STAFF REPORT
ACTION REQUIRED

Changes to the TTC Resignaling Contract

Date:	March 26, 2015
To:	TTC Board
From:	Chief Executive Officer

Summary

The purpose of this report is to gain Board approval for a contract change to the Alstom Power Transport Canada Inc (Alstom) Automatic Train Control (ATC) signaling contract. This change primarily transfers the Computer Based Interlocking (CBI) scope of work from Ansaldo-STS Canada, Inc (Ansaldo) to Alstom. This consolidates the signaling contracts under one supplier, Alstom and reduces the three contracts with Ansaldo and one contract with Alstom (total four contracts) to a single contract with Alstom. It also allows the ATC project to be completed within the current budget and on the current schedule with completion by 2020.

The existing TTC subway signaling system consists of an aging infrastructure and a train operation technology that is not capable of supporting an ever-increasing passenger ridership. The signaling system is therefore in need of both end of life replacement and an increase in capacity.

The current signaling contract arrangement for Line 1 has evolved since its inception in 2008 with a higher than anticipated passenger demand and an increased scope with the inclusion of ATC on TYSSE as well as technical challenges with the current CBI and interface to ATC. It is now a very complicated architecture and if completed as currently designed does not provide the full benefits of ATC to the City of Toronto.

An independent expert review led by Dr. Alan Rumsey of Parsons concluded that the highest level of confidence in delivering the project requirements on schedule and within budget, by a significant margin over the next best option, is to consolidate the resignaling delivery under one of the existing suppliers, Alstom. TTC concurs with this recommendation.

Recommendations

It is recommended that:

1. The Board authorize Subway Operations staff to proceed with a contract change to the Design and Supply of Radio Based Automatic Train Control (ATC) for the Line 1 and TYSSE Subway contract with Alstom Power Transport Canada Inc (Alstom) no later than March 31, 2015 in the amounts inclusive of taxes as follows:

    a. Increase $74,580,000.00 for adding the Alstom CBI system, equipping work cars for ATC and interfacing to the Wilson yard signaling system

    b. The expenditure of funds up to a total allowance amount of $6,203,700 for foreign exchange adjustment.

    c. The expenditure of funds up to a total allowance amount of $1,026,300 for extension of Letter Of Credit for performance of the contract

This results in a total authorized expenditure of up to $81,810,000.00 and a total contract value of $207,323,655.58

Implementation Points

Following approval of this recommendation adjustment to supporting related Speed Control System (SCS), Trainstop and Signal Equipment Supply contracts can be made as required.

Financial Impact

Sufficient funds for this expenditure are included in the estimated final cost of $562,835,228 in Capital Project 2.4 – Signal Systems – YUS ATC Resignaling in the 2015-2024 Capital Budget as approved by City Council at its meeting on March 10/11, 2015.

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

Decision History

2008: Existing Signal System Replacement with CBI – South Yonge (Contract C31PV07834)

Signal system replacement on South Yonge was identified as Phase 1 on Line 1 (i.e. St Patrick to Eglinton Stations). Approval was received from the Board for award of a contract in September 2008 for design, supply and installation of a CBI signal system on the south Yonge portion of Line 1 to Ansaldo. This was initiated through a pre-qualified competitive procurement process. Minutes of the Board meeting are available on the TTC website. Refer to agenda item 12 in the following link:

(http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2008/Sept_18_2008/Supplementary_Agenda/index.jsp)

2009: ATC – Entire Line 1 (Contract C31PV08752)

Approval was received from the Board in April 2009 for award of a contract to Alstom for design, supply and installation of ATC 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. Minutes of the Board 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/2009/Apr_27_2009/Agenda/index.jsp)

2011: ATC – Additional Trainsets for Line 1 (Contract C31PV08752)

A contract change was subsequently issued June 2011 to Alstom pursuant to approval from the Board to increase the supply of ATC equipment for Toronto Rocket subway trains from 39 to 60 trains (21 sets of equipment). Minutes of the Board meeting are available on the TTC website. Refer to agenda item 5 in the following link:

(http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2011/April_6_2011/Agenda/index.jsp)

2012: Existing Signal System Replacement with CBI – Remainder of Line 1 (Contract C31PV11825) and Addition of CBI on TYSSE Line (Contract A70-9)

Approval was received from the Board for award of contracts in March 2012 for design, supply and installation of a CBI signal system for the remainder of Line 1 in four phases and for the addition of a new CBI based signal system to the TYSSE line to Ansaldo 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:

(http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2012/March_30/Minutes_Other/Sup_Agenda_Mar_30.jsp

2013: ATC – Additional Trainsets for TYSSE (Contract C31PV08752)

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

2014: Changes to Scope and Schedule for Alstom ATC Contract

Approval was received from the Board in April 2014 for changes to the contract scope and schedule with Alstom for design, supply and installation of ATC on the entire Line 1 and supply of ATC 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:

(http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2014/April_30/Agenda/index.jsp)

Issue Background

The existing TTC subway signaling system consists of an aging infrastructure and a train operation technology that is not capable of supporting an ever-increasing passenger ridership. This results in delays due to signal equipment breakdowns, overcrowding on station platforms and customer service deterioration. The signaling system is therefore in need of both end of life replacement and an increase in capacity. The resignaling of the line achieves both of these objectives.

From 2008 TTC incrementally awarded publically tendered contracts to address the immediate, medium and long term challenges related to the resignaling of Line 1 and more recently the signaling of TYSSE. Ansaldo and Alstom won different elements of the overall solution as detailed in the Comments section of this report.

Over recent years, ridership growth predictions have increased, TYSSE signaling was added to the original ATC scope and in addition technical and schedule issues have arisen within the solutions of some of these contracts and interfaces which could not have been foreseen.

Given the implementation challenges of these contracts in 2014 TTC commissioned Parsons Consultants to conduct an independent study of the signaling contracts for Line 1 and TYSSE. This report concluded that the existing arrangements with four contracts and two contractors was the least efficient option against a background of rising costs and delays to deliver the project. The report determined the most effective solution to deliver on budget and schedule as well as the best way to manage the risks is to complete the resignaling of Line 1 and the signaling of TYSSE by consolidating the signaling contracts under one supplier, Alstom. This report aligns with TTC's Subway Operations own evaluation and is the recommendation of this report.

TTC is being proactive in making the difficult choice now to recommend adding the CBI scope to the Alstom contract and to cancel the Ansaldo contracts to ensure TTC gets the maximum performance and reliability from ATC for many years to come on both Line 1 and TYSSE.

Accessibility Issues

There is no accessibility issues related to this report.

Comments

Contracts for design and installation of a replacement signal system, CBI and an ATC system for Line 1, as well as a new signal and ATC system for the TYSSE, have been awarded and underway since 2008. The following provides a chronology of the contracts and contract changes.

Summary of Resignaling & ATC Contracts for Line 1 and TYSSE

Year	Contract and Contract Change	Contractor	Scope
2008	Design, Supply & Install Signal System For South Yonge Subway Contract No.: C31PV07834	US&S Inc. (later renamed Ansaldo STS Canada Inc.)	Phase 1 contract for CBI Upgrade the existing south Yonge signaling system with new CBI system Eglinton to Osgoode stations
2009	Design & Supply Radio Based ATC For YUS Subway Contract No.: C31PV08752	Alstom Transportation Information and Security Inc. (later renamed Alstom Power & Transport Canada Inc.	ATC contract for entire Line 1 including 39 sets of Carborne equipment for new TR trains.
2011	Design & Supply Radio Based ATC for YUS Subway Contract Change: Contract No.: C31PV08752	Alstom	Additional 21 sets of Carborne equipment for additional TR trains to replace H6 cars
2012	Design, Supply & Install Signal System For YUS Line Phases 2, 3, and 4 Contract No.: C31PV11825	Ansaldo	Phase 2 - 4 contract for CBI Upgrade of remaining Line 1 signaling system with new CBI based system.

