



STAFF REPORT ACTION REQUIRED

Procurement Authorization Amendment to Modify Toronto Rocket (TR) Trainsets to Accommodate One Person Train Operation

Date:	July 11, 2016
To:	TTC Board
From:	Chief Executive Officer

Summary

The Toronto Transit Commission's Five Year Corporate Plan includes the implementation of One Person Train Operation (OPTO) which will be implemented on all subway lines. The SRT Line 3 has operated under OPTO mode since opening in 1985.

A change directive was authorized to Bombardier Transportation Canada Inc. (Bombardier) in the amount of \$2,734,822.98 including taxes, for the engineering design of a prototype Train Door Monitoring (TDM) system and Correct Side Door Enable (CSDE) system on a Toronto Rocket (TR) train for a functional test.

A contract amendment in the amount of \$2,260,893.46 followed for the installation of the prototype TDM and CSDE systems on a TR train.

On February 18, 2016, a test of the TDM and CSDE systems were successfully conducted at Bessarion Station on Line 4 using a 4-car TR trainset. Based on this successful demonstration, it is planned to modify six 4-car TR trainsets on Line 4 for OPTO implementation in 2016. This would be followed by implementation of 76 x 6-cars TR trainsets for OPTO implementation on Line 1.

A contract amendment to Bombardier in the amount of \$38,463,069.25 CDN, inclusive of all applicable taxes, is required for these modifications to the TR train fleet.

Recommendations

It is recommended that the Board authorize:

1. A contract amendment to Bombardier, in the amount of \$38,463,069.25 CDN, inclusive of all applicable taxes, for the installation of the TDM and CSDE on the entire TR fleet of 82 trains to facilitate OPTO operation on Line 4 and Line 1.

Financial Summary

To proceed with the One Person Train Operator initiative, work must be completed both on-board the subway trains and on the subway platforms. The current approved 2016-2025 Capital Budget includes \$68.7 million for this work as shown in the table below. Current estimates are that only \$62.6 million will be required to complete this work yielding a reduced estimated final cost of \$6.1 million. These changes will be reflected in the 2017-2026 Capital Budget submission.

<u>Train Door Monitoring</u>			
	Current	Proposed	Change
	2016-2025 CB	2017-2026 CB	
	(\$ millions)	(\$ millions)	(\$ millions)
2.3 Communications (Subway Platforms)	12.2	12.8	0.6
4.16 Subway Car Overhaul (Trains)	56.5	49.8	(6.7)
Total EFC	68.7	62.6	(6.1)

The present Line 4 workforce roster is 30 train operators for 7 days/week service. OPTO will reduce the train crew size by 50% to 15 operators by changing from 2 crew members (operator and guard) to one crew member (operator only). However, four additional crew members would be required for a single step back at Sheppard Station after each round trip. The step back helps provide resilience to the train service schedule, by compensating for the additional time required for an operator to walk from one end of train to the other at both end terminals. Under OPTO the roster will be 19 operators with a reduction of 11 crew members. The average cost of an operator is approximately \$103,400/year including fringe benefits. A reduction of 11 crew members will result in an annual savings of \$1,137,400.

The roster for Line 1 is 359 operators for a 7 days a week operation. OPTO will reduce this number by 50% to 180 operators. An additional 10 crew members will be required for stepbacks at Vaughan and Finch Stations for the 7 day week. Under OPTO the roster will be 190 operators with a reduction of 169 crew members. This will result in an annual cost savings for Line 1 of \$17,474,600.

The total annual labour savings for both Lines 4 and 1 would equal \$18,612,000.

Return on Investment (ROI)

The return on investment or ROI calculation is based on the total cost for the Train Door Monitoring project of \$62.6 million.

The ROI is calculated as the gain on investment less cost of investment divided by the cost of investment; or by the following formula:

$$\text{ROI} = (\text{gain on investment} - \text{cost of investment}) / \text{cost of investment}$$

Applying the figures from Lines 4 and 1 above to the ROI formula from years 1 to 4 yields the following:

$$\text{ROI (year 1)} = (18.6 - 62.6) / 62.6 = -70\%$$

$$\text{ROI (year 2)} = (37.2 - 62.6) / 62.6 = -41\%$$

$$\text{ROI (year 3)} = (55.8 - 62.6) / 62.6 = -11\%$$

$$\text{ROI (year 4)} = (74.4 - 62.6) / 62.6 = 19\%$$

Conclusions

- A positive return on investment is achieved in year 4.
- The fleet modifications for the TDM and CSDE will be launched in 2016. It will take 3.5 years to complete.
- From the above ROI calculations, when OPTO is rolled out on Line 1 around 2019 after ATC project, it is possible to achieve positive returns sooner than 4 years. ATC is targeting to finish installations on Line 1 in 2019.
- In addition to the opportunities of redeployment to the station duties, it is expected that any surplus workforces could be absorbed by the new extensions of Eglinton Crosstown and Finch West Light Rail Transit.

As Line 4 is first to be migrated to OPTO, the operator roster is small and any surplus operators can be easily redeployed within Subway. The second deployment of OPTO on Line 1 has a much larger operator roster. To encourage union support, TTC would be prepared to manage the train crew reduction from two to one person through attrition (retirements and resignations), transfers and promotions within TTC and future service improvements.

