



Automatic Train Control – Lessons Learned and Program Update

Date: December 8, 2021
To: TTC Board
From: Chief Capital Officer

Summary

The purpose of this report is to provide the Board with a status update on the Line 1 and Line 2 Automatic Train Control (ATC) System, including Communication Based Train Control (CBTC) project deployments. The report contains initial lessons learned from Line 1 implementation in the following key areas:

- Project Management and Deployment;
- Scope Development;
- Schedule Development and Management;
- Materials Management;
- Contract Development;
- Phasing and Deployment;
- Risk and Hazard analysis; and
- Supporting Contracts.

The lessons learned from Line 1 will be used to support the further development and negotiation of Line 2 ATC/CBTC program requirements.

Given the funding made available for Line 2 of \$623 million from the City Building Fund approved by City Council in 2020, it is now possible to move forward on this key priority and leverage the lessons learned from Line 1 implementation.

Recommendation

It is recommended that the TTC Board:

1. Receive this report for information.

Financial Summary

There are no financial impacts arising from the adoption of this report.

Line 1

The total project cost for the Line 1 ATC Resignalling project is \$737 million, comprising costs to the end of 2020 of \$564.228 million and funding of \$172.772 million cash-flowed between 2021 and 2023 under Program 2.4 Signal Systems – YUS ATC Resignalling Project, State of Good Repair, as approved by City Council on February 18, 2021.

Some of the benefits realized to date from this project include service improvements, increased safety and cost savings:

- Travel times between the Vaughan Metropolitan Centre and Rosedale stations have improved on average by 3.5 minutes in each direction;
- Through run-as-directed trains, proactive station management and ATC service, on average the service delivered now meets the schedule, and on many occasions had exceeded a throughput of 28 trains per hour;
- By improving the reliability of the system and reducing the wayside equipment, maintenance activities have been able to refocus efforts to support other state-of-good-repair work;
- Reduction of Signal Violations on Line 1 by approximately 50% from 2017 to 2020; and
- The TTC has realized cost savings of \$0.804 million in 2021 with incremental savings expected in 2022 of \$0.117 million for a total of \$0.921 million.

Line 2

The total project cost for the Line 2 ATC Resignalling project is \$812.681 million, comprising costs to the end of 2020 of \$1.057 million and funding of \$734.542 million over the 2021-2030 Capital Plan period and post-2030 unfunded expenditures of \$77.082 million under Program 2.4 Signal Systems – Line 2 ATC Resignalling Project, State of Good Repair, as approved by City Council on February 18, 2021.

A total of \$623 million of Line 2 ATC Resignalling project was funded from the additional \$4.7 billion City Building Fund approved by Council in 2020.

It is expected that the completion of Line 2 ATC will result in the realization of similar service, safety and financial benefits as in Line 1.

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

Equity/Accessibility Matters

A cornerstone of the TTC's Corporate Plan 2018-2022 is accessibility, and we are committed to ensuring reliable, safe and inclusive transit services for all our customers. This is supported through the continued work of the ATC project, which will allow increased capacity and reliability on the TTC's Line 1 Yonge-University.

Implementation of new ATC systems requires numerous scheduled subway closures to safely install and test new signalling equipment. Frequent accessible shuttle buses are provided during these subway closures in order to accommodate all customers, as well as ensure Wheel-Trans service is available. Communications about the closures are made in numerous formats, including: audible announcements, posters in subway stations, media releases, TTC website and social media postings, and onsite Customer Service Ambassadors who are available throughout the closure zone to provide assistance.

Decision History

At its meeting on September 18, 2008, the TTC Board approved award of a contract (C31PV07834) for the design, supply and installation of a Computer Based Interlocking (CBI) signal system on the south Yonge portion of Line 1 (St Patrick to Eglinton stations) to Ansaldo STS USA Inc. This was initiated through a pre-qualified competitive procurement process.

At its meeting on April 27, 2009, the TTC Board approved award of a contract (C31PV08752) to Alstom for design, supply and installation of an Urbalis 400 ATC/CBTC (Automatic Train Control/Communication Based Train Control) system on the entire Line 1, and supply of ATC equipment for installation on 39 Toronto Rocket subway trains through a publicly advertised competitive procurement process.