2012	Design, Supply & Install Signal System For Toronto-York Spadina Subway Extension (TYSSE) Contract No.: A70-9	Ansaldo	TYSSE contract for CBI Provision of new CBI on TYSSE Line
2013	Design & Supply Radio Based ATC For YUS Subway Contract Change: Contract No.: C31PV08752	Alstom	Additional 10 sets of Carborne equipment for new TR trains for TYSSE.
2014	Design & Supply Radio Based ATC for YUS Subway Contract Change: Contract No.: C31PV08752	Alstom	Additional 10 sets of Carborne equipment for additional TR trains to meet capacity improvement resulting from ATC Implementation of ATC system on TYSSE. Implement scope changes to ATC contract and extend completion date of ATC work by 5 years.

ATC System – Moving Forward Plan

In almost all subways around the world, signal system replacement and ATC contracts are between the Subway owner and a single supplier. However, given the age (60 years) and the condition of the signal system on Line 1, a different approach was undertaken by TTC in 2008 to separately tender the CBI and ATC contracts. The CBI contracts are also separated into three contracts – Phase 1, Phase 2-4 and TYSSE. As this implementation evolved, delays occurred to the Phase 1 CBI schedule and incompatibilities arose between the two main suppliers, Ansaldo and Alstom. These incompatibilities would result in TTC not getting the maximum benefits from ATC and potentially an unacceptable signaling solution in that the capacity issue, i.e. the number of trains per hour, currently being offered doesn't meet the capacity requirements of the City of Toronto. This would result in an inadequate customer experience should the current arrangement continue. There are also significant risks to cost and schedule if the TTC continues with the current arrangement as further technical compatibility issues continue to be discovered between the two suppliers.

A number of complex scope and scheduling issues are significantly simplified and de-risked by combining the four contracts into one contract:

- Simplifying the signaling solution with a significant reduction in field equipment and less need to interrupt the existing system during implementation. The difficulties of introducing ATC to an operating subway line, without causing any extended delays to normal revenue service, are made easier. In tandem the maintenance of an old and unreliable system is easier with a less intrusive solution.

- With simplified and less field equipment, the interaction of the ATC project with other State of Good Repair (SOGR) programs can be greatly reduced. For example the ATC project will have less impact on the north Yonge asbestos abatement and deferral of Davisville Area Rehabilitation Program (track reconstruction between St Clair and Eglinton stations) as time and space requirements for ATC at subway track level are greatly reduced.

- Simplifying the signaling solution significantly reduces the testing required and eliminates the need for testing subsystems independently and then in parallel with ATC prior to a combined commissioning. This simplification also mitigates significant risks associated with commissioning two new systems simultaneously and again significantly reduces planned subway service closures. It also ensures a sole supplier is responsible for the integration risks of its own solution and not the TTC responsible for complex technical integration across two suppliers.

- A single supplier solution eliminates the significant risk currently faced that the budget would increase beyond its current value and the schedule extended beyond 2020.

<u>ATC Independent Expert Review</u>

Given the current state of the ATC project, the technical and complex issues to be addressed and the urgency to maintain approved schedule and budget, TTC procured the services of Dr. Alan F Rumsey, P. Eng, Vice President, Rail and Transit Systems of Parsons (resume attached) to lead an independent expert review of the ATC project in an effort to ensure that the ATC project remained on schedule and on budget.

Dr. Rumsey was retained as he is one of the world’s most renowned ATC experts with significant experience in ATC technology and the TTC environment.

Dr. Rumsey’s mandate was to assess all possible scenarios and delivery strategies with the objective of providing recommendations to TTC as to which alternative provides the highest level of confidence in delivering the project requirements on schedule and within budget and to provide a summary of the options considered and final recommendations.

A summary of the report is provided below and a copy of the full report is available.

For the purposes of the alternative analysis, two specific operating scenarios were considered.

Scenario A:

For scenario A the report describes the current Project System Architecture as consisting of the following three major components. This scenario assumes that the ATC system fails frequently enough to require service to be maintained by a secondary train protection system during those failures.

a) A primary ATC system, utilizing communications-based train control technology (CBTC) providing primary train protection functions;

b) A CBI and associated backup train detection (track circuits or axle counters) configured to support both the primary ATC system and provide a backup train protection system; and

c) A secondary train protection system, to support the backup CBI train protection system, comprised of an independent speed control system and/or wayside signals/train stops, and/or systems/equipment providing equivalent functionality.

Scenario B:

For scenario B the report describes an alternate System Architecture consisting of the following two major components which assumes that primary system failures would be very infrequent and backup control only required under certain circumstances, such as train failures or maintenance activities. The secondary train protection system would provide critical recovery functions until the primary ATC system is restored.

a) A primary ATC system, utilizing CBTC providing primary train protection functions and

b) CBI and an additional level of associated train protection and detection (track circuits or axle counters) configured to support the primary ATC system only.

Delivery Strategies Considered:

For each operating scenario, A and B, various delivery strategies were considered. In all, nine combinations were considered. These ranged from the current delivery for Line 1 by two suppliers to consolidating all components under one of the existing suppliers. Also considered was the option of cancelling all contracts and letting one new single contract with one supplier.

In evaluating the various alternatives, a risk-based approach was adopted where the level of risk in achieving the ATC project requirements (performance, functionality, operations, schedule, cost) was assessed by considering both the likelihood of the risk materializing and the consequences of the risk should it materialize.

The evaluation was conducted in two ways;

- First, by evaluating each option against twelve key risks and giving it a score against a predetermined scale.

- Second, by ranking the options against each other for each of the twelve risks.

NB: Budget and schedule compliance were two of the key risk areas considered.

The results show conclusively that the current delivery strategy is ranked eight out of nine in both cases.

Dr. Rumsey's recommended option, by a significant margin over the next best option is to consolidate the resignaling delivery under one of the existing suppliers, Alstom, with a system architecture supporting Scenario B.

Signaling System for TYSSE

The signaling system for TYSSE has inherently followed the same technological solution being implemented for Line 1. The current plan for TYSSE is to deploy CBI for opening day and subsequently deploy ATC after the line is open. Operationally, once open, TYSSE is an extension of Line 1 and will be required to operate using the same operating and maintenance procedures. The compatibility of the Ansaldo CBI system with the Alstom ATC system poses a significant risk to achieving the full benefits of ATC once the system is fully commissioned. It is therefore recommended that the signaling system on TYSSE be implemented with the same existing single supplier, Alstom, as Line 1.

Budget and Schedule

The approved Capital Program budget includes replacement of the existing signal system and installation of ATC on Line 1 by 2020 for an estimated final cost of $562.8 million.

Analysis of all associated costs indicate that the reduction in complexity, savings on existing implementation methods and much reduced subway closures, the project team will be able to deliver ATC within the approved budget.

The reduction in complexity, simplification of integration work and significantly reduced track access requirements indicate the project will also be delivered to the existing schedule with completion by 2020.

The key areas of savings that offset the cost of this contract change are;

- Reduced TTC construction costs, both material and labor as significantly less field equipment is required
- Greatly reduced number of subway closures
- Costs recovered from the cancellation of the existing CBI contracts
- Reduced effort in TTC design with one supplier not three
- Reduced testing and commissioning activities given the simplified solution as the need for independent subsystem testing is eliminated.
- The ability to test the new system during the day without inconveniencing the public, i.e. running the new system in shadow mode and ensuring greater reliability from day one.

The risks associated with current complex contract and technical arrangements are greatly reduced also allowing more confidence in cost and schedule.

The financial impact on future years is significantly reduced as the maintenance costs of the newly proposed solution are also greatly reduced.

The pricing offered by Alstom is conditional on receiving acceptance from TTC by March 31, 2015 in order to be entered in their order books for 2014/5; otherwise they have advised that there will be a significant price increase to their proposal, estimated in the order of $5M. Alstom have also indicated without mobilization on March 31, 2015 no assurances can be given to meet the project schedule.

Sole Source Justification

This report is recommending a sole source contract change to the Alstom ATC contract.