The Chief Financial & Administration Officer has reviewed this report and agrees with the financial impact information.

Accessibility Issues

Toronto Rocket trains are fully accessible and active consultations with the Advisory Committee on Accessible Transit (ACAT) will be continued.

Decision History

In September 2006, the TTC awarded a contract to Bombardier in the amount of \$674,787,602.52 for the purchase of 39 TR trainsets to replace the existing H4 and H5 subway vehicles that were approaching the end of their service life. Minutes of the meeting are available on the TTC website. Refer to agenda item 4 in the following link:

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2006/Sept_20_2006/Minutes/index.jsp

In June 2010, the Board approved the execution of Option 1(B) in the amount of \$317,212,249.73 in the contract for the purchase of 21 TR trainsets to replace the H6 subway vehicles, which were also approaching the end of their service life. And the Board approved Option 1(A) in the amount of \$162,708,071.30 for the purchase of 10 TR train sets to support the Toronto York Spadina Subway Extension (TYSSE) program. Minutes of the meeting are available on the TTC website. Refer to agenda item 5b in the following link:

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2010/June_2_2010/Minutes/index.jsp

In July 2010, the Board approved a contract amendment for the ATC Integration on 70 trainsets in the amount of \$34,784,863.92. ATC will help towards increasing overall system capacity and improving operational performance. ATC utilizes continuous communication between each train and the trackside to accurately monitor and control the movement of all trains along the Line 1. Minutes of the meeting are available on the TTC website. Refer to agenda item 5c in the following link:

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2010/July_14_2010/Agenda/index.jsp

In November 2011, the Board approved Spares, Special Tools and Test Equipment (Option 1(A) and 1(B) Trainsets) in the amount of \$28,000,000.00. Minutes of the meeting are available on the TTC website. Refer to agenda item 5a in the following link:

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2011/November_23_2011/Agenda/index.jsp

In March 2014, the Board approved the execution of Option 1(C) in the amount of \$216,788,870.00 for the purchase of 10 TR trainsets to address revised forecasts of future ridership levels, as well as the increased levels of service that will be achievable with Automatic Train Control (ATC). Minutes of the meeting are available on the TTC website. Refer to agenda item 5a in the following link:

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2014/March_26/Agenda/index1.jsp

In July 2014, the Board approved the retrofit of the TR fleet with low ceiling handholds in the amount of \$4,309,070.81 and the external door chimes in the amount of \$10,936,249.61. The total of the two changes was \$15,245,320.42 including all applicable taxes. Additionally, the settlement of items was made totalling \$14,781,041.02 as a result of the commercial settlements with Bombardier, resulting in a net increase of \$464,278.58 including applicable HST. Minutes of the meeting are available on the TTC website. Refer to agenda item 5c in the following link:

http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2014/July_23/Agenda/index.jsp

In October, 2014, Contract Amendment # 47 was issued for installation of ten De-Icing Systems on 5 trainsets for a total amount of \$8,346,654.19 including applicable taxes. This expenditure was included in the Project Change Requests (PCR) calculation of allowances in Appendix I of Board Approved execution of Option 1(C) report 5a above.

In March 2015, the Board authorized a change directive to Bombardier in the amount of \$2,734,822.98, including taxes, for the engineering design to facilitate the modifications of TR trainsets for a TDM system as part of OPTO. The report described the conversion of 6-car TR trainsets to 4-car trainsets that would be the subject of a future Board report. Minutes of the meeting are available on the TTC website. Refer to agenda item 5a in the following link:

https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2015/March_26/Agenda/index.jsp

In March 2015, Contract Amendment #52 for the TDM Prototype – Phase 1 was executed in the amount of \$2,260,893.46. The work covered installation of TDMS onto Trainset TS10 as a working prototype in order to test onboard components and prove system functionality could be achieved.

In May 2015, Contract Amendment #53 for the ATC Driverless Train Operation DTO Modifications (80 trainsets) was executed in the amount of \$1,176,072.96.

In June 2015, the Board approved a contract amendment to modify four TR trainsets from six cars to four cars to run on Line 4 in the amount of \$38,310,282.54. Minutes of the meeting are available on the TTC website. Refer to agenda item 13 in the following link:

https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2015/June_22/Agenda/index.jsp

In November 2015, the Board approved a contract amendment to retrofit the subway fleet with Pre-Boarding Announcement (PBA) in the amount of \$11,762,510.13. This forms part of TTC's long-term commitment to achieve a transit system which is accessible to customers of all abilities by 2025, and modify one TR trainset as a pilot for the proof-of-

concept, as well as to supply the materials required to subsequently retrofit all T1, TR, and SRT trains. Minutes of the meeting are available on the TTC website. Refer to agenda item 10 in the following link:

https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2015/Nov_23/Agenda/index.jsp

In May 2016, Contract Amendment #59 for the Non-ATC Mode Operation (82 trainsets) in the amount of \$1,984,182.22 was executed. The works entailed train modifications for non-ATC mode of operation. This was achieved by creation of an Emergency Manual Restricted (EMR) Mode which will non vitally enforce a speed limit on the TRs under non-ATC mode operation in CBTC (Communications-Based Train Control) territories.

