by peer system. At 37 years of age, Metrorail's vehicles are much older than the next oldest, LA Metro, with an average vehicle age of 23 years since original procurement of their vehicles — LA Metro has also not yet rebuilt their vehicles. Nevertheless, this will change dramatically in 2019 and 2020 as Metrorail's Hitachi vehicles progressively replace all Budd vehicles.

9.2 Failure analysis

Figure 32: Failures by peer agency in 2017[44]



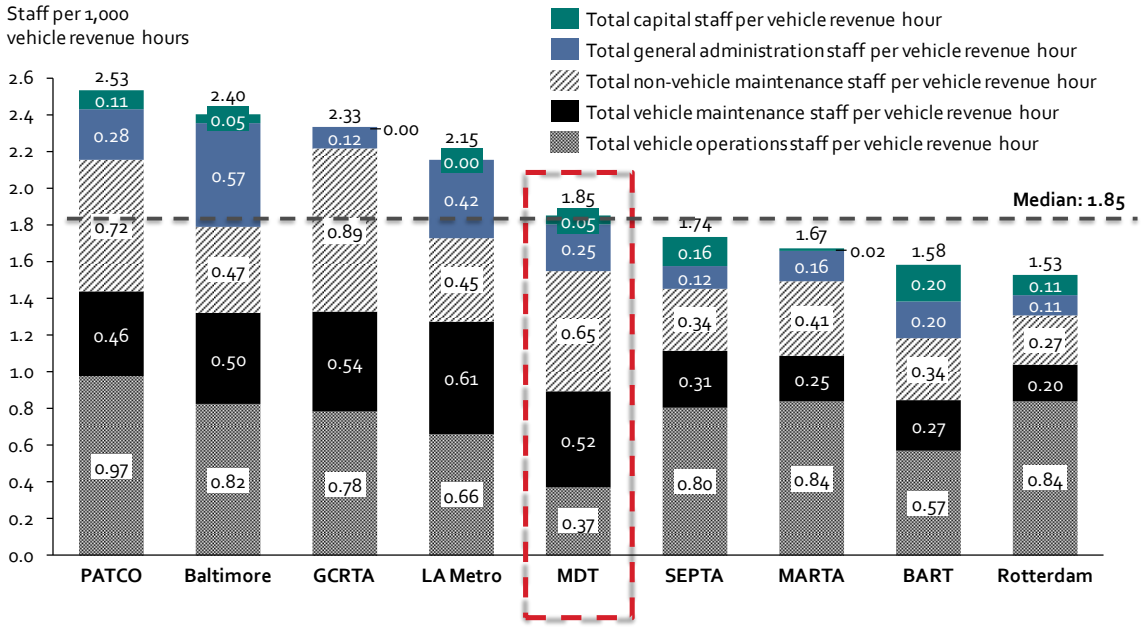
Note: Percentages displayed within or above bars refer to percentage of total failures that are major failures

Metrorail's total failure rate per million vehicle revenue miles is 2nd highest among peers, though the major failure rate is close to the median to peers. *Figure 32* displays failure data across peer systems. Major failures are defined by NTD as mechanical failures that prevent a revenue vehicle from completing or starting a scheduled trip (either due to physical impairment of the vehicle or safety concerns). Total failures include failures that, due to agency policy, prevent the revenue vehicle from completing or starting a scheduled trip even if the vehicle is physically able to. Given that both definitions may be subject to interpretation (especially on total failures), data reported to NTD on failures may not be consistent from agency to agency, making it difficult to draw a definitive conclusion. Nevertheless, the data on total failures in particular indicates that Metrorail may need to improve overall maintenance performance in order to mitigate the occurrence of failures.

[44] Failures per million vehicle revenue miles is calculated for both total and major failures as follows: (major or total mechanical failures reported to NTD / vehicle revenue miles) * 1,000,000.