The technical reasoning stems from the difficulties faced in recent years implementing solutions from different suppliers under different contracts. This is exacerbated by the realisation that the combination of these suppliers cannot deliver the maximum benefits of ATC for the long term. The independent Parson's report states that replacing the Ansaldo CBI with a CBI from any supplier, other than Alstom, presents the same complications currently faced.

Less equipment is required if provided by one supplier leading to a greater reliability.

From a cost perspective to cancel all contracts and re-tender the entire Line 1 and TYSSE signaling contracts is prohibitively expensive as all existing contracts would have to be cancelled. This would potentially add hundreds of millions of dollars to a protracted schedule and potentially the re-equipping of over 60 TR trains already successfully fitted and tested with Alstom ATC equipment.

It terms of schedule it is estimated that a retender would add a minimum of 2 years to the completion of Line 1 and impact the readiness of signaling for the TYSSE opening.

The estimated final cost of $81,810,000 based on the offer of $74,580,000 from Alstom plus an allowance for foreign exchange adjustment and cost of increasing the contract security is comparable to the current combined total value of $80,200,000 for the three existing Ansaldo contracts that are being cancelled and is considered reasonable by staff.

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Attachments

Appendix A – Dr. Alan Rumsey's resume

PARSONS

Education

Doctorate of Philosophy, Control Systems Thesis, University of Manchester, UK, 1974
Master of Science, Control Systems Thesis, University of Manchester, UK, 1971
Bachelor of Science, Electronics, University of Manchester, U.K., 1970
Bachelor of Arts, Mathematics, Open University, U.K., 1977

Professional Associations

Professional Engineer, 40062507 (Ontario, Canada)
Institution of Railway Signal Engineers – Fellow and Member of Council
Institute of Electrical and Electronic Engineers – Senior Member, Distinguished Lecturer and Chair, Rail Transit Vehicle Interface Standards Committee, Working Group # 2

Employment History

2008 – ongoing, Parsons (formerly Delcan), Markham, ON, Vice President, Rail and Transit Systems
1992 – 2008, Parsons, New York, USA, Sector Manager, V.P., Rail Systems Programs
1988 – 1992, Alcatel Canada, Inc., ON, Canada, Director of Engineering

Employment cont.-

1980 – 1988, Urban Transit Development Corporation (UTDC), Kingston, ON, Canada, Director, Systems Design

1977 – 1980, Canadair Services, Ltd., Kingston, ON, Canada, Supervisor, Safety and System Assurance
1974 – 1977, British Rail, Research and Development Division, Derby, England, Scientific Officer

Dr. Alan F. Rumsey, P.Eng.
Vice President, Rail and Transit Systems
Program and Project Management

Profile

Dr. Rumsey is a licensed Professional Engineer, a Fellow of the Institution of Railway Signal Engineers (IRSE), a Senior Member and Distinguished Lecturer of the Institute of Electrical and Electronic Engineers (IEEE) and was the Chair of the IEEE Rail Transit Standards Committee, Working Group #2 that developed industry consensus standards for Communications-Based Train Control (CBTC). He is a Canadian representative on Working Group #40 of the IEC TC9 committee developing international standards for Urban Guided Transit Management Systems and on Working Group #45 developing safety standards for fully automated (driverless) systems.

Dr. Rumsey leads Parsons (formerly Delcan's) rail and transit systems business in Canada and internationally, in addition to playing a significant leadership role for Parsons (formerly Delcan's) U.S. Rail and Transit operations. Dr. Rumsey has spent his whole career in the rail and transit industry with 40 years' experience in all phases of rail/transit system planning, design, integration, implementation, test & commissioning and safety certification. He has extensive project management experience for advanced technology projects in rail transit, having worked on major projects in North America, Europe and Asia.

Dr. Rumsey has a proven ability to integrate complex advanced technology systems in a rail transit environment, with consideration of all technical, contractual, schedule and institutional interfaces while at the same time managing multiple stakeholder interfaces. He is a recognized industry leader in CBTC for both new-start and re-signaling applications, including driverless systems, and has broad knowledge of the full range of signaling and communications, traction power, rolling stock and trackwork systems in the rail transit sector. Dr. Rumsey is regularly called upon to provide expert advisory services to major rail transit projects around the world.

Projects

London Underground Sub-Surface Railway, Automatic Train Control (ATC) Programme – Independent Expert Advisor
Dr. Rumsey provided Independent Expert Advisory Services to London Underground and Transport for London to ensure that appropriate actions and decisions were being made to ensure the success of the ATC Programme in delivering the core business objectives. The Parsons (formerly Delcan) Team, led by Dr. Rumsey, conducted key periodic reviews during the re-bid phase of the ATC Contract, providing expert advice and guidance.

Bay Area Rapid Transit (BART, San Francisco, CA) Train Control System Upgrade – Technology Evaluation
Dr. Rumsey provided expert technical input and oversight in

support of an evaluation of the benefits and costs of CBTC as a candidate signaling and train control technology for BART's train control modernization program.

Federal Transit Agency (FTA), CBTC Technology Study, Washington, D.C.
Dr. Rumsey was Parsons (formerly Delcan's) Senior Technical Advisor for a FTA study documenting and evaluating the retrofit of CBTC technologies at New York City Transit (NYCT) and the Southeastern Pennsylvania Transportation Authority (SEPTA). To achieve a comprehensive evaluation of CBTC technology, several objectives were established, including identifying the main benefit drivers for CBTC; assessing enabling technologies; evaluating the specific CBTC functional, performance, and safety requirements against industry standards; identifying implementation challenges and lessons learned; determining the ability of CBTC to supplant the functionality (operational, safety, etc.) provided by track circuits in conventional rail signaling systems; and providing a qualitative analysis of the capital costs associated with CBTC implementation. The study reached two major conclusions. First, the study validated broader industry experience that CBTC offers benefits that cannot be achieved with prior generations of signaling technology. Second, the study highlighted that the challenges in upgrading the signaling/train control systems on an existing high-capacity mass transit system should not be underestimated, and any shortcomings in project planning and execution can have significant risk, schedule, and cost consequences.

Metrolinx, Toronto's Light Rail Transit (LRT) Program
Parsons (formerly Delcan) is a leading member of the joint venture providing Project Management and Systems Engineering services to Metrolinx for the delivery of the LRT Program. Parsons (formerly Delcan) is leading the systems scope, with Dr. Rumsey providing leadership in the development of the Concept of Operations, and providing expert advisory services on all of the rail systems aspects of the program which includes building consensus among all stakeholders on the program vision, operating concepts and system design concepts for the new transit lines (including CBTC signaling/train control technology).

Railway Systems Expert Panel, Cross London Rail Links Limited
Dr. Rumsey is a member of the Systems Expert Panel carrying out independent high-level peer reviews of the Rail Systems and Rolling Stock specifications and designs for the Crossrail project in London, England. A key focus of the peer reviews is the project approach to systems engineering, systems integration, and systems assurance. Dr. Rumsey's specific role has been focused on the design and procurement of the critical CBTC signaling and train control systems to achieve a 30 trains/hour throughput in the central operating section of the new Crossrail line. Dr. Rumsey has provided guidance on the procurement approach, and approach to supplier qualification and selection, has assisted in the identification of project risks and development of appropriate risk mitigation strategies, and has supported the development of the technical specifications with particular emphasis on the critical

interfaces to the rolling stock, and to legacy control systems. Dr. Rumsey was selected for this position on the Systems Expert Panel based on his international reputation as an industry leader in the successful introduction of CBTC systems to rail transit.

Crossrail is a massive £15.9 Billion cross-London rail link project that includes the construction of a twin-bore tunnel on a west-east alignment under central London and the upgrading of existing National Rail lines to the east and west of central London. The project includes 55 miles of existing surface network with upgrades to 28 existing surface stations, and 11 major reconstructions.

CBTC was selected for the Crossrail central operating section as the least-risk signaling technology to achieve the sponsor requirements following a careful assessment of required functionality, system costs, and system risks.