At its meeting on April 6, 2011, the TTC Board approved a contract change (issued June 2011) to Alstom to increase the supply of ATC/CBTC equipment for Toronto Rocket subway trains to 60 trains from 39 (21 sets of equipment). Minutes of the Board meeting are available on the TTC website. Refer to agenda Item 5 in the following link:

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2011/April-6/Reports/Procurement_Auth_Ame.pdf

At its meeting on March 30, 2012, the TTC Board approved award of contracts in March 2012 for design, supply and installation of a Computer Based Interlocking (CBI) signal system for the remainder of Line 1 in four phases, including a CBI signal system for a test track in Wilson Yard [C31PV11825] and for the addition of a new CBI-based signal system for the TYSSE line [Contract A70-9] to Ansaldo STS USA Inc. through a pre-qualified competitive procurement process. Minutes of the Board meeting are available on the TTC website. Refer to agenda Item 13 in the following link:

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2012/March-30/Reports/13_PA_Design_Supply_Ins.pdf?rev=e484174a4fe84e4f954602b9f33a9000&hash=6FE3CB79E69DE8DAB8FCCDF1008F27E0

A contract change was issued January 2013 to Alstom to increase the supply of ATC/CBTC equipment for Toronto Rocket subway trains to 70 trains from 60. Approval for this contract change was within staff's signing authority under the Authorization for Expenditures and Other Commitments Policy.

At its meeting on April 30, 2014, the TTC Board approved changes to the contract scope and schedule with Alstom for design, supply and installation of ATC/CBTC on the entire Line 1, and supply of ATC/CBTC equipment for an additional 10 Toronto Rocket subway trains. Minutes of the Board meeting are available on the TTC website. Refer to agenda Item 5a in the following link:

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2014/April-30/Reports/Procurement_Authorization_Amendment_TYSSE_Contract_No_A8570_.pdf

At its meeting on March 26, 2015, the TTC Board approved the changes to the TTC's resignalling contract transferring the previously contracted work from Ansaldo STS USA Inc. to Alstom. This change had no impact to the existing approved budget of \$563 million and scheduled completion date of 2020.

<https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2015/March-26/Reports/52StaffReportAttachment.pdf?rev=85d2e580283b40de91a6ba5b6d3ede47&hash=C5FAD5F9D8D5D38272AD2EC0C6DC6A72>

At its meeting on January 24, 2019, the TTC Board received the Financial Update for the period ended September 29, 2018, including the update on the ATC/CBTC project identifying the requirement for an additional \$98 million.

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2019/January_24/8_Financial_Update_for_the_Period_Ended_September_29_2018.pdf?rev=627dd31fc5b04f1b978e186385d4eed3&hash=E32BF4E6BFF517CF7F8ADF2E4E2188E5

At its meeting on January 24, 2019, the TTC Board approved the TTC's 15-Year Capital Investment Plan and 2019-2028 Capital Budget and Plan, including the increase of \$98 million identified in the January Board Report for the ATC/CBTC project.

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2019/January_24/10_TTC_15_Year_CIP_2019_2028_Capital_Budget.pdf?rev=f310dd76b14841528800852b783d6a2b&hash=8DFFF4330DE1C50943EBAFEA0AB9330D

At the Special City Council Meeting on March 7, 2019, City Council approved the TTC's 2019-2028 Capital Budget, including the increase of \$98 million identified in the January Board Report for the ATC/CBTC project.

<http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2019.EX2.5>

At its meeting on April 11, 2019, the TTC Board endorsed the re-baselining of the ATC/CBTC project. This baseline included a revised project completion date of September 2022.

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2019/April_11/Reports/17_Automatic_Train_Control_Re-Baselining_and_Transit_Systems.pdf?rev=6b74a5815ecf491f8a07079526a724f0&hash=B536B0CA2BECA9D9DA5222673BD66AF0

At its meeting on January 27, 2020, the TTC Board approved the confidential attachment associated with the re-baselining of the ATC/CBTC project identified in the April 11, 2019 meeting. As part of the decision the ATC program was asked to conduct an extensive lessons learned on Line 1 implementation prior to Line 2.

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2020/January_27/Reports/3AutomaticTrainControlContractAmendment.s.pdf?rev=504ae4089cb344b987f6389795e5d1b3&hash=5A2F5031B78405BC654D12A798A8DEE6

https://ttc-cdn.azureedge.net/-/media/Project/TTC/DevProto/Documents/Home/Public-Meetings/Board/2020/January_27/Reports/Decisions/3_Automatic_Train_Control_Alto m_Contract_Amendment_Decision.pdf?rev=eac56505c2c3483a9cc8e29ba67bfd8a&hash=ED7E57B0776659C2BFD7250E9D45F0C5

Issue Background

Line 1's conventional "fixed block" signal system has been in place since the subway opened on March 30, 1954, more than 67 years ago. A fixed block signal system divides the subway line into geographical blocks. Only one train at a time is allowed in each block, while the adjacent blocks provide a buffer zone. While this system remains safe for operations, and despite staff's significant focus on preventive and corrective maintenance, its reliability is diminishing. The replacement of the current signalling system will improve the journeys for 825,000 customers (2019, pre-COVID-19) that use Line 1 every weekday by improving reliability and providing faster travel times. Furthermore, the new signalling system will provide the capacity required to serve more than 1.1 million weekday customers that are projected to use Line 1 in 2041.