9.3 Staffing levels

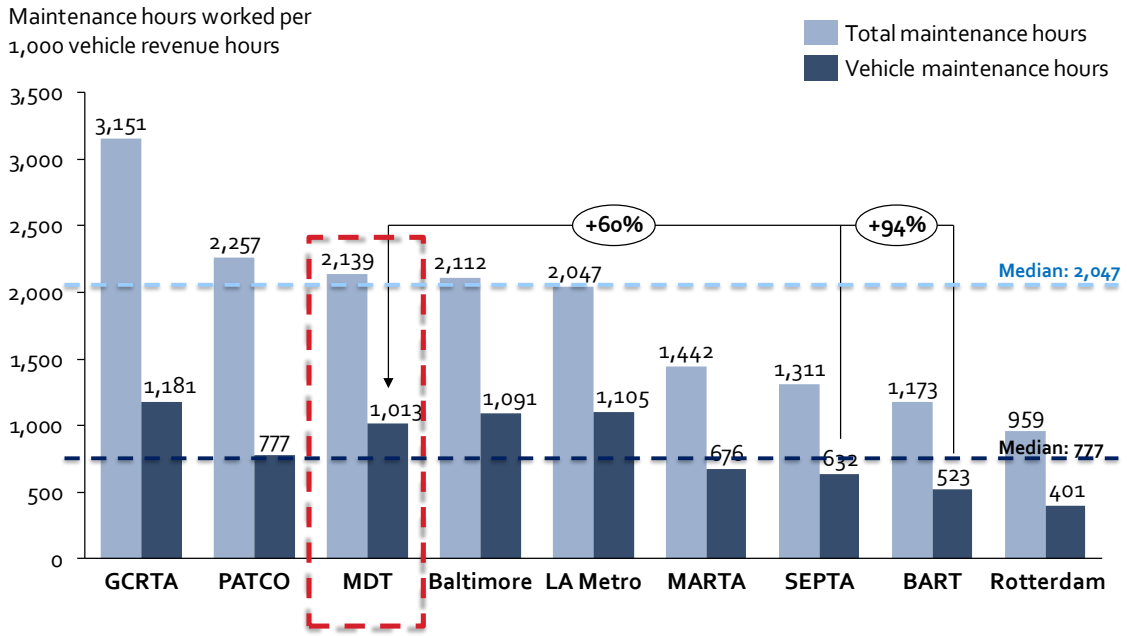
Figure 33: Staffing levels (2017) by peer system[45]



Metrorail's overall staffing levels are comparable with peers, though vehicle maintenance staffing levels are higher than most peers. *Figure 33* shows staffing levels across peer systems. Metrorail had 1.85 staff per 1,000 vehicle revenue hours in 2017, compared to 2.4 in Baltimore and 2.33 at GCRTA. While this is roughly at the median of peers, three peers (SEPTA, MARTA, and BART) have lower overall staffing levels than Metrorail. On vehicle maintenance staff specifically, Metrorail has the third-highest staffing level (0.52 vehicle maintenance staff per 1,000 vehicle revenue hours) in its 8-system peer group and roughly double the staffing level of BART and MARTA (at 0.27 and 0.25 vehicle maintenance staff per 1,000 vehicle revenue hours respectively) and 2.6x Rotterdam's level. The same is true for non-vehicle maintenance staff, where Metrorail had 0.65 staff per 1,000 vehicle revenue hours compared with 0.34 at BART and SEPTA. Despite having higher staffing levels, the Team's findings discussed elsewhere in this report suggest that current staffing is inadequate to properly maintain Metrorail, likely due to the presence of unqualified staff in maintenance roles.

[45] Staff per 1,000 vehicle revenue hours is calculated for each staffing category as follows: [(total full-time + part time staff by category) / vehicle revenue hours] * 1,000

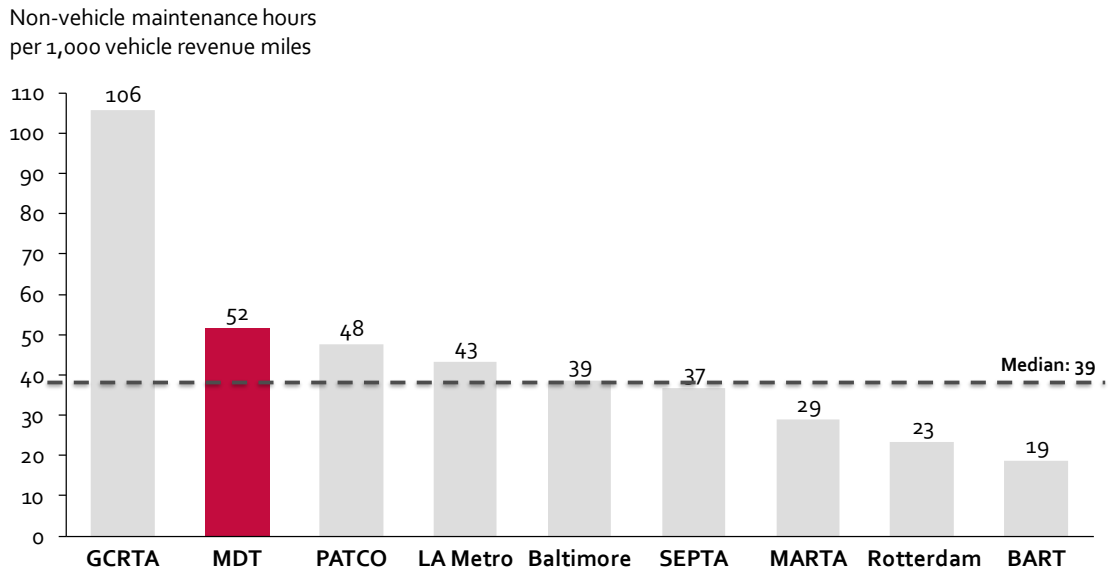
Figure 34: Vehicle and total maintenance hours (2017) per vehicle revenue hour[46]