Expert Advisory Services, Jubilee and Northern Line Upgrade, London England

Dr. Rumsey provided expert advisory services to London Underground/Tube Lines on the Jubilee and Northern Line CBTC upgrade project in London, England. His advisory services included an independent validation/benchmarking exercise of the costs of CBTC installations worldwide, with particular emphasis on identifying the cost drivers and significant cost differences between "green field" and resignaling projects. Working directly for the Chief Executive, Dr. Rumsey managed a Parsons (formerly Delcan) team that conducted independent reviews of the status of the Jubilee Line CBTC software development and field verification activities in order to establish a realistic project completion date.

London Underground manages approximately 1 billion passenger journeys per year, and the continued increase in the number of passengers led the Underground to develop a plan for the enhancement of two primary lines in the rail network, namely the Jubilee and Northern Lines. The Jubilee and Northern Line Upgrade Project (JNUP) will achieve a step-change improvement in operating performance, providing a 33% increase in capacity and 22% reduction in journey times. A major component of the project is re-signaling with CBTC technology; an upgrade that had to be implemented with minimum disruption to revenue service.

London Underground's experience has confirmed the business case and significant operational benefits that can be realized with CBTC technology, but has also highlighted the importance of a realistic up-front assessment of total project costs and implementation schedules, the need to minimize adaptation risks to existing service-proven CBTC products, and the value of careful cut-over strategy planning to minimize disruption to revenue service during system implementation.

Expert Advisory Services, Houston Metro

Dr. Rumsey is providing expert advisory services to Houston Metro with respect to their $1.5 billion LRT program, to provide confidence that the design solution developed for the CBTC/PTC-based signaling and related operating systems has been optimized with full consideration of safety and performance requirements, and financial expenditure.

Expert Advisory Services, Amsterdam Metro, Netherlands

Dr. Rumsey provided CBTC migration planning services to Amsterdam Metro in The Netherlands on their major re-signaling program, a program that included provisions to transition to driverless operations.

Metrolinx/GO Transit Electrification Study
Metrolinx sponsored a study of the electrification of the entire GO Transit commuter rail network, as a future alternative to the diesel-electric locomotives now in service. The objective of this electrification study was to assess future technology options, including future diesel, electric and alternative technologies; to review their viability in various corridor environments as well as at the network level; and to consider the potential benefits and costs associated with replacing the diesel-electric locomotives. Parsons (formerly Delcan), in joint venture, led this comprehensive study that considered factors such as reliability and service, environmental and health impacts, community and land use impacts, economic and system-wide impacts, such as funding and financing. Dr. Rumsey served as Project Leader on the Study providing executive level oversight of all activities and outputs of the study team and liaison with Metrolinx.

Sector Manager, Vice President, Rail Systems Programs (Parsons, New York, USA).
With Parsons, Dr. Rumsey was responsible for planning, directing, managing and overseeing all Parsons' Rail Systems projects world-wide, with authority to ensure Rail Systems were designed, constructed and installed in accordance with established industry standards, recognizing at all times that safety, reliability, maintainability and cost efficiency are paramount.
He managed a staff of approximately 200 engineers and technical specialists in multiple offices world-wide in the technical disciplines of signals/train control, traction power and overhead contact systems, communications and control centers, vehicle engineering, automatic fare collection, and rail transit systems engineering.

Projects that he was directly involved in included:

New York City Transit Canarsie Line CBTC Re-Signaling Project
Dr. Rumsey was the Consultant Project Manager/Project Director for an integrated consultant team supporting New York City Transit (NYCT) with the re-signaling of the Canarsie Line with a new state-of-the-art CBTC signaling system. Working closely with NYCT's signaling, program management, operations & maintenance and vehicle engineering departments, Dr. Rumsey led a structured process of consensus requirements capture and development of detailed procurement specifications, supported the tender evaluations and supplier short-listing, oversaw a multi-supplier demonstration test program that led to the selection of a lead contractor to re-signal the Canarsie Line, and managed the consulting resources that worked in partnership with NYCT and the selected CBTC contractor to support system installation, test, safety certification, and cut-over into revenue service.
The New York Metropolitan Transportation Authority (MTA) has

plans to upgrade the entire NYCT Subway system with CBTC technology to achieve a state-of-good-repair of its signaling systems, to enhance safety, and to significantly improve line capacity and operational effectiveness. The Canarsie Line was selected as the first line at NYCT to be re-signaled with CBTC and to establish CBTC standards for New York City Transit.
The Canarsie Line was the first radio-based CBTC system to be implemented into revenue service on a high capacity metro line in North America, and the first project to develop interoperability standards for this technology.

Port Authority Trans Hudson (PATH) Railcar & Signals Program
Dr. Rumsey was the Project Manager, as a member of an integrated consultant team, developing strategic plans, system designs, and CBTC procurement specifications to upgrade and re-signal the PATH rail network while maintaining revenue service operations. Specific responsibilities included the development of PATH's Railroad Safety Program Plan (RSPP) – compliant with the requirements of FRA Part 236 Subpart H - that served as the principal document for all processor-based safety-critical products to be deployed by PATH, and defined the minimum expectations for the development and implementation of the ATC system.

Toronto Transit Commission (TTC) Rapid Transit Expansion Program
Dr. Rumsey was the Deputy Program Manager-Systems for this major subway expansion program, responsible for all of the operating system elements of the program including signals/train control, traction power systems, communications equipment and trackwork. Responsibilities included liaison with TTC Operations, and interface with funding partners and other stakeholders. Responsibilities also included establishing an overall safety certification approach.

Kowloon-Canton Railway Corporation- Review of West Rail Signaling System
Dr. Rumsey led an independent review of the operational and maintenance performance of the new KCRC West Rail CBTC signaling system.

Hong Kong Mass Transit Railway Corporation ATC Replacement Project
Dr. Rumsey provided expert advisory services for the MTRC ATC replacement project.

Director of Engineering,
Alcatel, Ontario
Dr. Rumsey was responsible for management of up to 50 specialist engineering staff in the systems definition and hardware/software development of advanced technology, CBTC products for urban transit and main line railway applications.

Director, Systems Design
Urban Transit Development Corporation (UTDC), Kingston,

	ON Dr. Rumsey was responsible for management of the Systems Design group, providing systems integration expertise for the company's turnkey transit system projects. Specific projects included Scarborough Rapid Transit system (Ontario, Canada), Vancouver SkyTrain driverless system (British Columbia, Canada), and Detroit Downtown People Mover driverless system (Michigan, USA), all of which utilized CBTC technology. **Supervisor, Safety and System Assurance** **Canadair Services Limited, Urban Transit Development Corporation (UTDC), Kingston, ON** Supervised all reliability, maintainability, and system safety activities on the Intermediate Capacity Transit System (ICTS) development which included developing a System Safety Program Plan, establishing a Hazard Log, and conducting/reviewing PHA's, FMECA's and FTA's. **Scientific Officer** **British Rail, Research and Development Division, Derby, England** Responsible for the system design and software development for microprocessor-based train control systems.

Toronto Transit Commission

Automatic Train Control (ATC) Project

Independent Review of Project Delivery Alternatives

FINAL

Prepared by:

PARSONS

Date: 26 September 2014

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GLOSSARY OF TERMS

Term	Definition
AF	Audio Frequency
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
AWS	Auxiliary Wayside System
CBTC	Communications Based Train Control
CSS	Central Signalling System
PF	Power Frequency
PM	Protected Manual
SCS	Speed Control System
TTC	Toronto Transit Commission
TYSSE	Toronto York Spadina Subway Extension
YUS	Yonge-University-Spadina

EXECUTIVE SUMMARY

The Toronto Transit Commission (TTC) is currently implementing an Automatic Train Control (ATC) Project on Line 1, with plans to implement similar technology on Line 2 at some point in the future. The primary objectives of this project are to achieve a state-of-good-repair of the signalling/train control systems on the line (with associated improvements in system reliability/availability and reductions in system maintenance) and to provide a capability for a "step change" increase in passenger carrying capacity on the line, through the use of a modern, moving block, train control solution supporting safe, short-headway operations.