To date, other amendments (design changes etc.) have been carried out as contract amendments which have amounted to \$ 28,270,283.67. These have included works such as vehicle and non-vehicle related changes, safety changes, increase to contract security, HVAC reheat functionality, friction brake, AODA blue colored seats, digital cab thermostat, low ceiling handholds and exterior door chimes Option 1c, communication bench test equipment, improve passenger information system, relocation of office trailers at Wilson, water mist fire suppression system Phase 1 and preparation of TR Interactive Electronic Manual.

Table A below outlines the Board approved authority for the contract with Bombardier including the current amendment request for \$38,463,069.25.

Table A: Summary of Contract Authority Details for Bombardier TR Trainsets

Item		Vehicle Cost	Allowances	Total Authorization
Original Contract	Base Order (39 Trainsets – H4/H5 Replacement)	\$ 624,567,602.52	\$ 50,220,000.00	\$ 674,787,602.52
Previous Amendments	Option 1(A) (10 Trainsets - TYSSE)	\$128,551,071.30	\$34,157,000	\$162,708,071.30
	Option 1(B) (21 Trainsets – H6 Replacement)	\$ 269,957,249.73	\$ 47,255,000.00	\$ 317,212,249.73
	Option 1(C) (10 Trainsets – ATC/Forecast Growth)	\$ 176,567,020.00	\$ 40,221,850.00	\$ 216,788,870.00
	De-Icing System From Authorized allowance for Contract Changes Option 1(C) \$8,346,654.19			

Item		Vehicle Cost	Allowances	Total Authorization
	ATC Integration (70 Trainsets)	\$ 31,517,892.92	\$ 3,266,971.00	\$ 34,784,863.92
	Non-ATC Mode Operation (82 Trainsets)	1,984,182.22	NIL	1,984,182.22
	ATC DTO Mod (80 Trainsets)	\$1,176,072.96	NIL	\$1,176,072.96
	Spares, Special Tools and Test Equipment (Option 1(A) and 1(B) Trainsets)	\$ 27,242,504.43	\$ 757,495.57	\$ 28,000,000.00
	Low Ceiling Handholds and Exterior Door Chimes Base, Options 1a, b Credits from Bombardier (as a result of commercial settlement) (Delta \$464,278.58)	\$ 15,245,320.42 \$-14,781,041.84	NIL	\$ 15,245,320.42 \$-14,781,041.84
	Engineering for TDM System Modification	\$2,734,822.98	NIL	\$2,734,822.98
	TDM Prototype- Phase 1	\$2,260,893.46	NIL	\$2,260,893.46
	Modify 4 Trainsets for Service on Line 4	\$ 25,938,299.89	\$ 12,371,982.65	\$ 38,310,282.54
	All Other Amendments (Design changes, etc.)	\$ 28,270,283.67	NIL	\$ 28,270,283.67
	Subway Fleet Mods for AODA Compliance	\$ 11,762,510.13	NIL	\$ 11,762,510.13
Current Amendment	Modification of TDM System-Phase 2	\$ 38,463,069.25	NIL	\$38,463,069.25
Total Authorization Amount		\$ 1,371,457,754.04	\$ 188,250,299.22	\$ 1,559,708,053.26

These amounts include all applicable taxes. Exclusive of base order vehicle price, all other vehicle pricing is prior to a one-time adjustment for foreign currency exchange rate variance and net project costs will include tax recoveries under HST from the contract authorized amounts.

Issue Background

The Toronto Transit Commission's Five Year Corporate Plan includes the implementation of OPTO which will deploy on Line 4, with 4-car TR trains and Line 1 with 6-car TR trains. Line 3 is already operated under OPTO mode.

OPTO for Line 2 will be considered as part of the Line 2 Portfolio Plan which incorporates T1 fleet replacement, ATC, increased yard capacity and the Scarborough Subway Extension. This will be the subject of a future Board Report.

TTC subway trains on Lines 1, 2 and 4 are operated with a crew of two, both an operator and a guard. The operator is responsible for controlling the train's movement, watching for workers, customers, or obstructions at track level and following the routing and timing of the signal system. The guard is responsible for customer movement while the train is stationary, opening and closing the doors of the train and ensuring that customers are clear of the train as it moves off from the station platform. Both members of the crew assist in resolving customer and/or equipment related incidents.

OPTO removes the need for a guard on the train. The use of OPTO will permit the operator duties to be safely augmented to include monitoring customers boarding and exiting the train, operation of the doors and assisting in resolving customer and/or equipment related incidents.

The safety of OPTO technology has been tested in a vast majority of subway authorities including but not limited to Paris, London, Chicago, Los Angeles, Montreal and Philadelphia. Furthermore, the TTC's own Line 3 SRT is OPTO. The adoption of this new technology on all subway lines at the TTC will not sacrifice the overall safety of the system and will allow the TTC to modernize and grow.

The TDM System permits the operator to have a clear view of all subway car doors while maintaining an unobstructed view of track level and signals ahead of the train.