From 2006, the TTC has incrementally awarded contracts to address the immediate-, medium- and long-term challenges related to the resignalling of Line 1 and the Toronto-York Spadina Subway Extension (TYSSE), which opened in 2017.

Resignalling of Line 1 with ATC/CBTC includes the design, installation testing and commissioning of an interface to the existing Centralized Signalling System (CSS). It also includes the design, installation, testing and commissioning of ATC train-borne equipment on the Line 1 Toronto Rocket fleet.

The ATC/CBTC system is very complex and the installation, testing and commissioning activities can only be performed during non-revenue hours or scheduled subway closures. The replacement of the legacy “fixed block” system with an ATC/CBTC system allows the system to govern train movements, and rather than develop defined blocks to separate trains, an ATC/CBTC system allows the system to determine safe train movements based on a number of factors, including train speed, track geometry and obstructions along the line. The system sets a movement authority to allow trains to travel safely and efficiently along the guideway. This allows trains to safely run closer and improves system capacity.

The resignalling of Line 1 will improve reliability and increase capacity on Canada’s busiest subway line. The ATC/CBTC system provides the benefit of real-time central train control with precise train location. With ATC/CBTC, train speed and separation between trains controlled automatically through a moving block system, as opposed to a fixed block system, allowing for reduced travel times and more reliable service.

The completion of ATC deployment on Line 1 and Line 2 are integral objectives set out in the Capital Investment Plan and form a key element to improving the overall system capacity to support the growing demand on the TTC subway system.

Line 1 and Line 2 are part of Capacity Enhancement Programs to improve the reliability and system capacity of each line. ATC is part of this larger initiative that includes: traction power upgrades; new and/or replacement subway trains; improvements to station layout; second exits to improve station capacity; and making safety-related improvements, such as expanding emergency exit buildings and installing new or upgraded ventilation plants.

In Q3 2021, Phase 4 (Rosedale to Eglinton) was commissioned, enabling ATC/CBTC from Vaughan Metropolitan Centre Station to Eglinton Station. ATC/CBTC is progressing well in the next phase on Line 1, Phase 5 (Eglinton to Finch). As well, 15 subway work cars have been equipped to support safe operation of maintenance vehicles.

A Study Report titled “TTC Line 2 and 4 ATC Study Report” has been completed and provides a concept study, technology review, lessons learned, initial phasing and implementation plan. This study will now be advanced to support the Portfolio Management Office (PfMO) stage gate process and will be used as a basis to advance the Line 2 ATC program. Lessons learned will be used to develop specifications to support the Line 2 Implementation.

In addition, the TTC engaged the American Public Transportation Association (APTA) and the Union Internationale des Transports Publics (UITP) to conduct peer reviews of the ATC/CBTC implementation. The reviews were conducted over several weeks through document reviews and stakeholder consultation. Stakeholders from across TTC

departments were invited to participate in the reviews to examine current industry practices, review the implementation on Line 1 and identify what went well and what improvements can be made, including alignment with updated industry practice.

The end result was a set of observations and recommendations to support program goals moving forward on Line 2. As a result of the extended program, significant consideration was given to the impact on the changes to industry approaches due to the timing between award (2009) and final system revenue service (2022). It was recognized that industry approaches to a number of items and technologies have progressed since the Line 1 ATC contract was originally awarded. These reviews identified opportunities to bring the approach on Line 2 in line with industry practices.

APTA and UITP observed the TTC has a strong multidisciplinary for implementation and operation and noted the positive outcomes of the current program. They also observed the challenges due to the extended implementation duration, including re-phasing and changing the contracting approach, including vendor lock-in. It was recommended that a service contract with the Line 1 supplier (Alstom) should be in place with sufficient funding to provide support and upgrades as required, including the continuation of equipping new and outstanding work cars with Automatic Train Protection after Line 1 has been fully commissioned and the five-year warranty period has been completed.

Benefits to Date

ATC operates between Vaughan Metropolitan Centre and Rosedale stations which represents approximately 70% of Line 1. Travel times between Vaughan Metropolitan Centre and Rosedale stations have improved on average by 3.5 minutes in each direction. Before the COVID-19 pandemic, customers riding southbound from St George to Museum stations experienced an approximate 8% increase in the number of trains per hour. This is the equivalent to 1.8 additional trains or capacity for an additional 2,000 passengers, more reliable service and fewer delays due to signalling issues. The introduction of ATC on Line 1 has also resulted in a significant reduction of Signal Violations on Line 1 by approximately 50% from 2017 to 2020.