The current ATC System Architecture to deliver these objectives includes a primary ATC System, utilizing Communications-Based Train Control (CBTC) technology to deliver Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) functions, and a secondary train control systems comprised of secondary train detection systems (track circuits); and secondary train protection systems (wayside signals, train stops, and an independent speed control system (SCS). Both the primary and secondary systems interface to computer-based interlockings (CBIs).

The ATC Project is currently being delivered through multiple supply contracts, with TTC acting as the overall Systems Integrator. A number of concerns have arisen, however, with respect to the delivery of the critical CBI element of the System Architecture. TTC has therefore been exploring a number of potential Project Delivery Alternatives to address these concerns. In support of these efforts, the TTC commissioned the services of a Consultant, acting in an expert advisor role, to conduct a two-month, high-level, Independent Review of Project Delivery Alternatives with the objective of providing recommendations to TTC as to which Alternative provides the highest level of confidence of delivering the Project Requirements on schedule and within budget.

The ATC Project Requirements that formed the baseline for this Review included Performance Requirements (Capacity, Availability, Maintainability), Functional Requirements (ATP, ATO, ATS), Operating Requirements, Schedule Requirements (to specifically include TYSSE requirements), and Cost Requirements (both Capital Costs and Life Cycle Costs).

Given that the level of "mixed-mode" operations that is required to be supported can have a significant impact on the overall ATC System Architecture, two different Operating Scenario Alternatives were considered in this Review.

(Note: "Mixed-mode" operation is defined as the simultaneous operation on the line of trains that are detected (and protected) by the primary ATC system and trains that are not detected (and protected) by the primary ATC system. The former are referred to herein as "ATC trains" and the latter as "non-ATC trains". "Non-ATC" trains could include passenger trains/work trains that are not equipped with train-borne ATC equipment and passenger trains/work trains that have a total failure of train-borne ATC equipment, for example.)

In Operating Scenario Alternative A), it was assumed that "mixed-mode" operation could be a regular/frequent mode of operation on the line. In Operating Scenario Alternative B), it was assumed that "mixed-mode" operation would only be required as an infrequent/ emergency mode of operation on the line, for example as a result of ATC equipment failure or if there is a need to send a non-ATC passenger train or work train on to the line for other operational failure management reasons. Under Alternative B), all passenger trains/work trains operating on the line during revenue service hours should be ATC-equipped.

The current ATC System Architecture supports Operating Scenario Alternative A). While Alternative A) may be seen to offer the benefit of providing a degraded level of service in the event of infrequent failures in the primary ATC system, the introduction of a complex secondary train control system to the overall ATC System Architecture does result in increased capital costs, increased wayside equipment with increased life cycle/ maintenance costs, reduced performance/operational flexibility/system availability from the primary ATC system, and increased project delivery risk.

Within these two Operating Scenarios and associated System Architectures, the Project Delivery Alternatives were further grouped into two categories: ATC Project delivered through multiple contracts, managed and integrated by TTC; and ATC Project delivered through a single contract managed by TTC, but with this single contractor acting as the overall Systems Integrator.

In evaluating the various alternatives, a risk-based approach was adopted where the level of risk in achieving the ATC Project Requirements (performance, functionality, operations, schedule, cost) was assessed by considering both the likelihood of the risk materializing, and the consequences of the risk should it materialize.

The Alternatives Analysis concluded that the Alternative that provides the highest level of confidence in delivering the Project Requirements on schedule and within budget is the Alternative in which:

- The secondary train control system is significantly simplified (revised Operating Concept and ATC System Specifications), with emphasis placed on the delivery of a highly available primary ATC system; and

- Delivery of the total ATC project scope is the contractual responsibility of a single contractor (revised Delivery Method).

Acceptance of this Alternative does however also require acceptance by TTC of:

a) Operating Scenario Alternative B) being an appropriate and acceptable operating strategy for TTC, in which the likelihood of non-ATC trains operating on the line is minimized (all passenger trains/work trains that are likely to operate on the line are ATC-equipped), such that, in the end-state railway, the independent speed control system (SCS) can be eliminated and the number of wayside signals/train stops significantly reduced; and

b) Moving to a single-contractor delivery strategy can be accomplished contractually, within a reasonable time frame; and without placing at-risk the opening of TYSSE, at least in a fixed-block, protected manual (PM) mode.

Recognizing that time is of the essence, and the transition from the current delivery plan to any new delivery plan must be accomplished as expeditiously as possible, the following is recommended:

1) Immediate procurement action be taken, as necessary, to minimize continued expenditure on the design, delivery and installation of equipment/subsystems/ systems that will not form part of the final ATC System Architecture and are not required on an interim basis to support the defined Migration Plan;

2) A Concept of Operations (ConOps) document be developed reflecting the selected Operating Scenario;

3) The ATC Technical Specifications (specifically the Operating Requirements, Performance Requirements and Functional Requirements) be revised, consistent with this ConOps document but also reflecting the capabilities of service-proven CBTC and CBI products;

4) A revised ATC System Configuration Summary be developed, reflecting the high-level System Architecture for the revised ATC project;

5) A high-level Migration Plan/Schedule be developed defining the cut-over of the ATC system on the line, including TYSSE;

6) A Project Management Plan be prepared defining the management of the revised ATP project through hand-over to Operations;

7) A procurement strategy to transition to the new project delivery method be established (e.g. sole-source negotiations or competitive procurement); and

8) The cost and schedule impacts of any required changes in their contract scope to comply with the revised Technical Specification, Configuration Summary, Migration Plan and Project Management Plan be negotiated with the appropriate suppliers.

1. INTRODUCTION

1.1 BACKGROUND

The Toronto Transit Commission (TTC) is currently implementing an Automatic Train Control (ATC) Project on the Yonge-University-Spadina (YUS) Line (Line 1), with plans to implement an equivalent ATC project on the Bloor-Danforth Line (Line 2) at some point in the future.

The primary objectives of this project are:

1. To achieve a state-of-good-repair of the signalling/train control systems on the line, with associated improvements in system reliability/availability and reductions in system maintenance;

2. To provide a capability for a “step change” increase in passenger carrying capacity on the line through Automatic Train Operation (ATO) and the use of a modern, moving block, train control solution supporting safe, short-headway operations;

3. To implement the project with minimum impacts to revenue service operations;

4. To implement the project on schedule and within budget.

The current ATC System Architecture to deliver these objectives includes the following key components:

A. A primary ATC System, utilizing Communications-Based Train Control (CBTC) technology to deliver Automatic Train Protection (ATP), Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) functions, and comprised of the following major subsystems:
   a. Train-borne CBTC equipment, being installed on the new Rocket subway cars and interfacing with the propulsion, braking and other carborne systems;
   b. Wayside CBTC equipment, interfacing to computer-based interlockings (CBIs);
   c. Central Control CBTC equipment interfacing to TTC’s existing Central Control System (CCS); and
   d. Radio-based, train-to-wayside, CBTC Data Communications equipment.

B. An Auxiliary Wayside System (AWS), comprised of the following:
   a. Computer-based Interlockings (CBIs);
   b. Secondary train detection systems (Audio Frequency (AF) and Power Frequency (PF) track circuits); and
   c. Secondary train protection systems (Wayside Signals and Train Stops, and an independent Speed Control System (SCS), performing similar functions to the mechanical train stops and grade-timed signals, and comprised of train-borne SCS equipment; and track-based transponders interfacing to the Wayside Signals).

A critical element in this System Architecture is the CBI in that:

- The primary ATC System (CBTC System) requires reliable and timely inputs from the CBIs, and requires timely responses of the CBIs to the CBTC System inputs, in order to support safe, short-headway, automatic train operations through interlockings; and

- The secondary train protection systems require operational CBIs to perform their intended functions.