When looking at maintenance labor hours, a similar picture emerges of Metrorail. Maintenance staff worked roughly the median number of total maintenance and vehicle maintenance staff hours per vehicle revenue hour (the medians are 2,047 and 777 hours respectively), as shown in *Figure 34*. The MDT system trailed MARTA, SEPTA, and BART in productivity, with BART and MARTA using roughly half the number of vehicle maintenance staff hours per vehicle revenue hour in 2017 (and Rotterdam even less).

[46] Maintenance hours per 1,000 vehicle revenue hours is calculated for both total and vehicle maintenance as follows: (total or vehicle maintenance hours worked as reported to NTD / vehicle revenue hours) * 1,000.

Figure 35: Non-vehicle maintenance hours (2017) among peer systems[47]

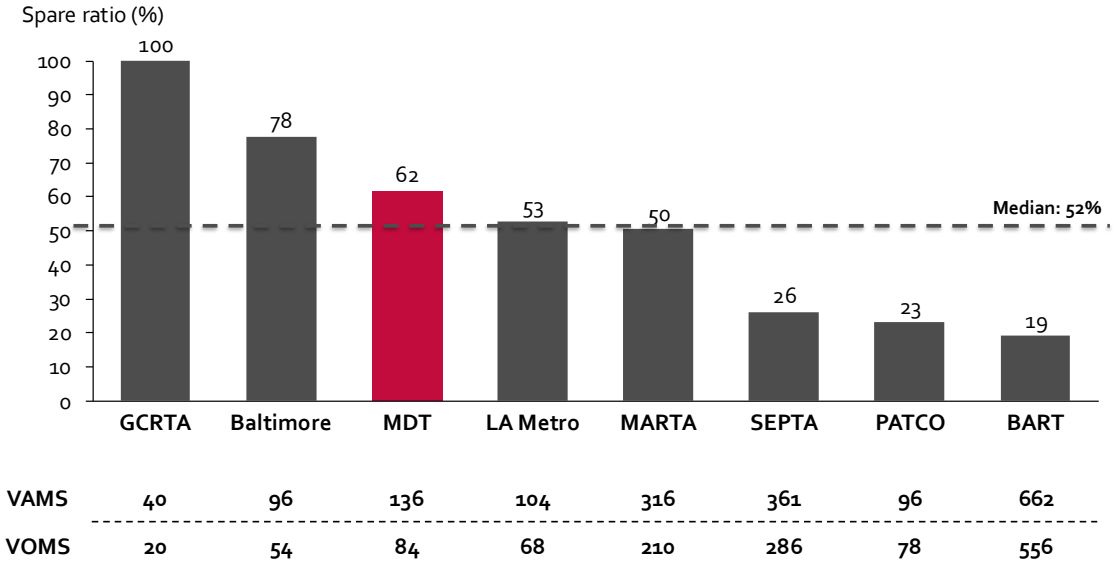


DTPW staff hours worked on non-vehicle maintenance is 2nd highest among all peer systems. Non-vehicle maintenance hours, such as those spent on track and guideway maintenance, is likely driven more by the vehicle revenue miles instead of hours. As shown in *Figure 35*, Metrorail's non-vehicle maintenance staff worked 52 hours per 1,000 vehicle revenue miles in 2017, compared to a peer median of 39 and BART's 19 hours per 1,000 vehicle revenue miles.

[47] Non-vehicle maintenance hours per 1,000 vehicle revenue miles is calculated as follows: (non-vehicle maintenance hours worked as reported to NTD / vehicle revenue miles) * 1,000.