ATC's positive impact extends throughout the entirety of Line 1, even where ATC is currently not installed. Before the pandemic, the scheduled southbound service in the morning peak at Bloor-Yonge Station was 25.5 trains per hour, whereas previously achieved service was approximately 22 trains per hour. Through run-as-directed trains, proactive station management and ATC service, on average the TTC operates 25.5 trains per hour as scheduled, and has exceeded a through-put of 28 trains per hour prior to the pandemic. As the city recovers, this improved service reliability and capacity will be critical to attracting customers back to the system.

Assuming 2019 demand, the economic benefit generated by time savings due to ATC on the converted portion of Line 1 (Rosedale to Sheppard West), based on reduced trip time and fewer delays, is \$219,000 a day (based on a value of time of \$17.50/hour, consistent with Provincial's valuation of customer time). The annualized benefit is approximately \$67 million per year. Even during the pandemic, assuming November 2020 ridership levels (22% of normal ridership), the economic benefit of ATC is valued at \$49,000 per day, due to reduced trip times and fewer delays. November 2020

ridership was referenced as it was the last month prior to lockdown. (Note: the benefit is higher when comparing the stretch from Rosedale to Vaughan Metropolitan Centre. However, there is no previous comparison for the TYSSE segment as it opened with ATC).

The implementation of ATC on Line 1 has also had a benefit to on-going maintenance programs. By improving the reliability of the system and reducing the wayside equipment, maintenance resources have been realigned to support other critical state-of-good-repair work. Signals Maintenance crews have increased switch inspections by 31% from 2019 to 2020, and have further increased inspections by an additional 25% as of June 2021. As a result, switch faults have decreased by 60% on Line 2 and 16% on Line 1, since 2018.

Comments

On Saturday, September 11, 2020, Line 1 ATC/CBTC was extended to Eglinton Station. This was a significant milestone in the delivery of the Line 1 ATC program. The remaining scope for Line 1 is presented below.

ATC Phases	Construction and Installation of ATC Assets	Testing	In Service Date	Status
Phase 1 (Yorkdale to Dupont)	100%	100%	Q4 2017	Completed
Phase 2 (VMC to Sheppard West)	100%	100%	Q4 2017	Completed
Phase 2B/2C (Wilson Yard Interface)	100%	100%	Q4 2018	Completed
Phase 3A (Dupont to St Patrick)	100%	100%	Q2 2019	Completed
Phase 3B (St Patrick to Queen)	100%	100%	Q1 2020	Completed
Phase 3C (Queen to Rosedale)	100%	100%	Q4 2020	Completed
Phase 4 (Rosedale to Eglinton)	100%	100%	Q3 2021	Completed
Phase 5 (Eglinton to Finch)	100%	TBD	Q3 2022	On Schedule
Phase 6 (System Wide)	N/A	0%	TBD	Scope under development

The TTC has completed an initial study of Line 2 and Line 4 with SNC Lavalin Inc. The study involved stakeholder review, analysis of current ATC and CBTC signal systems as well as Line 2 and Line 4 implementation constraints and key interfacing projects, such as the Next Subway Train (NST) program. The study also reviewed Line 1 lessons learned and contains an initial assessment of phasing, implementation strategies, including space proofing and other key deployment considerations. The information derived from the study, including the lessons learned from Line 1, will be used to inform and guide the Line 2 ATC project as it moves through the stage gate process and more detailed and accurate schedule and budgetary information is developed. The key factors to be considered are summarized below.

Governance Structure

The governance structure on Line 1 was developed prior to the establishment of the Portfolio Management Office (PfMO) and the requirements set out in the Project Management Framework. Initiatives, such as the Executive Change Review Committee (ECRC), provide additional oversight and accountability on the Line 1 ATC project to bring the project in line with principles set out in the framework to support the project as it approaches completion.

The Line 2 ATC/CBTC is classified as a Category 3 project within the project management framework, and as such will follow the established requirements and stage gate process. Any deviation to the processes set out in the framework will be subject to review and approval by Project Sponsors and the PfMO.

The governance structure will ensure project delivery is in alignment with the project management framework. The governance will ensure strong oversight and improve visibility to senior management on the delivery of the project and ensure alignment with the overall capacity improvement program. Specifically, the governance will consist of a steering committee comprised of the key operating Chiefs (Chief Operating Officer, Chief Infrastructure and Engineering Officer, Chief Vehicle Officer and Chief Capital Officer).

The Charter for the steering committee will establish key elements, including roles and responsibilities, risk, estimates, schedule and key interfacing projects, which include vehicle procurement, Line 2 extension project, State of Good Repair (SOGR) projects and any future projects that impact the overall project scope and schedule.

The intent of the approach is to:

- Provide Predictability of project outcomes via early identification of issues and opportunities to minimize “surprise element”.
- Ensure Consistency through standard processes, procedures, tools and systems.
- Support successful project execution by ensuring Competitiveness through continuous benchmarking.
- Perform independent fact-based project analysis to assure Transparency.
- Provide access to the Right information at the Right time to support the Right decisions.

