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INDEPENDENT STATE AUDITOR'S REPORT ON CERTAIN ACTIVITIES OF THE MASSACHUSETTS BAY TRANSPORTATION AUTHORITY REGARDING THE PURCHASE OF GREEN LINE CARS

MAY 1, 2002 TO DECEMBER 31, 2005

OFFICIAL AUDIT REPORT

FEBRUARY 16, 2007

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The passage of the Americans with Disabilities Act (ADA) in 1990 recognized, among other rights, that people with disabilities should have equal access to transit services and facilities that are available to the non-disabled public.

In response to this need to ensure equal access for all patrons, the Massachusetts Bay Transportation Authority (MBTA) commissioned a feasibility study to review impediments to the disabled from accessing its transit system. The results of this study, issued by the MBTA in September, 1990, centered on feasibility investigations for full accessibility for persons in wheelchairs on the MBTA's Green Line. In response to this study, on September 5, 1990, the MBTA Board authorized the General Manager to implement the recommendations of the study, which included utilizing elevators, escalators, ramps, and most importantly the use of low-floor, wheelchair accessible, light-rail vehicles as a means of providing accessibility on the Green Line.

To accomplish the low-floor light-rail vehicle concept, the MBTA Board of Directors voted on February 8, 1995 to award a contract for $215 million to Breda Costruzioni Ferroviarie (AnsaldoBreda) of Pistoia, Italy. Under the terms of the contract, Breda agreed to furnish 100 wheelchair-accessible low-floor No. 8 Green Line cars, provide spare parts, and modify the 115 existing No. 7 Kinkisharyo cars for operational compatibility with these new No. 8 cars.

Our review, which is a follow-up of a prior audit of this contract (Audit No. 2002-0583-3A1) was conducted to determine the overall effectiveness of the MBTA procurement process and oversight over the delivery of these 100 low-floor accessible Green Line cars and the current status of this contract.

The MBTA did not properly oversee the activities of its design and consultant engineers for the purchase of 100 Breda No. 8 Low-Floor Green Line cars initially projected to cost the Authority approximately $215 million dollars in February, 1995. Subsequently, due to design errors, change orders, consultant fees, car derailment problems requiring wheel modification costs, and increased track maintenance expenses, the projected costs to purchase these cars and also ensure against future derailments, will cost the Authority an additional $101 million over the expected 20 year life of these cars.

At the inception of the Breda No. 8 Low-Floor Green Line cars contract, the MBTA could not provide detailed track standards and conditions data necessary for Breda to properly design these low-floor cars to operate on the existing Green Line track infrastructure. This lack of detailed track information played a significant role in the dispute between the MBTA and Breda over whether the derailment issue was caused by car design or track conditions. Moreover, because of design delays at the outset of the contract, the MBTA improperly allowed Breda to combine and accelerate the testing and debugging of the prototype cars prior to authorizing full production of these vehicles by the contractor. These ill-advised decisions by the MBTA directly contributed to the faulty accepted design of these vehicles and their propensity to derail, and ultimately delayed providing their disabled patrons access to these vehicles.

INTRODUCTION

Background

The Americans with Disabilities Act (ADA) of 1990 ensures that all Americans have access to basic transit services. ADA mandated that all self-contained light rail systems built and designed after January 26, 1992 provide level boarding to ensure equal access for wheelchair passengers. Since the Massachusetts Bay Transportation Authority (MBTA) Green-Line stations were built prior to 1992, the ADA allowed these "grandfathered" transit systems to implement Key Station plans that would not require level boarding, but would instead allow for substitute measures such as ramps, lifts, etc. Key Station Plans focus on making the essential station elements accessible. Key Station criteria can be summarized as follows:

- Stations with high passenger boarding (15% above average)
- Transfer stations between transit lines
- Internal transfer stations
- End stations
- Stations serving activity centers

Accordingly, the MBTA, due to the age and nature of its system, could have met the ADA's accessibility requirements through wayside or car-borne-lifts, mini-high platforms, or other means. In order to assess its ADA accessibility requirements for the Green Line, the MBTA commissioned a feasibility study. The results of this study, titled "Light Rail System Accessibility - Final Report", dated September 1990, focused on the feasibility of making the Green Line fully accessible for persons with disabilities, including wheelchair users. The study recommended the use of elevators and ramps to make surface-to-platforms accessible. Platform-to-vehicle options included full platform (high-level) loading, mini-platforms, wayside lifts, on-board vehicle lifts, and low-floor cars.

The following were cost estimates provided in this study for ADA compliance and various alternatives for compliance for the MBTA's Green Line:

Platform to Vehicle Assistance Work Item	Estimated Cost
Full Platforms for High Level Loading	$425 Million to $540 Million
Mini-Platforms for High Level Loading	$125 Million to $185 Million
Wayside Lift to Assist Boarding at Platform	$95 Million to $145 Million
On-board Vehicle Lifts	$140 Million to $180 Million
Low-Floor Cars	$314 Million to $452 Million

Surface to Platform Assistance Work Item	Estimated Cost
Elevators	$15 Million to $25 Million
Ramps	$75 Million to $125 Million
Vertical Platform Lifts	$15 Million to $30 Million
Inclined Platform Lifts	$25 Million to $50 Million
Wide-Step Escalators	$30 Million to $60 Million
Inclined People Movers	$80 Million to $140 Million
Inclined Elevators	$20 Million to $39 Million

On September 5, 1990 the MBTA Board of Directors authorized the General Manager to proceed with the low-floor cars, elevators, and ramps as a means of providing accessibility on the Green Line.