The ATC Project is currently being delivered through multiple supply contracts, with TTC acting as the overall Systems Integrator, specifically:

- The Primary ATC System (CBTC System) is being delivered by Alstom;
- CBIs (and secondary train detection system) are being delivered by Ansaldo; and
- The SCS (part of the secondary train protection system) is being delivered by Thales.

1.2 CURRENT PROJECT STATUS

As noted above, the CBIs represent one of the most critical components of the overall ATC System Architecture, and a number of significant concerns have arisen with respect to the delivery of this element of the System Architecture. These concerns fall into two major areas:

1) Delays in implementation of the CBIs, resulting in substantial additional internal costs to TTC; and
2) Functional performance issues and the ability of the CBIs to support short, moving block, headways under automatic train operations.

In response to these concerns, TTC has been exploring a number of potential Project Delivery Alternatives to address these concerns. In support of these efforts, the TTC has commissioned the services of a Consultant, acting in an expert advisor role, to conduct a two-month, high-level, Independent Review of these Project Delivery Alternatives with the objective of providing recommendations to TTC as to which Alternative provides the highest level of confidence of delivering the Project Requirement on schedule and within budget. In conducting this Independent Review, the Consultant was to consider both the System Architecture and the Project Delivery Method.

1.3 INDEPENDENT REVIEW APPROACH

This Independent Review was conducted by:

- Dr. Alan F. Rumsey, P.Eng, FIRSE, MIEEE
- Mr. Jonathan Hulse, P.Eng.

In conducting this Independent Review, the Consultant has drawn on inputs from a number of sources including, but not limited to:

1) Inputs provided by key TTC Stakeholders either verbally (through interviews/ workshops), or through written reports;
2) The Consultant's familiarity with the TTC, TTC Operations, and the ATC Project;
3) The Consultant's experience from other major ATC/CBTC upgrade programs on operating rail transit systems around the world, including familiarity with the inherent delivery risks associated with such projects;

4) The Consultant's familiarity with service-proven ATC/CBTC/CBI products available in the market-place;

5) Any inputs that may be available to the Consultant through other sources (such as public-domain information available through the internet).

This report documents the findings and recommendation resulting from this Independent Review.

1.4 REPORT ORGANIZATION

The report includes the following sections:

Section 1: Provides the Background to the Review and the Review Approach.

Section 2: Defines the ATC Project Requirements.

Section 3: Provides a discussion of two different Operating Scenarios addressed in the Review.

Section 4: Describes the Project Delivery alternatives considered in the Review, and the evaluation criteria used in assessing the risks associated with each alternative.

Section 5: Provides the results of the Alternatives Evaluation

Section 6: Summarizes the Conclusions and Recommendations arising from the Review.

2. ATC PROJECT REQUIREMENTS

The following ATC project requirements apply to the Yonge-University-Spadina (YUS) Line (Line 1), including the Toronto-York Spadina Subway Extension (TYSSE).

These requirements apply to the "end-state" railway after ATC has been fully implemented.

2.1 PERFORMANCE REQUIREMENTS

Headway/Capacity Requirement

The ATC project is to deliver a capability for a "step change" increase in passenger carrying capacity on the line through Automatic Train Operation (ATO) and the use of a modern, service-proven, moving block, train control solution supporting safe, short-headway operations.

A capability for a sustained operating headway of the order of 105 seconds (approximately 34 trains-per-hour) under driver-supervised ATO, is desired.

The train headway will always be constrained by the safe train separation requirements of the Automatic Train Protection (ATP) functions of the ATC system, with the recognition that the achievable headway involves certain factors that are outside the control of the ATC system, such as track alignment, gradients, civil speed limits, train acceleration and braking rates, station dwell times, terminal track configurations, etc.

System Availability Requirement

The ATC project is to deliver a primary ATC system with high levels of system availability. Unless non-redundant equipment is proven to be sufficiently reliable to satisfy the overall system availability requirements, it is anticipated that appropriate levels of equipment redundancy will be employed such that the failure of a single component, processor, or device will not render the primary ATC system unavailable or an operationally critical function non-operative.

The primary ATC system downtime, or unavailability of an operationally critical function, is to be minimized through the use of local and remote diagnostic capabilities and appropriate operating and maintenance procedures to minimize the mean-time-to-repair and the time to restore full service operation.

System Maintainability Requirements

The ATC project is to reduce the maintenance requirements for the signalling/train control systems; specifically, by reducing the quantity of track-based components/equipment.

2.2 FUNCTIONAL REQUIREMENTS

The ATC project is to deliver the following primary functions:

Automatic Train Protection (ATP) Functions

The ATP functions are required to provide fail-safe protection against collisions, derailments, and other hazardous conditions, through a combination of:

- Train detection (to establish the location of, and track the movement of, all trains operating on the line);
- Interlocking protection (to provide route interlocking functions equivalent to conventional interlocking practice to prevent train collisions and derailments within interlocking boundaries);
- Safe train separation assurance (to maintain a safe separation between trains operating on the line in accordance with an agreed safe braking model), and
- Overspeed protection.

Automatic Train Operation (ATO) Functions

The ATO functions include speed regulation, programmed station stopping, door control, performance level regulation, and other functions otherwise assigned to the train operator.

Automatic Train Supervision (ATS) Functions

The ATS functions monitor train movements, adjust the performance of individual trains to maintain schedules, provide data to control centre operators to adjust service to minimize inconveniences otherwise caused by irregularities, and include manual and automatic route-setting functions. The ATS functions are achieved through ATC system interfaces to TTC's existing Central Signalling System (CSS).

2.3 OPERATING REQUIREMENTS

The ATC project is to deliver increased operational flexibility, for example through support to bi-directional train operations.

For a more detailed discussion of operating concepts/alternatives, refer to Section 3.

2.4 SCHEDULE REQUIREMENTS

The ATC project is to deliver the above performance, functional and operational benefits on the line by 2020.

The Migration Plan for the introduction of the new ATC system is to be such that the ATC project is not on the critical path for the opening of the TYSSE.

(Note: For the purposes of this Analysis, it is assumed that Wilson Yard interfaces do not influence the selection of a preferred ATC Project Implementation Alternative, although the definition of this interface may be revised based on the Alternative selected.)

2.5 COST REQUIREMENTS

The ATC project is to be implemented within the currently approved budget.

The ATC project is to be implemented with an objective of minimize life-cycle costs.

3. CONCEPT OF OPERATIONS

3.1 "MIXED-MODE" OPERATIONS

"Mixed-mode" operation is defined herein as the simultaneous operation on the line of trains that are detected (and protected) by the primary ATC system and trains that are not detected (and protected) by the primary ATC system. The former will be referred to as "ATC trains"; the latter will be referred to as "non-ATC trains".

"Non-ATC" trains could include:

- Passenger trains/work trains that are not equipped with train-borne ATC equipment;
- Passenger trains/work trains that have a total failure of train-borne ATC equipment;
- Passenger trains/work trains operating on a section of the line not equipped with the wayside ATC equipment; and
- Passenger trains/work trains operating on a section of the line with a total failure of wayside ATC equipment.

"Mixed-mode" operation could potentially be required in one or more of the following scenarios:

a) As a regular/frequent mode of operation on the line;

b) As an infrequent/emergency mode of operation on the line, for example as a result of ATC equipment failure or if there is a need to send a non-ATC passenger train or work train on to the line for other operational failure management reasons; and

c) During the transition period only, as a new ATC system is cut-in.

Given that the level of "mixed-mode" operation that is required to be supported can have a significant impact on the overall ATC System Architecture, for the purposes of this Analysis, two Operating Scenario Alternatives are considered.

Scenario A: Both a) and b) above are to be supported

Scenario B: Only b) above is to be supported

This specific ATC Migration Plan/Cut-Over Plan will define the extent to which c) needs to be supported during the cut-over.

3.2 OPERATING SCENARIO ALTERNATIVE A

Operating Scenario Alternative A requires the simultaneous and sustained operation of ATC trains and non-ATC on the line. For example, passenger trains with failed train-borne ATC equipment could continue in operation on the line, at a reduced headway, in a degraded mode of operation.