Timeline for Line 2 Implementation (Stage Gate)

The ATC Line 2 Project is progressing toward Stage Gate 1, which is scheduled for completion in Q3 2022. To support this work, the ATC Project team has completed the initial study identified. The ATC Project team is continuing to develop, gather and update the requirement specifications from Line 1 to generate an updated specification for the Line 2 ATC System Supplier Tender. To assist with this process, the ATC Project team will award a Master Services Agreement (MSA) to obtain specialized Engineering Services. At current schedule, the project is planning to achieve Stage Gate 1 in Q3 2022. With all pre-planning work in progress, the ATC Project team is planning on releasing tender specifications to market in Q4 2022 for the ATC Line 2 Supplier Contract and award is proposed, in line with a Stage Gate 2, in Q4 2023 subject to agreement on funding of the new vehicles from three levels of Government.

The total project cost for the Line 2 ATC Resignalling project is \$812.681 million, comprising costs to the end of 2020 of \$1.057 million and funding of \$734.542 million over the 2021-2030 Capital Plan period and post-2030 unfunded expenditures of \$77.082 million under Program 2.4 Signal Systems – Line 2 ATC Resignalling Project, State of Good Repair, as approved by City Council on February 18, 2021.

A total of \$623 million of Line 2 ATC Resignalling project was funded from the additional \$4.7 billion City Building Fund approved by City Council in 2020.

TTC Line 2 and 4 ATC Study Report

In support of the work on Line 2 moving towards Stage Gate 1, the ATC Project has developed a study titled, “TTC Line 2 and 4 ATC Study Report”. The study analyzes different elements of the implementation of ATC/CBTC system on a line. Key scope items in the study and the report include:

- Review of current technology from CBTC system suppliers active in the North American market.
- Review of the existing signalling equipment on Line 2 and Line 4, including wayside/trackside equipment, signalling equipment rooms (SERs), yards, line expansions, and transitions between Line 1 to Line 2, and between Line 1 to Line 4.
- Review of current and future radio frequency data communication system requirements.
- Assessment of availability and space requirement for CBTC signal equipment rooms.
- Review of the integration of the new CBTC system for Line 2 and Line 4 within the TTC’s Transit Control Centre (TCC).
- Review of the integration of the new CBTC system on the New Subway Trains (NSTs) and on the TTC’s work car fleet.
- System operational and capacity analysis.
- Review of the interdependencies with other ongoing and planned work on Line 2 and Line 4.

- A review of options for achieving interoperability of Line 2 and Line 4 with Line 1, with consideration that Line 4 trains are required to travel from Line 4 to Davisville and Wilson yards on Line 1 for maintenance, and that Line 2 trains may be required to support service on Line 1 and vice versa in emergency situations.
- Project phasing and installation concepts and strategies.

Throughout the development of the study, lessons learned were identified through stakeholder consultations/discussions that resulted in key lessons learned. The critical lessons learned are identified below. These items will be tracked throughout the development of the project specifications and implementation.

Lessons Learned

Project Management and Deployment

Overall Scope Development (including work cars)

The initiation of Line 1 resignalling was to put priority on state of good repair. The priority was the update of the end-of-life and out-of-date signalling system in operation on part of Line 1. Key interfacing projects like the Toronto Rocket (TR) Vehicle program were not fully defined and not properly integrated into the upgrade program. As well, the original timeline of the major extension was not compatible with system procurement.

The challenges are documented in the April 30, 2014 and March 26, 2015 Board reports, and confirm that the original scope of the project was not able to integrate key interfacing work and projects, including the TYSSE project, works associated with SOGR and other initiatives that impacted the project scope, planning and ultimate solution.

The referenced Board reports outline a number of issues that resulted in a significant extension to the original program that need to be considered in the development of the Line 2 program to ensure that the Line 2 project timelines reflect the needs of interfacing projects. When the program was changed to a single contractor for the project, the addition of work cars was necessary to reduce the need for operation of non-equipped and/or non-communicating trains. The additional of work cars into the scope ought to have been considered as well as the impact of phased implementation with unequipped work cars and the need for more significant mixed-mode operation.

The Line 2 Project schedule will be developed considering all known and defined interfacing projects, and interfaces will have risks identified to carry impact in the overall program. Any concerns and issues associated with interfacing programs will have a rapid escalation path through sponsors and steering committee to ensure prompt identification of issues with a supporting structure to resolving assumptions, issues or concerns to allow the program to move forward with confirmation from stakeholders.

The Line 2 Project will review work impacts associated with work cars and vehicle equipping as well as phasing to minimize the duration required to support both legacy and ATC operations. This will reduce the hazard associated with operating trains within multiple signal systems and potential for operator confusion between the systems.