To implement the low-floor car portion of the approved accessibility plan, on February 8, 1995 the MBTA board approved a contract for $215 million to Breda Costruzioni Ferroviarie (now AnsaldoBreda) of Pistoia, Italy, to furnish 100 low-floor No. 8 Green-Line cars with spare parts and to modify the existing No. 7 Kinkisharyo cars for operational compatibility with the new No. 8 cars. The modification of the No. 7 fleet became necessary in order to fulfill the ADA requirement of at least one accessible car per multiple car train. In addition to accommodating persons with disabilities, the MBTA envisioned that these new No. 8 cars would eventually replace the aging Boeing-Vertol fleet and provide improved passenger access, automatic station announcements, and extensive operational and diagnostic repair information.

Currently, the MBTA has been working to bring its 80 identified Key Stations into compliance. To date, 50 Key Stations comply with accessibility guidelines. In addition, all 119 MBTA stations (including 69 Non-Key stations) are deemed accessible under ADA requirements.

Request for Proposal

On February 18, 1994, the MBTA released Request for Proposal (RFP) No. CAP-44-93 for the furnishing and delivery of 100 low-floor accessible cars, spare parts, and No. 7 car compatibility

modifications. The RFP was based on a competitive negotiation process, where price was weighted at 90% and product quality was rated at 10%.

Four car builders responded to the RFP, and after preliminary evaluations of price and product quality, Breda was ranked first with a bid of $243.1 million. Subsequently, the MBTA entered into competitive negotiations with the four firms allowing for their best and final offer. Breda was again ranked first with a best and final bid of $215.3 million.

Breda's successful low bid of $215,343,946 consisted of the following components:

- Furnishing and delivering 100 No. 8 Green Line low-floor cars: $198,500,000
- Providing specified spare parts: $8,664,894
- Modifying the existing No. 7 Kinkisharyo fleet (115 cars) for operational compatibility with the new No. 8 Breda cars: $8,179,052

Prototype and Pilot Car Program

In anticipation of design and vehicle performance issues and reviews prior to initiating full production of these 100 No. 8 cars, the MBTA's contract with Breda provided for a phased program of production, testing, and debugging of two prototype cars. The primary purpose of this prototype phase was to initiate debugging, proof of testing design, and systems integration testing. The objective was to ensure that the final approved car design would achieve the intended level of vehicle performance prior to producing the remaining 98 cars. The ultimate goal of the prototype cars was to minimize delays in delivery and reduce the chances for costly retrofits to the production cars.

Upon completion of successful testing and debugging of the prototype cars, and before delivery of any production cars, Breda was required to deliver two pilot cars, incorporating into their design all the modifications deemed necessary by the MBTA and Breda as a result of the prototype-car program. The pilot program was similarly intended to ensure that all modifications identified during the prototype program would be successfully integrated into the final car design, thereby eliminating costly redesign and modifications once Breda went into full production.

Contract Support Costs

To assist in preparing and reviewing contract specifications and to oversee the procurement, testing and acceptance of the No. 8 low-floor cars, the MBTA executed the following contracts:

Date	Name	Services Provided	Original Amount	Revised (12/31/2005)
02/25/1994	LTK Engineering	Prepare design specifications	$ 650,642	$ 650,642
04/26/1995	Booz-Allen and Hamilton, Inc.	Consultant Engineers	8,236,596	16,933,354
08/23/2000	TTCI	Derailment Consultants-	N/A	217,750
10/22/2001	TTCI	Interim Wheel/Rail Profile	N/A	233,791
8/08/2001	HNTB	Maintenance Standards-Green-Line	N/A	225,000
09/11/2001	HNTB	Track/Interface Wheel profile	N/A	225,000
12/21/2000	Holland & Knight	Legal Services	N/A	1,100,000
03/05/2002	Trak-Tech Corp.	Geometry of Right of Way	N/A	170,000
02/23 through 08/08/2002	American Public Transportation Association (APTA)	Peer Review	N/A	18,106
		Total	$8,887,238	$19,773,643

No. 8 Car Derailment

The No. 8 Breda low–floor cars entered limited revenue service in March 1999. However, after experiencing brake performance problems, the MBTA immediately withdrew the No. 8 cars from revenue service until April 2000. From April 16, 2000 to July 10, 2000 four derailments occurred. After the fourth derailment on July 10, 2000, the MBTA again removed the No. 8 cars from service and began an investigation into the derailment problem.

To assist them in their investigation and to determine the cause of these derailments, the MBTA hired Transportation Technology Center Inc. (TTCI) of Pueblo, Colorado to investigate these derailments, determine the cause, and develop recommendations for corrective action to enable these cars to return to service.