The TDM System consists of four strategically placed CCTV cameras that are installed on the subway platform to provide live clear video of all 24 train doors while the train is in the station. The video images are collected and transmitted by means of a wireless system to the subway train. Similar equipment is installed on each train to collect, process and feed the video images to a monitor in the operator's cab.

The monitor is installed in the operator's cab in such a manner that it does not obstruct the operator's view of track level and the signal system while considering the ergonomics for the operator. The view on the monitor is split in four providing a live view from each CCTV camera on the subway platform.

The TDM System provides the operator with the ability to view the subway car doors from a forward facing position in the cab while the train is in the station and as the train is leaving the station. The operator will have the ability to discern objects or people caught in

the doors. The system automatically turns on and off as the train enters the station and does not require any action by the operator to operate.

For OPTO, the operator must also be able to operate door controls that open and close the doors from the operator's seat. Door control buttons are presently located on both sides of the cab for the guard in a location that requires the guard to stand and look out the window to observe the subway car doors. The door control used by the guard depends on which side of the subway the platform is located. Consequently, the door control system must be modified and relocated in the cab to an ergonomic position that can be easily operated from the operator seat.

The on-board CSDE includes two new sets of door control push buttons which can be reached from the operator's seated position. The CSDE software provides indications and functionality to the door control buttons by ensuring that doors are opened on the correct side and that all doors are on the platform.

A Concept of Operations has been created for OPTO that details the management of normal, abnormal, degraded and emergency scenarios (such as train evacuations, fire/smoke exposure, etc). Procedures have been developed to deal with the required change in communications. Emergency exercises have already commenced which provide underpinning evidence that one person operation works.

Change directives to Bombardier were issued for engineering design to add a TDM and CSDE systems on TR trains and to retrofit a prototype train for a functional demonstration. A successful demonstration on prototype TS10 was held on February 18, 2016 at Bessarion Station on Line 4.

TTC invited members of APTA to conduct a Peer Review of OPTO on Line 4. The review occurred on May 23 to 27, 2016 and was attended by members from APTA, Chicago Transit Authority, Massachusetts Bay Transportation Authority and Los Angeles County Metropolitan Transportation Authority (all three authorities successfully operate OPTO). The Peer Review Panel was convened to assist the TTC in reviewing the progress, status and implementation strategy for OPTO. APTA conducted interviews inviting TTC departments to discuss their role in helping to develop the OPTO program. The observations and recommendations provided through the peer review were offered as an industry resource to be considered by the TTC to strengthen its strategies to achieve successful roll out of OPTO. As a result of the week-long findings, APTA was very encouraged and highly supportive of the OPTO program being developed by the TTC. Some of APTA's comments include the following:

- All staff responsible for planning and implementation of technology and support systems for OPTO have worked in a strong coordinated team spirit.
- The technology being introduced to support OPTO has incorporated state of the art resources to enhance safety and minimize operational hazards.

TTC has also provided Amalgamated Transit Union Local 113 opportunities to be involved in the development of OPTO. This included inviting Local 113 to attend an open house of the OPTO cab mock-up on display at Wilson Carhouse from September 28 to October 9, 2015. Recently Local 113 representatives attended and actively participated in the APTA Peer Review sessions on May 26 and 27, 2016. It is anticipated that the APTA Peer Review can help promote ongoing dialogue between TTC and 113 on OPTO. While Local 113 currently opposes implementation of OPTO, the TTC will proceed with implementation on Line 4 effective September 4, 2016, with briefing sessions to the membership at large followed by the training of its Operators.

Comments

The next steps required for implementation of the OPTO fleet are the following:

- The safety case of TDMS and CSDE installations onto TRs (4 or 6 car units) to obtain a SIL 4 level integrity level.
- Installation of TDMS onto the 6 x 4-cars TRs for Line 4 OPTO.
- Installation of onboard CSDE into the 6 x 4-cars TRs for Line 4 OPTO.
- Installation of TDMS onto 76 x 6-cars for Line 1 OPTO.
- Installation of onboard CSDE into the 76 x 6-cars TRs for Line 1 OPTO.

Bombardier is the Original Equipment Manufacturer (OEM) for the TR trains. A Request for Quotation (RFQ) was prepared and issued to Bombardier for the engineering design of the necessary provisions on the TR trains to accommodate the OPTO concept. The design included mounting details, structural modifications, panel and dashboard modifications, wiring systems and software modifications.

As the TR supplier, Bombardier's design expertise has been utilized to optimize wiring and equipment mounting within the cab. Bombardier's engineering design allowed for a simple and expedient installation of the TDM equipment.

Safety assurance is required with the installation of CSDE to provide a safety assurance to a safety integrity level (SIL) of 4 which is the highest level according to the International Electrotechnical Commission's (IEC) standard, IEC 61508. Approximately \$5 M out of the total \$38.5 M (as requested for this amendment) is required to complete the safety certification of CSDE to SIL 4. There is a reuse benefit in that the safety case and assurance for SIL 4 for 6 x 4-cars TR on Line 4 can be applied for the safety case and assurance for the 76 x 6-cars TRs on Line 1. The remaining costs will be used for the implementation of TDM and CSDE system upgrades onto the 6-cars TR fleet for Line 1.