Comprehensive Scope Development (including work cars and yard requirements)

Developing the overall scope of the project needs to go beyond the definition of the interfacing projects and some of the known issues at the outset. Through the Line 2 study and the discussion with external peer reviewers, the ATC team identified the need to review the ATC/CBTC suppliers products and understand differences between product-based solutions and the project requirements. These differences were not fully assessed for Line 1 and have resulted in some functional differences during implementation.

For Line 2, the project team will explore options to closing the differences through product and project requirements with a goal of ensuring that the scope of delivery is defined prior to ATC/CBTC Line 2 RFP and subsequent contract award.

The development of the Line 2 requirements will also ensure that the full scope of the ATC deployment is assessed. This will include not only mainline and revenue vehicle scope, but also an upfront comprehensive assessment of work car needs as well as yard interface requirements for Greenwood, Keele and other storage locations. The requirement gathering process will include transition points, extent of ATC implementation within the yard and operational requirements to ensure scope for the yards and work car requirements are reviewed and agreed to by the key stakeholders before tender award.

Achieving this could be through market sounding or early engagement with suppliers prior to awarding contracts. This has assisted other transit agencies to minimize contract changes by ensuring that the program requirements are integrated (within the program and with other agency projects, including SOGR) prior to the award of the contract(s), and by developing a clear architecture for the intended systems prior to contract award.

Where suppliers propose changes to the agreed delivery strategy, the impact on TTC risk and operations will be assessed fully prior to authorizing the changes. Authorized changes will then be communicated to the established steering committee and relevant stakeholders. Introduction of a formalized change control Board, with operational representation, improved Line 1 delivery.

Schedule Development and Management

The scheduling/integrated program has faced challenges to properly develop and maintain a full project schedule by the contractor, as per contract. The responsibilities for developing and managing project controls changed during the consolidation of the contracts, this led to confusion around responsibilities which will be clearly defined in Line 2 ATC contract.

Other lessons learned with respect to the overall integrated schedule:

- Planned activities to be co-ordinate with the needs of SOGR work.
- Intermediate software releases to be planned and not limited to planned phase commissioning updates.
- Schedules to be resource loaded to avoid creating delays in non-critical activities.
- Minimise the co-ordination and submission of phase-specific designs.
- System design and material supply schedules to be integrated with the installation schedule to allow for the desired flexibility in the planning and implementation of construction activities.
- Coordinate track access with maintenance activities.

Moving to Line 2, the ATC Project team will work through relevant scope split and develop a clear set of responsibilities and requirements for schedule development and adherence that need to be met by the contractor and the TTC. This will look at identifying the relevant schedules (Project, Design, Installation, Testing and Commissioning) and confirm responsibilities associated with development and integration of the schedules.

Schedule requirements will make provisions to support items, such as revenue service issue resolution, including the need to identify intermediate system software releases to support issue resolution.

Schedules will be resource loaded and will provide a milestone/gating requirement for any phase specific designs to ensure issues can be captured and resolved within a given phase.

Planners will work with various departments on short- and long-term SOGR initiatives to identify major interface activities and develop a schedule that reflects the needs and timing of the other planned SOGR work. This will help avoid rework and delays arising from conflicts with SOGR work.

Materials Management

On Line 1, installation materials and warranty materials were not separated or secured, and were stored in a shared warehouse. Working with staff from the Materials Management Department, the Line 2 ATC/CBTC project will identify and implement procedures for material tracking and delivery for the project. This will be documented and followed by all stakeholders. The project will develop a Material Management Plan early in the project cycle to ensure warehousing and controls are established and followed throughout the project execution.

Contract Development

Scope Definition: Two Contractors

There are a number of challenges that were faced on the Line 1 ATC deployment using multiple contractors. The challenges of the multiple contractor solution are documented in the March 26, 2015 Board report. The report identifies a number of challenges with the integration, co-ordination and impact on system performance due to the multiple contractor/multiple contract solution. This report reflects a late change in the overall program to move away from a multiple contractor/multiple contract solution to a single contract and single contractor solution.

Line 2 ATC program will be moving forward with the intent of using a single contractor and a single contract for the entire Line 2 scope, including the ATC/CBTC system and the Computer Based Interlocking (CBI). As part of the initial technical study, technology and contracting options will be reviewed. However, based on the lessons learned from Line 1, a single supplier would prove to be beneficial and provide a better approach to managing deployment, as well as better management of program risks.

This approach would eliminate the need for the TTC to act as integrator between contractors and provide a number of additional benefits now being seen on Line 1 ATC deployment. Specifically, the single contractor solution:

- Simplifies the signalling solution with reduced field equipment;
- Simplifies maintenance routines and program;
- Lowers impact to installation and testing with ongoing service;
- Improves system performance to meet long-term needs for Line 2;
- Provides better interaction with SOGR projects; and
- Lowers risk of continued cost and schedule increases.