Alternative A therefore essentially requires two train control systems, and interfaces between these two train control systems – a primary, moving block ATC system for ATC trains, and a secondary, fixed block train control system for non-ATC trains where the secondary train control system includes:

- Secondary train detection to detect non-ATC trains (e.g. track circuits);
- Interlocking protection for non-ATC trains (i.e. CBI);
- Safe train separation assurance for non-ATC trains (e.g. wayside signals and train stops, and SCS); and
- Overspeed protection (e.g. grade times signals or SCS).

The current ATC System Architecture therefore supports Alternative A.

3.3 OPERATING SCENARIO ALTERNATIVE B

Under Alternative B), there would be no requirement for sustained revenue service operations during a primary ATC system failure.

Following a failure in the primary ATC system affecting either a particular train operating within any area of control, or all trains operating within a particular area of control, the operating requirements would only be to a) safely/efficiently re-enter the failed train into primary ATC system operation, or b) safely/efficiently remove the failed train from service, or c) safely/efficiently repair/restart the failed wayside CBTC equipment, depending on the specific nature of the primary ATC system failure.

Under Alternative B), all passenger trains/work trains operating on the line during revenue service hours should be ATC-equipped. Under an infrequent scenario when a non-ATC passenger train/work train were required to operate on the line during revenue service it is assumed that:

- The non-ATC train would be detected by the primary ATC system (through a secondary train detection system), and the primary ATC system would prevent ATC trains entering an area of track occupied by a non-ATC train;
- The safe movement of a non-ATC train through interlockings would be assured through the CBI;
- The movement of a non-ATC train would be authorized by central control through verbal commands, or potentially through wayside signals; and
- The movement of a non-ATC train would be at a restricted speed (by means of train-borne speed governor and/or by operating procedure).

For Operating Scenario Alternative B, therefore, the complexity of the secondary train control system can be significantly reduced. Specifically:

- No requirement for an independent Speed Control System (SCS) or grade timed signals; and
- Wayside signals/train stops could be eliminated or significantly reduced.

3.4 COMPARISON OF ALTERNATIVES

A high level comparison of the two alternatives is provided in the table below:

	Primary ATC	Secondary Train Control System	
Function		**Alternative A**	**Alternative B**
Train Detection	CBTC	Track Circuits or Axle Counters	Track Circuits or Axle Counters
Interlocking Protection	CBTC/CBI	CBI	CBI
Safe Train Separation	CBTC	Wayside Signals/ Train Stops and SCS	Primary ATC prevents ATC train entering section of track occupied by non-ATC train Non-ATC train movements authorized verbally by procedure and/or by Wayside Signals
Overspeed Protection	CBTC	Grade-timed Signals or SCS	Train-borne speed governor or equivalent

It should be noted that the CBI provides interlocking protection functions for both ATC trains and non-ATC trains under both Alternative A and Alternative B, and that the CBI is an independent system interfacing to CBTC. If the CBTC and CBI functions were to be provided by the same supplier, the possibility exists for these functions to be provided through a single integrated system.

While Alternative A may be seen to offer the benefit of providing a degraded level of service in the event of infrequent failures in the primary ATC system, the introduction of a more complex secondary train control system to the overall ATC System Architecture does result in:

- Increased capital costs, including TTC's associated costs for enabling works, installation/test support, etc.;

- Increased wayside equipment with increased life cycle/maintenance costs;

- Reduced performance/operational flexibility/system availability from the primary ATC system as a result of interfaces to the secondary train control system and the need to integrate both moving block and fixed block signaling principles; and

- Increased project delivery risk.

Furthermore the failure management capabilities offered by modern radio-based CBTC systems should allow rapid restoration or normalization of service. This is addressed further in Section 4.

3.5 TYSSE-SPECIFIC CONSIDERATIONS

For either Alternative A or Alternative B, the optimal and least cost implementation strategy would be to implement both the primary ATC system and the secondary train control system on the TYSSE under a "green field" environment, prior to entering the extension into revenue service. If, for whatever reason, this optimal solution could not be implemented within the TYSEE project schedule, then to the maximum degree practical, any interim signalling/train control solution should support the final end-state railway solution to minimize the need to upgrade/remove/replace equipment under a "brown field" operating environment.

Specifically, if the CBI in the interim solution is not "ATC-ready", it will have to be upgraded and/or replaced during revenue service operations to support an ATC-equipped line.

4. PROJECT DELIVERY ALTERNATIVES AND EVALUATION CRITERIA

4.1 PROJECT DELIVERY ALTERNATIVES

For the purposes of this Alternatives Analysis, and as discussed under Section 3, two specific operating scenarios have been considered.

Under Operating Scenario Alternative A, the ATC Project System Architecture is assumed to consist of the following three major components:

a) A primary ATC system, utilizing communications-based train control technology (CBTC) providing primary train protection functions;

b) A computer based interlocking (CBI) and associated secondary train detection (track circuits or axle counters) configured to support both the primary ATC system and a secondary train protection system; and

c) A secondary train protection system comprised of an independent speed control system (SCS), and/or wayside signals/train stops, and/or systems/equipment providing equivalent functionality.

Note: b) and c) combined are referred to herein as the Auxiliary Wayside System (AWS).

Under Operating Scenario Alternative B, the ATP Project System Architecture is assumed to consist of the following two major components:

a) A primary ATC system, utilizing communications-based train control technology (CBTC) providing primary train protection functions and

b) A computer based interlocking (CBI) and associated secondary train detection (track circuits or axle counters) configured to support the primary ATC system only.

Note: This scenario does not preclude the provisions of a temporary secondary train protection system during the cut-over to the new primary ATC system.

Note: This scenario does not preclude the integration of CBI and ATC functions within a single "system".

Within these two operating scenarios/System Architectures, the project delivery alternatives were further grouped into two categories:

1) ATC Project delivered through multiple contracts, managed and integrated by TTC; and

2) ATC Project delivered through a single contract managed by TTC, with this single contractor acting as the over Systems Integrator.

Operating Scenario Alternative A + ATC Project Delivered through Multiple Contracts

Alternatives considered within this group are:

i) Primary ATC (Alstom) + CBI (Ansaldo) +SCS (Thales); this is the current baseline.

ii) Primary ATC and CBI (Alstom) + SCS (Thales); Alstom replaces Ansaldo

iii) Primary ATC (Alstom) + CBI ("Supplier X") + SCS (Thales); "Supplier X" replaces Ansaldo

Note: Herein, "Supplier X" represents any other suitably qualified supplier (other than Alstom or Ansaldo) and could include Thales

Operating Scenario Alternative A + ATC Project Delivered through a Single Contract

Alternatives considered within this group are:

i) Alstom to supply both the primary ATC and the AWS (CBI + secondary train detection + secondary train protection); Alstom takes on total ATC project delivery.

ii) "Suppler X" to supply both the primary ATC and the AWS (CBI + secondary train detection + secondary train protection); "Supplier X" takes on total ATC project delivery.

Operating Scenario Alternative B + ATC Project Delivered through Multiple Contracts

Alternatives considered within this group are:

i) ATC (Alstom) + CBI (Ansaldo); Ansaldo scope modified to reflect simplified secondary train control system; Thales scope (SCS) eliminated.

ii) ATC (Alstom) + CBI ("Supplier X"); SCS eliminated and "Supplier X" takes on Ansaldo modified scope.

Operating Scenario Alternative B + ATC Project Delivered through a Single Contract

Alternatives considered within this group are:

i) Alstom to supply primary ATC and CBI (including any required secondary train detection); Alstom takes on total ATC project delivery.

ii) "Supplier X" to supply primary ATC and CBI (including any required secondary train detection); "Supplier X" takes on total ATC project delivery.

4.2 EVALUATION CRITERIA

In theory, given enough time and money, any of the above delivery alternatives could be made to work.

In evaluating the various alternatives, therefore, a risk-based approach was adopted where the level of risk in achieving the ATC Project Requirements (performance, functionality, operations, schedule, cost) was assessed by considering both the likelihood of the risk materializing, and the consequences of the risk should it materialize.