TTC staff has evaluated the latest Bombardier quotation for \$38.5 M. The quotation is considered to be both technically and commercially acceptable. The cost for this work has been verified by the TTC as reasonable for the level of effort required in completing the change. All rates have been verified per the contract documents.

Commercial Analysis of Recommended Approach

The TTC secured a third party auditor (CH2M Hill Canada Limited) to review the proposed pricing. The audit scope included a review of the actual expenditure of the previous change directive for the prototyping works and the reasonableness of the labor & material costs, along with a review of the engineering hours. The audit was carried out at the manufacturing plant in Thunder Bay, a copy of which is attached to this report.

Bombardier demonstrated their approach to address engineering, procurement, production, and management costs associated with the modifications. The audit report indicated that there is a potential cost saving opportunity of up to 10% from the line item of “Other Direct Cost” which could possibly yield a maximum value of up to \$272,861.44. As a result of this finding, TTC staff further negotiated with Bombardier and was able to obtain a maintenance package in total value of \$288,156.89, including capital spare parts and special tools, to maintain the TDM system and CSDE in the future i.e. Bombardier will provide this package at no extra cost to the TTC as part of the offer. Accordingly, the auditors have concluded that the car builder’s Variation Order Request costs are justifiable.

Contact

Gary Shortt
Chief Operating Officer
Phone: 416-393-3392 Email: gary.shortt@ttc.ca

Mike Palmer
Deputy Chief Operating Officer
Phone: 416-393-4356 Email: mike.palmer@ttc.ca

Glen Buchberger
Head – Plant Maintenance
Phone: 416-393-2114 Email: glen.buchberger@ttc.ca

Attachment: CH2M Hill Canada Limited Audit Report

FINAL REPORT - UPDATED

Audit Report for Train Door Monitoring System for the Toronto Rocket Train: Costing of Material and Labour Audit

Prepared for

Toronto Transit
Commission

April 15th, 2016



ch2m.
inc.

CH2M HILL Canada Limited (CH2M)

Revision Log

Revision	Date (yyyy.mm.dd)	Description of Change	Prepared by	Checked
0	2016.04.06	Draft release.	Peter Doggett	Jeffrey Rankin
1	2016.04.08	Final release.	Peter Doggett	Jeffrey Rankin
1.2	2016.04.15	Updated re ODC and schedule risk reply from BTAME.	Peter Doggett	Jeffrey Rankin

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Audit Report for Train Door Monitoring System for the Toronto Rocket Train: Costing of Material and Labour Audit

1. Introduction

In 2006, the Toronto Transit Commission (TIC) awarded Bombardier Transportation Americas (BTAME) a sole source contract for 39, 6-car subway trains at a cost of \$624,567,602 referred to as the Toronto Rocket (TR). As an added function of the TR trains, the TIC has requested that a Train Door Monitoring System (TOMS) be developed and a Proof of Concept (PoC) be provided for the system (phase 1). Once the PoC is completed to the satisfaction of the TIC the TOMS is to be installed on the TR fleet as a post manufacture modification with integrated wayside equipment procured for each station on Line 1 and 4 (phase 2-2). Additionally, the TIC has requested that the Yard Maintenance Support System (YMSS) be upgraded at the TIC's Davisville Yard and at each station along Line 4 (phase 2-1).

CH2M HILL Canada Limited (CH2M) was commissioned by the TIC's Rail Car and Shops group to perform a high level audit on the material and labour costs associated with Bombardier's proposal to provide the TOMS for the TR fleet. The CH2M team conducted an audit at Bombardier's Thunder Bay facility on March 30th and 31st 2016.

The approach used by the audit team was in accordance with the agreed upon audit plan by the parties impacted by the activities (TIC, BTAME, and CH2M). The audit plan consisted of reviewing specific documents provided by BTAME and meetings with BTAME key project team members including Program Management, Engineering, Finance, Methods, Production, Quality Assurance (QA)/Quality Control (QCL Supply Chain Management and Product Introduction/Customer Service (PI).

An exit meeting was held following the audit on March 31st 2016, during which CH2M summarized their findings to Bombardier and a TIC representative who reviewed the audit findings documentation and signed these documents to indicate the TIC had reviewed and received a copy of the audit finding documents. This report details how the audit was conducted, the findings, concerns identified and formed during the audit process and the CH2M audit team's opinion of the justification provided by BTAME for the costs of the TOMS change order.

2. Audit Conclusion

The CH2M Audit Team conclude that the remaining budget for the TDMS phase 1 'prototype' modifications are adequate to complete the outstanding prototyping work and that there is little expectation that there will be any remaining budget available to be transferred to phase 2 of the project. Furthermore, the CH2M Audit Team conclude that the TDMS modification costs for all 82 trains, wayside equipment (side platform tags and YMSS upgrades are within reasonable expectations for phase 2. However, the Other Direct Costs (ODCs) presented for all activities are considered high by CH2M and could be an area that the TIC may wish to challenge BTAME. The ODCs are considered in the region of 10% higher than justifiable given the data provided during the audit.

CH2M notes a concern that any delay to the anticipated schedules for Engineering, Methods, PI/ Customer Service and Supply Chain activities will impact the planned modification delivery schedule.