9.4 Spare ratio

Figure 36: Spare ratio (2017) for peer systems



	GCRTA	Baltimore	MDT	LA Metro	MARTA	SEPTA	PATCO	BART
VAMS	40	96	136	104	316	361	96	662
VOMS	20	54	84	68	210	286	78	556

Metrorail operated at a relatively high spare ratio in 2017 when compared with peers. Spare ratio by system is displayed in *Figure 36*. The spare ratio is a measure of the additional capacity available for peak service (as measured by the percentage of extra vehicles available). The relevant terms to calculate spare ratio are: Vehicles Available for Maximum Service (VAMS) and Vehicles Operated in Maximum Service (VOMS). The formula is defined below:

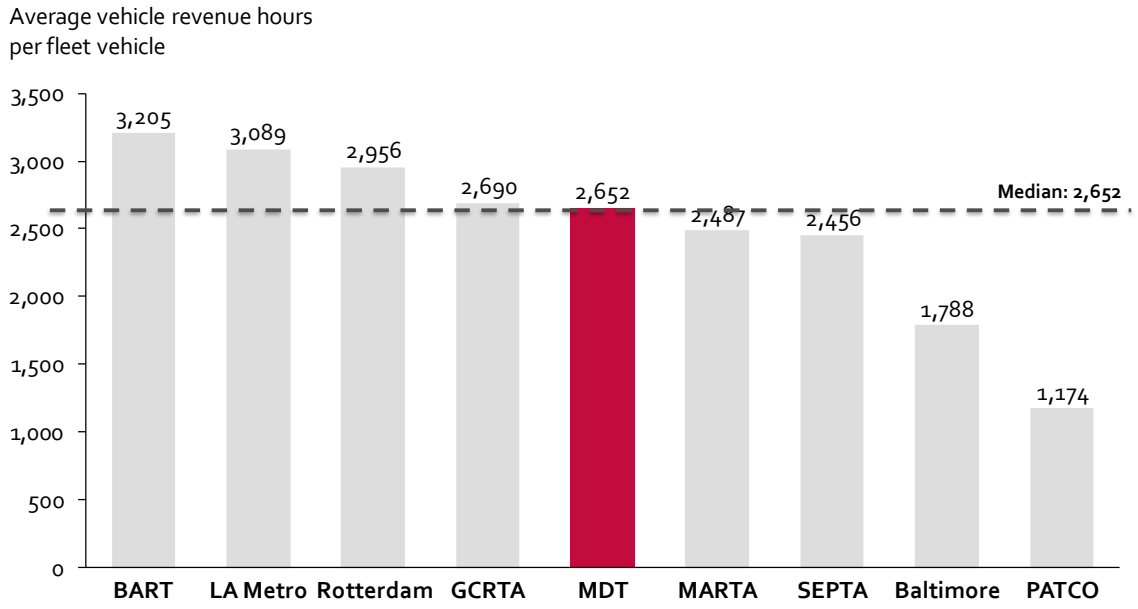
$$\boldsymbol{Spare\ ratio} = \frac{VAMS - VOMS}{VOMS}$$

While a high spare ratio may indicate that peak service can be reliably met due to the availability of excess vehicle capacity, it can also indicate that a system is holding on to a high number of out-of-service vehicles or is taking a long time to return vehicles to service that need maintenance. In MDT's case, the Team has noted low mean vehicle availability (45% for Peak AM service in September 2018 and only 20% for Peak PM service), which may contribute to a higher spare ratio. The Team has also heard anecdotal evidence suggesting some Budd vehicles have been "cannibalized" due to parts unavailability. Therefore, many spares are likely not in working condition even though they are counted as "available" for service.

Spare ratio was even higher in 2018 than in 2017, at 126%, but this is likely driven by the delivery of Hitachi vehicles and the presence of Budd vehicles as a temporary contingency. Metrorail's NTD submission for 2018 is expected to show 172 vehicles available for maximum

service and 76 operated for maximum service. Therefore, the Team would expect the spare ratio to decline as Hitachi vehicles replace Budd vehicles.

Figure 37: Average revenue hours per vehicle (2017) by system[48]



While Metrorail does not "formally" rotate its vehicles through service to even out mileage or hours, the average vehicle revenue hours run per fleet vehicle is at the median of peers. *Figure 37* displays average revenue hours per vehicle. This may indicate that most of Metrorail's vehicles are used consistently, though more data would be required to verify the vehicle revenue miles and hours per vehicle.

[48] Average revenue hours per fleet vehicle is calculated as follows: vehicle revenue hours / total fleet vehicles.