After conducting detailed engineering and rail/wheel interface simulation testing of the No. 8 cars and the track where the derailments occurred, TTCI submitted their findings in a February 2001 draft report. The TTCI findings were as follow:

- The No. 8 car is sensitive to reverse curve (S) track geometry.
- Wide track gauge significantly increases derailment risk.

- Derailment potential increases with speeds above 15 mph on reverse curves and above 42 mph on other track geometries.

- The No. 8 car has a design issue associated with the lack of independently rotating wheels of the center truck. The possibility of wheel-flange-climb coupled with the 63-degree maximum flange angle of the Green-Line track was a major factor contributing to the derailments.

TTCI recommended the following as a short term fix to return the No. 8 cars to revenue service:

- The Authority should consider equipping all reverse curves with restraining rails.

- The Authority should implement Class 5 and 6 new Federal Railroad Administration (FRA) 31-foot alignment and surface standards on Green-Line.

- Restrict maximum speed to below 15mph on reverse curves and below 30mph on all other Green-Line track.

On February 23, 2001 the MBTA forwarded the results of the TTCI study to the Breda Project Manager and indicated its willingness to implement the recommended track upgrades on several branches of the Green Line. In turn, the MBTA wanted Breda to address the design issue of the center truck wheel profile, as presented in the TTCI report.

In response, Breda hired Politecnico di Milano to perform an analysis of the derailment issue. The results of that study indicated that the No. 8 car had no discernable design issue and that the derailments were caused by track conditions.

Based on the implementation of track work on the Green Line and a reduction of speed to 30 mph, on April 21, 2001 the MBTA returned 17 of these cars to revenue service on just the B branch of the Green Line.

However, from June 9, 2001 to August 20, 2001, three additional derailments of the No. 8 cars occurred. On August 20, 2001, the MBTA's Safety Department ordered that these 17 No. 8 cars be removed from service effective August 21, 2001.

On August 21, 2001 the Massachusetts Department of Telecommunications and Energy (DTE) deemed the No. 8 derailments "frequent in nature and…critical within the meaning of 220 CMR (Code of Massachusetts Regulations) Section 151.06." Accordingly, DTE ordered the MBTA to investigate the derailment problem and submit a report including a corrective action plan (CAP) by

September 30, 2001. Until the DTE accepted the CAP, the MBTA was prohibited by DTE from returning these low-floor cars to service.

DTE approved the B line CAP and service resumed in March 2003. The C line CAP was submitted in October 2003. The CAP included the following:

- New wheel profile on all No. 8 vehicles.
- Implementation of new track maintenance standard.
- Track upgrades including rail grinding.
- Identification of hot spots.
- Implementation of a new derailment investigation procedure.
- New operating rules and restrictions.
- A plan for future work.

Once again, four derailments occurred following the resumption of service in March 2003. The date, location and preliminary cause of these derailments were as follows:

Date	Location	Cause
05/31/2003	Hynes	Loose Wheel
06/28/2003	Kenmore Loop	Cover Guard Interference
07/07/2003	Riverside Carhouse	Movement of Hoist
09/10/2003	Lake Street	Excessive Speed

The Authority concluded, and DTE agreed, that these derailments were caused either by maintenance issues or driver error and not by recent changes to the wheel profile or track. Therefore the MBTA decided to continue these cars in revenue service.

Breda Corrective Action

Per the Authority's request, Breda submitted a "Green Line Corrective Action Plan" dated August 29, 2001 and a revised version on September 7, 2001. As a short-term measure, Breda proposed a review of the Central Subway track and the correction of all deviations from the standards Breda used for track gauge, alignment, and elevations. Also, Breda would commission a study to review the possibility of track degradation caused by the No. 7 Kinkisharyo cars. As a long-term measure, Breda recommended that the MBTA modify the wheel profile for all No. 7 cars and to limit lateral

vehicle motion. Breda also recommended that the MBTA track maintenance standards incorporate new or modified rail inspection for "side wear" caused by the No. 7 Kinkisharyo cars.

The MBTA's response to the Breda claims was that the No. 7 Kinkisharyo cars were not causing excessive wear on the rails; the No. 7's were not contributing to the derailment issues; and the current track conditions were within the specifications of the original contract. In addition, the MBTA indicated that Breda was aware of the "side wear" issue as early as 1995, yet never indicated to the Authority that this issue would adversely effect the operation of their No. 8 car. Moreover, the Authority pointed out that neither the Boeing or Kinkisharyo cars have ever exhibited operational problems due to side wear of the rails.

Finally, it was the MBTA's belief that the Green Line must operate as a system. Accordingly, each of its components (i.e., the rails, Boeing cars, Kinkisharyo cars, and Breda cars) all will effect the operation of the system to some extent. However, despite these inherent effects, only the Boeing and Kinkisharyo cars continue to operate successfully throughout the entire Green Line system without the need for corrective measures.