Post Audit Note: Following this report being tabled with the TIC, BTAME have replied to questions raised by the TIC regarding the level of ODCs and the risks to the project schedule identified in this Audit Report. An update to the report has been provided for completeness of the report. The TIC has taken action and followed up the concerns raised in the report with BTAME and there appears that no further cost reduction is possible.

3. Audit Limitation

The brief time frame allocated to perform the actual audit and BTAME's requirement to have a signed Non Discloser Agreement (NDA) in place before the release of any 'confidential information' added constraints and delays to the audit process. The following are some limitations encountered by the CH2M Audit Team:

The audit focused on the labour hours BTAME stated they have incurred and are planning to incur for the remainder of phase 1 of the TDMS project. The Audit also looked at the planned costs for the completion of phase 2 of the project. The installation of the TDMS modification to the complete fleet of TR trains.

The information presented by BTAME was accepted at face value with inquires limited to open meeting discussions with BTAME's key staff on the TR Project. High level supporting information was presented by the BTAME project team. For example, the hours for the completion of phase 1 of the TDMS (prototype) were supplied as line items in a table, for each of the departments involved in the project. A further breakdown of these hours were provided by the Product Introduction team (PI) but not for any of the other five groups involved in the modification of the trains to install the TDMS.

To assess the material cost of the TDMS, a view was formed on the basis of reviewing eleven purchase orders (POs) issued by BTAME to their suppliers for components required for the TDMS prototype work. The TDMS requires many orders for materials and as such estimating has been used to complete the planning for the Bill of Materials (BOM) required.

A list of the information presented to the CH2M audit team to review and conduct the audit is provided in Section 5 below.

The BTAME team was professional, cooperative and willing to assist the audit team understand BTAME's reasons for the costs. At BTAME's request and as per the signed NDA, the detailed information shown to the audit team is considered by BTAME as 'confidential information' and is not presented in this report and therefore the report is limited to generalities and our professional opinions.

4. Approach

The approach used in this audit was a high level review of the pricing provided in BTAME's commercial offer dated November 23, 2015 for the TOMS phase 1 'prototype' costing. The costing breakdown (VO # 144) for modifying the TR fleet in phase 2 of the TOMS dated March 2016. These offers was made in response to TIC's request for the TR to be trains that are capable of running in passenger service and being controlled by the train operator without the need of a second person to operate the passenger door system. These offer documents were reviewed during the audit and show a break down by function of the groups' costs. Also included in these documents are Other Direct Costs (ODC) for each of the functional groups which is providing hours to the TOMS project for both phase 1 and phase 2.

To understand the cost breakdown for the TOMS project the audit team reviewed the workforce hours estimated by BTAME. The audit team reviewed a sample of BTAME's supplied information indicating the planning that has taken place for phase 2 of the TOMS project and the expected component and material costs required for the trains to undergo the prototyping and then the entire TR fleet to be modified for door controls to be made available to the train operator.

CH2M audit team was provided a meeting room in BTAME's Thunder Bay facility where discussions and presentations were held. The CH2M audit team extends their appreciation to BTAME for the use of this facility and the time and cooperation of their project team. During the audit key members of the TR project in Thunder Bay provided slide presentations and supporting spreadsheets on their development of the breakdown in the hours and costs required to provide the requested modification to the TR fleet. The audit team proposed questions regarding the development of the hours and costs planned for the TOMS and explanations were provided by BTAME in the form of documents and spreadsheets that are considered confidential and will therefore not be presented in the audit team's report.

The information supplied by BTAME was taken at face value and was not challenged to be supported with other evidence or forms of support for the hours or costs presented.

5. Documentation Review

The following documentation was provided by the TIC and BTAME to conduct the audit:

- BT-TOMS-1: TOMS TIC Audit 2016-03-30
- BT-TOMS-2: TOMS TIC Audit-Phase 1
- BT-TOMS-3: Rocket TOMS-Costing Breakdown-Phase 1 Prototype
- BT-TOMS-4: Bombardier Transportation-Toronto Rocket-TOMS Phase 1 Planning (1)
- BT-TOMS-5: Bombardier Transportation-Toronto Rocket-TOMS Phase 1 Planning (2)
- BT-TOMS-6: (BT-GC-1543) Train Door Monitoring System Phase 1 (Prototype) Costing
- BT-TOMS-7: Phase 1 to Phase 2 timeline and Task Evolution- 160329
- BT-TOMS-8: TOMS TIC Audit-Phase 2
- BT-TOMS-9: Costing for 19011 Rocket-TOMS-Phase 2-Costing Breakdown (VO#144)- March 2016
- BT-TOMS-10: (BEM-13104) Commercial Offer for TOMS Phase 2 for Approval
- BT-TOMS-11: Enclosure 4: TOMS-Phase 2 Milestone Schedule