As part of the Line 2 ATC/CBTC study, the ATC Project team and consultants will be reviewing technology solutions available, and will be reviewing implementation options considering integration issues seen on the Line 1 deployment.

Phase and Deployment Strategy

The project deployment was reviewed and re-phased twice. Once in the April 30, 2014 Board report, which changed the phasing to six phases from four phases and revisited the sequencing to accommodate the TYSSE extension as a priority. The second major change to the phasing was identified in the April 11, 2019 Board report to increase the phase and timeline for implementation to nine phases. The resulting changes to the phased approach have contributed to the delay in delivery and increase in the schedule.

The development of the Line 2 ATC/CBTC system will establish innovative project schedules recognizing the brownfield nature of the environment. Working with key stakeholders, including Operations, Closures and Diversions, Infrastructure and Engineering and other groups, a comprehensive cutover and phasing strategy will be developed early in the program.

The phasing and implementation strategy will be developed considering known major SOGR work, extensions and other TTC initiatives as part of the Line 2 capacity improvements and key interfaces, including vehicle procurement and Line 2 extension.

The phase boundaries and control territories will be reviewed and agreed and mandated to the contractor. The control zones and phasing boundaries will be reviewed to balance operational requirements during implementation and end solution, with the increase in equipment cost and integration issues/risk by introducing additional control territories.

Risk and Hazard Analysis

With recent changes to the project structure starting in 2019, Line 1 ATC/CBTC project has performed a detailed QRA in 2019 as recommended and approved in the April 11, 2019 Board report and redefined the budget, including risk and schedule.

The project relied heavily on the implementation of an industry leading vital ATC/CBTC system that is in safe operation in many transit systems. The product developed and deployed on Line 1 is consistent with the contractor's product implementation. However, a hazard and functional analysis on the system would have identified changes to manual operation procedure or changes required in system implementation to avoid confusion and issues when operating outside the ATC/CBTC system in emergency manual operation.

The ATC/CBTC project is reviewing any hazards that are mitigated through manual procedure (outside the ATC/CBTC system) to ensure that all hazards mitigated are identified, reviewed and agreed to with internal stakeholders. Where necessary, work with the contractor to improve system functionality to address these hazards is ongoing. A review is ongoing to look at hazards and system functionality on Line 1 and verify if any system or procedural changes are required.

Moving forward on Line 2, the ATC Project team will develop a Quantitative Risk Assessment (QRA) to support key decisions in the development of the project scope and costs and will perform a hazard analysis and functional analysis early in the development of the project. This will build on the work from Line 1 and compare hazard and functions between the ATC/CBTC system with the current operational signal system. The ATC Project team will develop a comparative hazard analysis pre- and post-ATC/CBTC installation to review changes to hazard mitigations.

The outcome of this analysis will result in a set of requirements to ensure a level of hazard mitigations are properly identified and captured in the contract requirements.

Contractor Responsibilities for Program Management

The original ATC contract placed responsibilities for program management of schedule, installation co-ordination, cutover planning and other areas on the contractor without consideration of the required scope split between contractor and the TTC roles and responsibilities.

When the project was re-baselined with the consolidation of the Computer Based Interlocking (CBI) and ATC/CBTC contracts into a single scope of supply (March 26, 2015 Board report), the roles and responsibilities split between the ATC/CBTC contractor and the TTC should have been reviewed, and requirements and responsibilities adjusted as required. There are requirements on the contractor that would be difficult or impossible to implement and manage in accordance with the contract, leading to confusion and lack of adherence to the contract.

Responsibility for leading this work should remain with the contractor. However, closure planning, cutover planning and installation requires close co-ordination with the TTC as the work requires significant involvement from the TTC, which puts significant responsibility on the TTC to support this work.

Line 2 program requirements for the implementation and co-ordination of the overall program will be developed based on a scope split and responsibility matrix. Key responsibilities will be assigned to the group (contractor or TTC) that is in the best position to manage the responsibilities. The ATC Project team will also review responsibilities based on the governance structure to confirm internal responsibilities for project control and implementation are agreed to internally.

Supporting Contracts

For Line 2, the project team will work with the Procurement and Category Management Department to ensure that supporting contracts are being assessed and awarded based on scope and defined at the onset of the project. The ATC Project team will develop resource planning based on Line 1 experience and will work during the initial study to define required support throughout the entire project life cycle. The ATC Project team will investigate splitting contracts based on needs, and will ensure that all contracts contain priced options for each phase of implementation, and will ensure that all costs are captured with the ability to review consultant performance at the completion of each contract phase.

All consultant contracts will be estimated based on effort required for Line 1 ATC, and the scope of supply for Line 2. All changes and additional staff required will be subject to proper change control and visibility.