Peer-Review Committee

The MBTA requested a peer-review committee of representatives from the American Public Transportation Association (APTA), a non-profit trade association representing transit systems, business members, and government entities. APTA was retained to provide recommendations for operational and design issues related to procurement, management, and future dealings between the MBTA and Breda. The goal of the peer review was to assist the MBTA in safely returning the No. 8 cars to service. Some of the issues that the MBTA specifically requested were:

Operational Issues:

- Acceptance testing
- Use of fleet in revenue service
- Interfaces between the No 7 car and the No. 8 car
- Speed restriction and enforcement procedures

Design Issues:

- Short and long term solutions
- Vehicle truck/track system design compatibility
- Acceptable track standards
- Wheel/rail profile issues
- MBTA resolution process

Maintenance Issues:

- Track standards and procedures
- Maintenance & training program changes
- Identification of track "hot-spots"

The March 2002 APTA final report states, in part, that

> *…the fundamental problem is that the MBTA under-estimated the technical risk involved in introducing a first of its kind, unique and totally unproven car design on a severely limiting and unforgiving infrastructure such as the Green Line.*

Also, the APTA panel agreed with the MBTA staff and TTCI that the combination of the Green Line track profile and the No. 8 car design creates a situation where the car operates at or near the theoretical limit for a derailment.

The panel's recommendations included upgrades to Green-Line track to accommodate the track standards of the Breda Cars as designed and built, a program to optimize the wheel to rail contact angle, and selected speed restrictions. The panel believed that this short-term program would be adequate to return the No. 8 cars to revenue service.

At worst case, the panel believed that the MBTA should develop a contingency plan incorporating extensive redesign of the center truck section of all 100 Breda No. 8 cars. The panel estimated that this redesign could take at least two years and may cost $250,000 to $500,000 per car, or $25-$50 million in total.

The peer review found, at its exit conference, that the MBTA had taken a sound approach in returning the No. 8 cars to limited service. The Authority had aggressively met its short-term goals of track work and understanding of the wheel rail profile. However, the panel found that the Authority had not met the long-term recommendations of developing a contingency plan (redesign of the center truck) and an expanded program to allow the unrestricted operation of the No. 8 cars on the entire Green Line system. The panel reiterated its belief that any associated costs incurred to implement these long-term recommendations should not be the sole responsibility of the MBTA, but rather should be apportioned between the MBTA and Breda.

Track Modifications; Enhanced Track Maintenance Standards; and Interim Wheel Profile

The MBTA, per the recommendations of its consultants TTCI, HNTB and APTA, implemented track modification work; new track maintenance standards; and redesigned interim wheel profile on its No. 8 and No. 7 cars to discourage wheel climb derailments. Moreover, these recommended track modifications were intended to reduce the high rail wear pattern caused by the existing wheel profile. The MBTA had to address this unacceptable wear pattern so that the re-profiled wheels with modified flange angles would not continue to scar and wear the track profile at the current 63 degree derailment prone angle.

The estimated costs associated with these interim track modifications were, as follows:

Green-Line Track Work/Modification Per TTCI Recommendations (Projected)	Estimated Costs
B - Commonwealth Ave Line	$ 4,305,722
C - Beacon Line	1,608,600
D - Highland Branch	18,928,800*
E - Huntington Ave Line	5,288,000
Rail Grinding Invoiced by ARM	4,100,000
Total	$34,231,122

*****The DTE would not allow the MBTA to run the No. 8 cars along the Highland Branch (D) Line until the track infrastructure was brought into service grade condition. Projections for this work included the following:

16 Strap Guard rail locations	$ 28,800
Tie and rail renewal - Riverside to Fenway	18,900,000
Estimated total	$18,928,800

Currently, the MBTA has expended approximately $12 million on these No. 8 track work related items.

The APTA report also recommended that the Authority update its standards for inspection and maintenance of the Green Line track because of the sensitivity of the No. 8 cars to track irregularities. Recommended new maintenance standards would include:

- Grinding support
- Surfacing and lining
- Geometry car support
- Rail renewal
- Restraining rail bolt tightening operations

The MBTA has projected that adopting these new maintenance standards would increase its Green Line track maintenance costs by approximately $7.3 million in year one of these new standards, plus $7.5 million each year thereafter, for the life of these Breda cars. The breakdown of these additional annual maintenance and inspection costs for year 2 and thereafter were projected by the MBTA as follows:

Maintenance: Labor and Materials	$6,000,000
Inspection	800,000
Contract Services	700,000
Total Annual Increased Costs	$7,500,000

Interim Wheel Profile (IWP)

The APTA report believed that the ultimate solution to the derailment problem was a combination of Green Line track changes and the No. 8 car design changes. The MBTA aggressively implemented the modifications for the IWP at their Riverside car house. This modification to the IWP was intended to increase the No. 8 car wheel flange angle from 63 degrees to 75 degrees. This modification was proposed by the MBTA's consultant, TTCI, and supported by APTA. It was hoped that this redesign would increase the margin of safety against flange climb derailments. As a result, the MBTA had to retrofit the 115 existing No. 7 Kinkisharyo cars currently in service to this new 75 degree standard. The estimated costs to perform these modifications were, as follows:

Interim Wheel Profile Estimated Costs

Materials – No. 7 and 8 Wheel Modifications	$2,115,000
Force Account	910,000
No. 7 Suspension Upgrades - 209	924,800
Total	$3,949,800

Preliminary Liquidated Damages

Section C, Part 8.03 of the contract between the MBTA and Breda provides for the assessment of liquidated damages to be imposed if Breda fails to perform the work within the required time allotted and within the parameters of certain technical specifications. Specifically, liquidated damages may be assessed for the following:

- Weight: when the weight of the car, fully equipped, exceeds the specified weight by more than 500 pounds (maximum penalty computed at $10 per pound, times the excess weight)
- Delivery: $500 per car, per day beyond the delivery dates as specified in the contract for pilot and production cars

The maximum total liquidated damages that can be assessed per the terms of the contract is 5% of the contract cost per car, or $100,000 per car, and $10 million in total.