- BT-TOMS -12: Toronto Rocket Train Door Monitoring System-High Level Schedule (Doc. 1)
- BT-TOMS -13: Train Board Monitoring System On-Board System Integration Technical Proposal-Train Integration and Performance (TIP)
- BT-TOMS- 14: TOMS TIC Audit-Engineering
- BT-TOMS -15: TOMS (Phase 2) VOR Engineering Labour Task Assumptions
- BT-TOMS -16: YMSS Upgrade Phase 1 Technical Proposal
- BT-TOMS -17: Engineering ODC
- BT-TOMS -18: TIC VO's-TOMS (Phase 2)- PCR-530- 2016-02-29
- BT-TOMS -19: TIC VO's-TOMS (Phase 2)- PCR-530- 2016-02-29- Classic WBS AME
- BT-TOMS- 20: TOMS: Engineering Detailed Headcount
- BT-TOMS- 21: TOMS: Total Engineering Headcount
- BT-TOMS- 22: TOMS TIC Audit- Methods
- BT-TOMS- 23: Summary Methods TOMS Phase II & Platform Side Detection
- BT-TOMS- 24: TOMS & Platform Side Detection- Methods Hours
- BT-TOMS- 25: Hand Tools Phase 1 – 16 Sets
- BT-TOMS- 26: TOMS TIC Audit-Quality
- BT-TOMS- 27: QA Hours Summary
- BT-TOMS- 28: QA ODC Summary
- BT-TOMS- 29: TOMS TIC Audit-Project Management
- BT-TOMS- 30: PM Costing-TOMS Phase II
- BT-TOMS- 31: PM ODC Summary
- BT-TOMS- 32: TOMS TIC Audit-Production Introduction
- BT-TOMS- 33: PI Hours
- BT-TOMS- 34: PI Hours Summary
- BT-TOMS- 35: PI TOMS Manpower Work Loading Matrix
- BT-TOMS- 36: ST-Bruno Engineering Services Change Request Evaluation Form Summary
- BT-TOMS- 37: TOMS TIC Audit-Supply Management
- BT-TOMS- 38: Supplier Costing Analysis
- BT-TOMS- 39: (BT-GC-0459) Final Proposal for ATC Integration Change in the Work
- BT-TOMS- 40: PO Example (1)
- BT-TOMS- 41: PO Example (2)
- BT-TOMS- 42: PO Example (3)
- BT-TOMS- 43: PO Example (4)
- BT-TOMS- 44: PO Example (5)

- BT-TOMS-45: PO Example {6}
- BT-TOMS-46: PO Example (7)
- BT-TOMS-47: PO Example (8)
- BT-TOMS-48: PO Example {9}
- BT-TOMS-49: PO Example {10}
- BT-TOMS-50: PO Example (11)

6. List of Attendees

The following attendees participated during the audit over the two-day period:

Name	Title	Company
Wenceslao Torres Brent Mandryk	Project Director	Bombardier
Marc Leschuk	Material- Supply Management Labour-	Bombardier
Alexandre Bazinet	Engineering Manager Labour-	Bombardier
Geoffroy Vouillot	Engineering Labour- Engineering	
Filip Luczak	Labour- Quality and Testing	Bombardier
Murad Jafari	Labour- Methods/Production	Bombardier
Wenceslao Torres	Labour- Project Management	Bombardier
Francois Cardinal	Labour- Project Management	Bombardier
Pat Sabino	Labour- Product Introduction	Bombardier
Mike Ross	Labour- Product Introduction Modifications	Bombardier
Due Bui	Finances	Bombardier
Peter Doggett	Lead Auditor	CH2M HILL
Zachary Kuzmicz	Auditor	CH2M HILL

7. Engineering

This modification project to the TR trainsets involves changes to a number of the engineering systems on the Train. The 'hard' wiring of the modification will take place in the cab cars of the train. No other cars will require modifying as part of installing the Train Door Monitoring System. The cab cars will have changes made to the Operator's desk that include a Visual Display Unit (VDU), two button plates and a green indicator light to the top edge of the operator's desk. There are also a number of components that are required to be added to the underside of the cab car including, a 'tag' reader added to the underside of the car. Additionally, 'side platform tags' are required to be added to the wayside of each station at track-level.

The Engineering workload needed for this modification is of a highly complex nature involving software changes to at least two systems, safety certification of the modification and the systems that are effected, re-design and calculations of space availability for the changes to the cab desk, checking and calculations of the electrical loads now placed on the control system of the train, integration of the closed circuit video images over a Wi-Fi system and the integration of a new set of hazards for the door system that must be accounted for in the vehicle's hazard log. The different types of testing for the modification need to be developed and supported by the Engineering function to ensure the correct tests are completed to ensure system performance and reliability are achieved. BTAME Engineering has identified 19 engineering functions that will be assigned work packages to complete this process of the TDMS modification.

Part of the 'proof of concept' phase has been carried out on Trainset 10. This POC has been carried out on the same Trainset that was used as the 'proof of concept' for the four car TR train project. This phase of the prototype has been demonstrated to the TIC with the remaining prototype phase to be carried out on the remaining 4 car trainsets and scheduled to be completed in December 2016.

The system is to meet SIL level 4 (10⁻⁹), as the hazards are identified as Category 1. Additionally, the Operational Safety Report (OSR) Certification will need a high number of hours to ensure the train does not have a wrong side door opening in service and is suitable for safe passengerservice.

The Engineering department provided its ODCs for the remaining phase 1 activities and the planned phase 2 activities as part of the costing for the modification. These ODCs are considered high by CH2M and could be an area that the TIC may wish to challenge BTAME. The ODCs are considered in the region of 10% higher than justifiable given the data provided during the audit.