This will ensure that the Steering Committee, Executives and the Board are aware of predicted supporting contract costs.

Overview of Peer Reviews: APTA and UITP

In Q2-Q3 2021, the American Public Transportation Association (APTA) and Union Internationale des Transports Publics (UITP) conducted peer reviews of the ATC/CBTC implementation.

The reviews focused on a number of key topics associated with ATC implementation, including operational aspects, contracting, technical and elements on cyber-security. The review included document reviews, but mainly on consultations through a series of workshops.

Observations and recommendations were provided to support program goals moving forward on the ATC projects. The observations and recommendations did note that the TTC had deployed a strong multi-disciplinary team associated with the implementation and that the ATC solution was consistent with industry practice.

Both organizations provided a series of recommendations for consideration, (some of the common recommendations are provided below) during the development of the Line 2 ATC specifications and through the program the recommendations and implementation details will be reviewed and agreed through the project steering committee:

- A long-term maintenance agreement with the vendor as partner should be considered an integral part of any state-of-the-art technology projects toward achieving continuous improvement, mitigation of obsolescence and cybersecurity vulnerabilities.
- Specify clear governance structures and procedures for operational and maintenance changes.
- Improved approach to issue monitoring and data collection to support issue investigation and resolution. This could include remote access and central monitoring of the ATC system(s).
- Projects, such as ATC/CBTC, need heavy co-ordination between various departments and should be executed accordingly.
- The TTC should follow through on conducting a third-party security assessment and implement the recommendations from the effort.

The outcome of this review highlighted the intricacy of the systems, confirming the need for a unique approach to secure an integrated IT and OT in the public transit system environment. The panels highly recommend considering a harmonized approach to cybersecurity by potentially utilizing a single vendor responsible for both parts of the solution.

Osgoode Interlocking Incident Status and ATC Updates

In response to the Osgoode Interlocking Incident, a corrective action plan was developed and a total of 32 corrective actions were identified. At the time of writing this report only 3 actions are still on-going with the remaining 29 actions closed. Out of the remaining actions 2 will be closed by the end of 2021 with the remaining being closed with Phase 5 ATC Revenue service.

Specifically, for the ATC program, the corrective action plan included a sequential release of improvements to the flanking and fouling protection for trains that are not under system protection and operated in Emergency manual mode. The enhancement provides additional system reactions and enforcements should an Emergency train (either failed or non-equipped) violate a restrictive aspect and approaches a switches fouling point. To date, two enhancements have been implemented in the subsequent phases of ATC implementation, with one update remaining. The next update will ensure communicating revenue trains operating under the ATC authority are brought to a stop

in the event an Emergency train violates the restrictive aspect of a flanking signal and approaches a switches fouling point.

Due to the additional functionality and to support on-going system implementation, the project is introducing an additional deployment phase. The scope of Phase 6 is currently being assessed, but will be a planned release of system functionality to support operational needs. The scope and timeline assessments are on-going, but this will only include required operational functionality and will not impact the overall safety certificate. The full scope of the post revenue release is on-going.

ATC Functional Hazard Analysis

The project has also contracted an external party to perform a quantitative fault tree analysis on the ATC/CBTC system being installed on Line 1 and in support of Line 2 ATC deployment. The intent of the work is to identify and quantify operational risks associated with hazards mitigated through operational procedure and manual operation rather than by the ATC/CBTC system. This work will focus on a functional comparison between the hazards associated with the existing fixed block system and the ATC/CBTC system being implemented, and will look at the operating rules and procedures associated with the mitigations to ensure effective mitigation. This will result in set or recommendations on both the ATC system, and if necessary, operating rules and procedures.

The main objective is to assess if the implementation of the ATC system has met a minimum performance required and that the new ATC system does not introduce any additional hazards from the legacy system without sufficient and effective mitigations.

This work is ongoing and is expected to be completed in Q1 2022.

ATC Table Top Exercises

In August 2021, ATC functions were evaluated through simulation tabletop exercises developed to test and validate stakeholder capability, procedures, training and equipment. Tabletops assist in clarifying roles and responsibilities to support ATC operations and improve inter-departmental co-ordination.

Stakeholder input and the identification of gaps during the development and conduct of tabletop exercises have significantly improved plans and procedures for mitigation, response and recovery to ATC systems and computer halts. Transit Control processes for train operators with ATC territory routing and ATC train communication have been comprehensively documented. The tabletop exercises have improved individual and departmental performance and preparedness through practice.

Exercise evaluations focus on ensuring robust procedures are in place for safe, efficient and effective ATC operations. An After Action Report and Improvement Plan for each tabletop includes Corrective Action Requests submitted to stakeholders to ensure the exercise objectives and any gaps or stakeholder input is addressed, and provides objective and material proof of improvements.

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