The delivery start date for production cars was to be November 10, 1998, or 42 months after the Notice to Proceed of May 5, 1995. Per the contract, the cars were scheduled for delivery at the rate of 4 to 6 cars per month, with the 100th car scheduled to arrive 67 months after the Notice to Proceed, or December 12, 2000.

As of December 31, 2005, or approximately 10.5 years after the Notice to Proceed, Breda had delivered only 46 of the 100 contracted cars. Therefore, the Office of the State Auditor (OSA) determined that liquidated damages, computed per the contract terms but not assessed, total over $83 million, which exceeds by $73 million the maximum eligible penalty that can be assessed under the contract.

Current Contract Status

As of April 30, 2002, the MBTA had stopped accepting delivery and testing of the No. 8 cars pending resolution of the cited center truck design as well as completion of the proposed Green Line track upgrades. However, it was Breda's position that the MBTA had improperly issued a stop work order and also improperly suspended acceptance of the cars pending resolution of the derailment issue. Breda indicated to the MBTA that it intended to seek compensation for all relevant and ongoing damages incurred by them and their sub-contractors as a result of the MBTA actions. Accordingly, on August 15, 2002, Breda submitted a claim for increased costs and delays to the MBTA in the amount of $43,480,000.

In response to this claim, the MBTA prepared a similar multi-million dollar list of damages suffered due to contract nonperformance by Breda, including additional costs for consultants, engineering studies, track upgrades, and additional vehicle testing time and expenses.

After protracted negotiations between the parties, Breda agreed to participate in the process of instituting a new wheel profile for the No. 8 cars. In return, the MBTA agreed not to direct Breda to stop assembling the remaining cars, in an attempt to minimize any future claims that Breda might have, since the business decision to continue assembly was made solely by Breda.

On December 15, 2005, the MBTA and Breda entered into an Interim Settlement Agreement (ISA) meant to resolve the contractual differences and claims for the No. 8 cars. It was agreed that Breda's $43,480,000 claim for damages and the MBTA's counterclaim would be waived between the parties. The intent of this ISA was to finally achieve successful operation of these No. 8 cars in accordance with the contract specifications; reduce future costs and delays for implementation of these cars to revenue service, and achieve a final close-out for this contract, with the last car scheduled for delivery no later than January 1, 2007.

Since executing the ISA, twenty-seven (27) new vehicles have been delivered, bringing the total number of vehicles delivered to seventy-five (75). Reliability has improved, and Breda is on target to meet its schedule to complete all No. 8 low-floor vehicle deliveries in early 2007.

Audit Scope, Objectives, and Methodology

Our audit, which covered the period May 1, 2002 to December 31, 2005, was conducted in accordance with applicable generally accepted government auditing standards for performance audits as issued by the Comptroller General of the United States, and included such procedures and tests considered necessary by the OSA to meet those standards. The purpose of this audit is to follow up on our prior audit (No. 2002-0583-3A1) of the MBTA's purchase of Green Line cars and associated track work and car modifications. The objectives of this audit were to review the following:

- MBTA's compliance with competitive bidding requirements.
- Contract costs incurred, including approved change orders.
- Operational and safety issues encountered.
- Steps taken by the MBTA to resolve operational issues, including consultant reports assessing options for corrective action and estimated costs.
- Penalties eligible to be levied for delays under the contract and the current revised estimated contract completion date.
- Legal proceedings between the parties and current contract status.

Our methodology included reviewing 1) MBTA's RFP bids and evaluations for the selection of the contractor(s) for track survey work, track modification work, and consultants hired to redesign the center truck wheel flange; 2) contract costs and approved change orders; 3) consultant reports commissioned by the MBTA; 4) legal claims and counter claims filed; and 5) contract correspondence and policies and procedures for monitoring contractor activities. In addition, we interviewed responsible MBTA officials.

Our review indicated that, except as noted in the Audit Results Section of this report, the MBTA had complied with applicable laws, rules, and regulations for the areas audited.

AUDIT RESULTS

1. THE MBTA'S INABILITY TO ENSURE THAT THE NO. 8 LOW-FLOOR GREEN LINE CARS WERE PROPERLY DESIGNED FOR THE GREEN LINE INFRASTRUCTURE WILL COST THE AUTHORITY APPROXIMATELY $101 MILLION IN ADDITIONAL CONTRACT AND TRACK MAINTENANCE COSTS

The Massachusetts Bay Transportation Authority (MBTA) did not properly oversee the activities of its design and consultant engineers for the purchase of 100 Breda No. 8 Low-Floor Green Line cars initially projected to cost the Authority approximately $215 million in February, 1995. Subsequently, due to design errors, change orders, consultant fees, car derailment problems requiring wheel modification costs, and increased track maintenance expenses, the projected costs to purchase these cars and also ensure against future derailments, will cost the Authority approximately $101 million additional over the expected 20 year life of these cars.