CH2M is of the opinion that the hours presented for the Engineering group were within reasonable expectations.

8. Material Costs

BTAME advised the audit that the POC work has been carried out by BTAME's specialist group and as such did not follow the normal route in purchasing materials for the modification. There are a number of materials that have been used to collect information to form a BOM for the modification but for the materials that were not identified an estimate has been formed using prices from 2014 with an estimated increase.

8.1 Material Costs- Phase 1 and Phase 2

The material costs for the POC work on the cab cars could be considered as the market rate for these materials. This work was not part of an on-going program or part of a sizable order to suppliers, thus being no reason for a supplier to provide the material at a 'discounted' cost. However, during the

remaining POC prototype work on the remain 6 x 4 car trainsets a robust BOM can be compiled. With this BOM applied to the 82 trains to be modified, a reduced cost of materials could be negotiated from suppliers.

The cost of the materials from the supplier of the wayside equipment (side platform tags) required for the modification that identifies the side of the train adjacent to the platform is reported as confirmed at the quoted level.

In conclusion, CH2M find that the material cost is understandable and in these situations of limited production units and a restricted supply base.

8.2 Material Delivery-Phase 1 and Phase 2

The prototyping for the remaining four car fleet of TR trains for phase 1 will have the materials provided by the purchasing department of BTAME and this will assist in the formalization of the BOM for the modification materials required for all trains (both 6 car and 4 car) during phase 2 of the project. The audit was advised that the PI team, who will be installing the modification will be supplied the materials in 'kit' form. These 'kits' are to be compiled by BTAME's Services group and then supplied to the PI team at the required location of the modification work.

In view of these facts, CH2M's opinion is that the 'kitting' of the modification material is within reasonable expectations. However, there is a concern that the planning for the phase 2 BOM will be negatively impacted if Engineering is unable to complete the design within the anticipated schedule.

9. Product Introduction/Customer Service

BTAME cited the PI/Customer Service group will be responsible for all of the modifications made to the 82 vehicles at an average rate of one complete modified train per 5-day week. However, there is concern that delays in the other departments (for example: Engineering Methods, etc.) will impact the ability for the PI/Customer Service group to meet the planned modification schedule.

CH2M is of the opinion that the hours presented for the PI/Customer Service group were within reasonable expectations. However, the ODCs presented are considered high by CH2M and could be an area that the TIC may wish to challenge BTAME. The ODCs are considered in the region of 10% higher than justifiable given the data provided during the audit.

10. Project Management

CH2M is of the opinion that the hours presented for the Project Management group were within reasonable expectations. However, the ODCs presented are considered high by CH2M and could be an area that the TIC may wish to challenge BTAME. The ODCs are considered in the region of 10% higher than justifiable given the data provided during the audit.

11. Methods and Production

CH2M is of the opinion that the hours presented for Project Management group were within reasonable expectations. However, the ODCs presented are considered high by CH2M and could be an area that the TIC may wish to challenge BTAME. The ODCs are considered in the region of 10% higher than justifiable given the data provided during the audit.

CH2M notes that there is concern that the Methods resources that are shared with other projects may not be able to support the activities as anticipated and will impact the modification schedule.

12. Quality and Testing

CH2M is of the opinion that the hours presented for the Project Management group were within reasonable expectations. However, the ODCs presented are considered high by CH2M and could be an area that the TIC may wish to challenge BTAME. The ODCs are considered in the region of 10% higher than justifiable given the data provided during the audit.

13. Limitations

All reports, drawings, specifications, documents, and other deliverables of CH2M HILL, whether in hard copy or in electronic form, are instruments of service for this Project, whether the Project is completed or not. Client agrees to indemnify CH2M HILL and CH2M HILL's directors, officers, employees, subcontractors, and affiliated corporations from all claims, damages, losses, and costs, including, but not limited to, litigation expenses and legal fees arising out of or related to the unauthorized reuse, change or alteration of these Project documents.

14. Post Report Information

14.1 Other Direct Costs

The TIC requested BTAME to clarify the Audit Report finding of 'high' ODC amounts with regard to the Engineering, Method & Manufacturing, Quality Assurance, Project Management and Product Introduction functions. On the 13th of April, 2016 BTAME responded that the *"DDC projection is based on the proposed scope of work for the TOMS Phase 2"* and that *liThe costing is aligned with the BTAME standard practices for projecting DOC's. The ODe's include the YMSS deployment and consulting fees. Also, there are no provisions included in the ODC costing."* This issue is now closed.

14.2 Risks to the Project Schedule

In the same email request to BTAME, the TIC requested that BTAME provide their mitigation measures for the project schedule risks identified by the Audit Report. In the same email response dated 13th of April, 2016 BTAME replied that *"BTAME understands the importance of good control of the project schedule..."* And that *"mitigation measures to protect the schedule include: procuring material for the TOMS from vendors currently used on the TR Project, initiating pre-shipment inspections of material at the vendor sites and BTAME is prepared to issue purchase orders upon notice of award of the contract amendment for the Phase 2 TOMS."* This issue is now closed.