In an attempt to identify a cause for these cars derailing, the MBTA retained the American Public Transportation Association (APTA), to review the vehicle design; adequacy of testing; wheel profile and proposed modifications; current track conditions; and current and proposed track maintenance standards. APTA concluded that the MBTA underestimated the technical risks involved in introducing a first of its kind and totally unproven car design that these low-floor cars represented, on such a severely limiting infrastructure such as the Green Line. Specifically, they concluded that the car's center truck as designed, which included stub axles with independently rotating wheels, combined with the current wheel flange/track contact angle created a situation where these No. 8 cars operated at or near the theoretical limit of derailment when run on the current Green Line track infrastructure.

To address these operational safety deficiencies, the APTA report recommended that the Authority update its standards for inspection and maintenance of the Green Line track because of the sensitivity of the No. 8 cars to track irregularities. Recommended new maintenance standards would include:

- Grinding support
- Surfacing and lining
- Geometry car support
- Rail renewal

- Restraining rail bolt tightening operations

In order to determine the actual track work needed to prevent these No. 8 cars from derailing, the Authority hired Transportation Technology Center Inc. (TTCI) of Pueblo, Colorado to conduct a survey of actual Green Line track conditions, identify potential "hot spots" for derailment, and recommend actions to be taken, both short-term and long-term, by the MBTA. The results of this survey indicated that for the short-term, the MBTA should install restraining rails on all reverse curves with a radius less than 2,000 feet and lengths less than 300 feet; implement new track alignment standards; reduce maximum speeds to 30 miles per hour; and perform track modeling to ensure that the No. 8 cars have acceptable performance for the track profiles, as designed. Long-term recommendations included the design and implementation of a new wheel/rail profile to provide an acceptable margin of safety from flange climb derailment and adoption of new track alignment standards. Future suggested work included acquiring new track geometry data for the entire Green Line to identify all derailment "hot spots" in order to develop an acceptable MBTA speed profile.

In addition to the substantial costs incurred by the Authority to study and attempt to remedy the derailment problems with these cars, the MBTA has incurred additional costs for authorized extra work change orders during the initial production of these cars. Finally, the Authority is also expected to incur substantial ongoing maintenance and track work expenses needed to ensure the safe operation of these cars over their useful life. As of December 31, 2005, the MBTA either has incurred, or per its consultants' estimates and in-house departmental estimates, may incur, the following additional expenses over the 20 year projected useful life of these No. 8 cars:

Extra Work Item	Additional Cost
Approved Change Orders	$ 6,636,819 (Actual)
Consultant Fees	10,886,405 (Actual)
Wheel/Profile Changes	3,949,800 (Estimate)
Track Modifications	34,231,122 (Estimate)
New Track Maintenance Standards	45,000,000 (Estimate)
Total Additional Costs	$100,704,146

Because the MBTA did not properly oversee the activities of its design and consultant engineer to ensure that the wheel/rail interface for these low-floor No. 8 cars was compatible with its Green Line infrastructure, the MBTA may incur as much as $101 million in additional costs over

the next 20 years in order to ensure that these low-floor cars operate safely on the Green Line track.

Recommendation

To improve its procurement efficiency and cost effectiveness, the MBTA should:

- Improve communications between its various user departments and procurement departments during the design-specification phase in order to reduce the need for change order work negotiated after the contract has been awarded.

- Ensure that adequate pre-design testing and accurate track geometry data for existing track conditions are available and utilized during the design phase for all revenue vehicle procurements. A properly designed vehicle for the existing track infrastructure is vital to the safety of its passengers and the success of each vehicle procurement.

Auditee's Response

The MBTA purchased low floor vehicles to achieve its goal to improve transit service and meet the ridership needs of persons with disabilities. As the first transit system in the nation to introduce low floor cars onto a mature light rail infrastructure, the MBTA faced many challenges during its procurement of the No. 8 car. This was new technology, which had not previously been deployed on a system with the characteristics of the Green Line. Many lessons were learned during the process, by all parties, including the wisdom of consistent maintenance and investment in track infrastructure and the need for better understanding of existing track conditions through infrastructure studies in advance of any rail car procurement. The end result is, however, a safe, dependable, and accessible vehicle.

The actual incremental cost for contract and track maintenance charges directly related to the No. 8 car are estimated at $54 million over the life of the fleet, when routine system maintenance costs are excluded and actual cost savings achieved through innovative approaches are considered. This figure, when added to the cost of the Breda contract, is substantially below the lowest figure originally budgeted for the entire procurement.

- *The $101 million figure, described as "additional contract and track maintenance costs." includes significant capital infrastructure and routine track maintenance costs unrelated to the No. 8 vehicle and is also based on outdated information. Therefore, the figure is inflated. Based on actual costs incurred over the years since introduction of the new track maintenance standards, the MBTA estimates that the correct figure should be $54 million.*

- *The original budget for the Low-Floor cars, as stated on page 2 of the OSA Audit Report, was estimated between $314 million and $452 million. Even after adding additional costs incurred above the $215 million contract sum with Breda, the total cost of the procurement remains well below this range.*

- *The increased cost per year to maintain the track for the benefit of the No. 8 is now projected at $1,000,000 annually. Therefore, the total of increased costs for track*

should be corrected in line with the revised, experience based projections, to $20 million.

- *The No. 8 car procurement was a challenging project from its inception due to the introduction of new vehicle technology on an aging track infrastructure. The MBTA was the first North American transit agency to adopt this innovative approach to serve disabled riders.*

Auditor's Reply

Contrary to the MBTA's assertions, the estimate of additional expenses to be incurred by the Authority over the 20-year useful life of these vehicles is both accurate and conservative. The major difference between our estimate and the MBTA's estimate lies in the actual reason for the reconstruction of the D Line to Riverside. It should be noted that currently the No. 7 and Boeing cars are operating on this line, while the No. 8 cars have been restricted by the DTE and the MBTA from operating on this portion of the Green Line track. Therefore, we think it reasonable to assign the major cost of reconstructing this Line to the acquisition of the No. 8 cars. The Authority contends that none of these costs should be associated with the No. 8 cars and these costs are simply a result of overdue reconstruction of this track infrastructure. However, the $18.9 million estimated to complete this track work might ultimately prove to be too low. Moreover, the MBTA's current accounting system does not identify maintenance costs by individual lines (i.e. Red, Blue, Orange, Green, Silver) but rather by the entire system. They then judgmentally prorate these costs to each Line, with 27.5% being the current portion charged to the Green Line. This inability to match actual maintenance costs to work locations may impair the Authority's ability to ever know what actual increased costs they are incurring due to these No. 8 cars now and in the future. Finally, we agree with the MBTA that this was a technologically unique procurement, and we reiterate the need for the Authority to improve its communications between departments to reduce unnecessary and costly work change orders and redouble their efforts to ensure that all its vehicle specifications are prepared using current and accurate track data for all future vehicle procurements.

2. THE MBTA DID NOT ADEQUATELY PLAN AND TEST THE NO. 8 LOW-FLOOR CARS, THEREBY CONTRIBUTING TO A DERAILMENT FLAW THAT CAUSED A SIGNIFICANT DELAY SERVICING ITS DISABLED PATRONS

At the inception of the Breda No. 8 Low-Floor green Line cars contract, the MBTA could not provide detailed track standards and conditions data necessary for Breda to properly design these low-floor cars to operate on the existing Green line track infrastructure. This lack of

detailed track information played a significant role in the dispute between the MBTA and Breda over whether the derailment issue was caused by car design or track conditions. Moreover, because of design delays at the outset of the contract, the MBTA improperly allowed Breda to combine and accelerate the testing and debugging of the prototype cars prior to authorizing full production of these vehicles by the contractor. These ill-advised decisions by the MBTA directly contributed to the faulty accepted design of these vehicles and their propensity to derail, and ultimately delayed providing their disabled patrons access to these vehicles.

Green Line Track Data

The MBTA during the pre-award stage (1991-1994) provided Breda with sketches and information on Green Line track design. However, theses sketches and track standards did not reflect the entire Green Line infrastructure, but rather gave an overview of the system. Correspondence between the MBTA and Breda reflected mutual concerns over: wheel profiling, lateral wear, prior derailments and track irregularities that occurred during the pre-award stage.

Of particular significance was Breda's request for critical track information of extreme vertical and horizontal curves at Lechmere Station and other worst-case locations to use for reference in the car design. The MBTA responded that

> *…We cannot locate track layout drawings for worst case curve locations and that accurate dimensions of the absolute worst case scenarios were difficult to obtain, therefore you should proceed with the existing track information of worst case alignments (different locations and requirements than requested).*

In those cases where the MBTA track irregularities data were unavailable, it was agreed by the MBTA and Breda that these unknown track conditions were, for vehicle design purposes, to be deemed similar to track conditions that existed on similar lines such as Washington D.C., Los Angles, and San Francisco. In fact, prior to the design phase, Breda received permission from the MBTA to use the "San Francisco Line Geometry Data" and worst case track irregularity data computed using VAMPIRE Rail Vehicle Dynamics Software, an internationally-recognized railway vehicle dynamic simulation modeling program, instead of the actual track geometry of the Green Line, which was unknown to the MBTA at the time. To compound this ill-fated decision, the VAMPIRE program did not include a model for vehicles such as the No. 8 cars, which have independently rotating wheels in the crucial center-truck portion of the vehicle.

Documentation indicated that the MBTA and Breda had continuing dialogue after the contract award date regarding track warp, reverse curves, center truck design, and No. 7 Kinkisharyo cars compatibility and lateral stability issues. On June 9, 1995, for example, the MBTA could not provide dimensions of the worst case reverse curves, and Breda, in the absence of that specific information, evaluated two different scenarios rather than actual track data. On November 9, 1995, the MBTA, in a letter to Breda, raised concerns over the lack of steering of the center truck. Because the center truck would be guided primarily by flange contact on the rail, the MBTA was concerned with the following issues:

- Risk of derailments due to high lateral forces
- Excessive flange wear on the center truck and increased rail wear
- An increase in noise by the flange to rail contact

Breda, in turn, voiced their concern to the MBTA that some European design concepts had delivered appalling performance on certain North American systems.

Ultimately, the MBTA authorized Breda to base their design for these No. 8 cars on the limited track data that was available during the design phase, VAMPIRE computer modeling, and previously designed European cars. The Final Report of the American Public Transportation Association (APTA) Peer Review Panel for derailment issues involving No. 8 cars, dated October 2, 2002, concluded that:

> *the MBTA did not have essential standards that could be practically implemented for inspection and maintenance of Green Line track and the fact that such a standard was not provided to Breda as a basis for car design at contract inception played a significant role in the cause of derailment….*

Prototype and Pilot Testing

Because the MBTA was introducing a unique low-floor design to its Green Line system, the contract specifications called for an 18-month testing and debugging period prior to full production. The testing period was broken down into a two-phase program consisting of 12 months of testing on two prototype cars, followed by 6 months of testing on two (modified prototype) pilot cars.

Correspondence between the MBTA and Breda revealed that on September 21, 1998, the MBTA approved the reduction of the testing period from 18 months down to 13 months. Breda had made this request to accelerate lost time in scheduled milestone payments. This revised testing period considered all four car prototypes, eliminated the pilot cars, and forgave eligible liquidated damages based on the original specified testing period. The reduction and combined testing period eliminated an important debugging phase and condensed the testing time period by 40%. This reduction in the testing and the fact that the four prototype cars were tested primarily between midnight and 5 a.m. before the heating of the track may have contributed to the inability of the MBTA to detect the derailment issues associated with these cars.

The peer review by APTA dated April 3, 2002 concluded that:

> *the fundamental root of the problem is that the MBTA under-estimated the technical risk involved in introducing a first of its kind, unique and totally unproven car design on a severely limiting and unforgiving infrastructure such as the Green Line…. The MBTA followed standard rail transit industry procurement practices. Unfortunately, that practice can lead to big problems for new unproven designs that involve technical risk.*

The report went on to conclude that:

> *normal rail transit procurement is not adequate for a unique first of its kind car design employed on the infrastructure of an old center city rail transit line. As a result the acceptance testing process did not anticipate a vehicle operating at the verge of the theoretical limit of derailment.*

The result of improperly allowing Breda to proceed with the full production of these contracted vehicles without ensuring the safe and acceptable operation of the cars on the existing Green Line track infrastructure is a direct contributing cause as to why it has taken over 10 years to procure these cars, and why they are still not fully operational and available for use by the Authority's disabled patrons.

Recommendation

In order to ensure that this type of flawed procurement does not occur again, the MBTA should require that a comprehensive system of Pilot/Prototype cars with a strict plan for testing and debugging be a mandatory part of all future vehicle procurements. The order to proceed with the full production of any future vehicles must be based on the satisfactory completion of this

two-phased testing plan. Moreover, the Authority should ensure that all future pre-award planning include obtaining all required data necessary for a successful vehicle design. Finally, the Authority should redouble its efforts to return all cars to revenue service as soon as possible for the convenience of its disabled patrons and the comfort of all its passengers.

Auditee's Response

The MBTA has adopted changes derived from "lessons learned" on this project including, for example, performing an Infrastructure Compatibility Study in advance of its procurement of the No. 12 vehicles for the Orange Line. A similar action is planned for the procurement of cars to replace the No. 1 Red Line fleet.

- *Consolidation of the prototype and pilot programs did not cause or contribute in any way either to the derailments or any failure to detect a "derailment flaw" in either the track or the vehicle. The prototype and pilot vehicles (4 in total) covered significant mileage in test and revenue service before any derailment occurred. Such mileage (including more than 30,000 miles in actual revenue service) is significantly higher than would accrue during a typical prototype testing program, where a single car would be limited to less than 75 miles a night.*

- *The derailments occurred in each case on Green Line track that did not meet industry and MBTA standards "after" introduction of the vehicle into revenue service.*

- *<u>During</u> the design phase, in the absence of other suitable data within the industry, the MBTA agreed to Breda's proposed use of "worst case" data from elsewhere in the U.S., and in the Vampire model. The Vampire model used during design of the No. 8 car <u>did</u> model independently rotating wheels, and was, at the time, the best, if not only, available model of such configurations.*

- *While prototype testing took place mostly between midnight and 5 am, the 30,000 miles of revenue service covered by the initial fleet before the first derailments was accrued during the heat of the day, providing ample further opportunity to detect any derailment issues.*

- *The testing period overlapped with revenue service, such that the true prototype test period was much longer than the 18 months originally anticipated in the contract.*

Auditor's Reply

We acknowledge the Authority's revisions to its procurement practices based on the "lessons learned" from the No. 8 cars' infrastructure compatibility issues. This is a major improvement in its vehicle design and track specifications planning and review process. However, we reiterate the importance of ensuring that a comprehensive system of Pilot/Prototype car testing and debugging remains an integral part of all future revenue vehicle procurements. Accordingly, we urge the Authority to forbid any combining or shortening of this vital testing period prior to authorizing the manufacturer to proceed with the full production of any contracted vehicles.

Adherence to this process should minimize the risk of a repeat of the No. 8 cars initial performance issues.