The following list of specific delivery risks was considered. The consequences of the risk occurring (Critical, Major or Minor), considering both Operating Scenario A and Operating Scenario B, are identified in brackets:

A. Risks related to delivering the ATC Project Performance Requirements:
    a. Risks related to delivering a capability for a "step change" increase in passenger carrying capacity on the line (a sustained operating headway of the order of 105 seconds or approximately 34 trains-per-hour) under driver-supervised ATO **(Critical)**

       Risks related to delivering a primary ATC system with high levels of system availability (**Major for Operating Scenario A; Critical for Operating Scenario B**)

    b. Risks related to delivering a reduction in the maintenance requirements for the signalling/train control systems; specifically by reducing system complexity and the quantity of track-based components/equipment (**Minor**)

B. Risks related to delivering the ATC Project Functional Requirements:
    a. Risks related to delivering fail-safe protection against collisions, derailments, and other hazardous conditions (**Critical**)

    b. Risks related to providing ATO functions, through interfaces to the subway car's propulsion, braking and other systems (**Major**)

    c. Risks related to delivering ATS functions, through interfaces to TTC's existing Central Signalling System (**Major**)

C. Risks related to delivering increased operational flexibility, through the primary ATC system, during normal operations (**Minor**)

D. Risks related to delivering the ATC Project Schedule Requirements
    a. Risks related to delivering the above performance, functional and operational benefits on the line by 2020 (**Critical**)

    b. Risks related delivering the ATC Project in a way that supports the on-schedule opening of the TYSSE in ATO (**Minor**)

    c. Risks related to delivering the ATC Project in a way that supports the on-schedule opening of the TYSSE in protected manual (PM) mode (**Critical**)

E. Risks related to delivering the ATC Project Cost Requirements

a. Risks related to delivering the ATC project within the currently approved capital budget, including TTC costs (**Critical**)

b. Risks related to delivering the ATC project in a way that minimizes life-cycle costs (**Major**)

For each of the above identified risks, an assessment of the risk level was made in accordance with the Table 1 below. Based on the severity (consequence) and likelihood (probability) of the risk occurring, the risk levels were colour coded and numbered for evaluation.

Table 1: RISK LEVELS

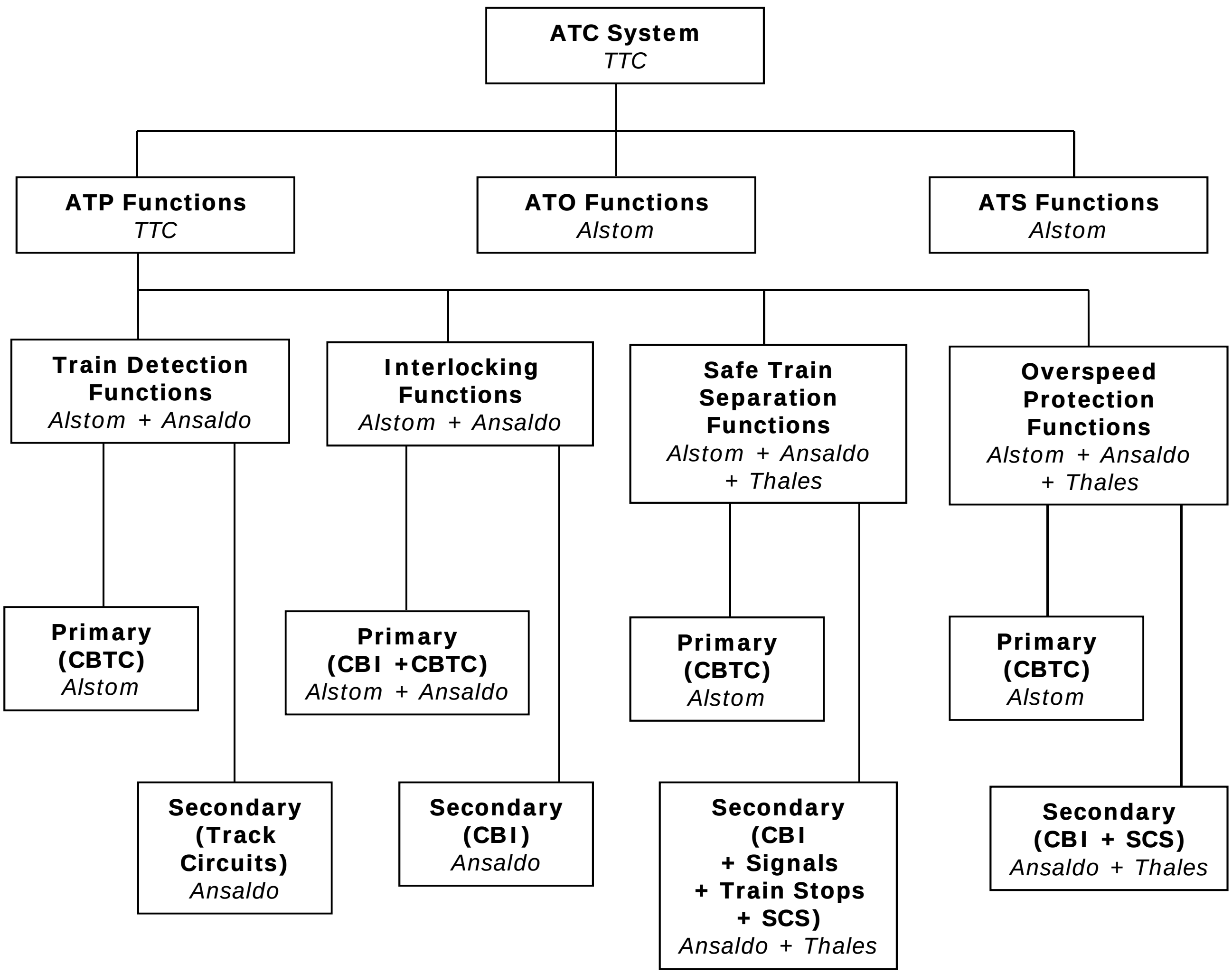
	Likelihood of Risk Occurring		
	Low Probability	**Medium Probability**	**High Probability**
	The risk could occur, but is considered unlikely (for example, because this delivery risk has previously been mitigated in a service-proven design)	There is a reasonable probability that this risk will occur (for example as a consequence of the complexity of the system architecture and delivery method)	There is a high probability that this risk will occur (for example, based on current project status and industry experience)
Consequences of Risk Occurring			
Minor	Risk Score 1	Risk Score 2	Risk Score 3
Major	Risk Score 2	Risk Score 3	Risk Score 4
Critical	Risk Score 3	Risk Score 4	Risk Score 5

Table 2, in Section 5.10 shows the overall assessment with the totals risk scores for each alternative. The alternative with the lowest aggregate score would offer the least risk alternative

5. EVALUATION OF ALTERNATIVES

5.1 ALTERNATIVE A.1.I

This Alternative reflects the current System Architecture and Delivery Method as the current baseline for the analysis and is represented graphically below with responsible parties identified in italics. Note: If ATP functions are delivered by more than one supplier, TTC is identified as the responsible party, as Systems Integrator.



Reference	A.1.i
Operating Scenario	A
Alstom Scope	ATC
Ansaldo Scope	CBI
Thales Scope	SCS
"Supplier X" Scope	
Systems Integrator*	TTC

***Note:**
The term "Systems Integrator" is used in this and following tables to identify the entity primarily responsible for integrating the various ATC project subsystems (i.e. responsible for managing the various internal ATC System interfaces). External ATC System Interfaces are managed by TTC.

RISKS	Consequence	Level	Comments
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		Given the complexity of the solution, the interfaces necessary to be resolved and difficulties currently reported there is a high probability that the desired increase in line capacity will not be achieved
Risks in delivering high level of system availability	Major		The complexity, numbers of subsystems, interfaces and quantities of trackside equipment all lead to a high probability that system availability targets for primary ATC will not be achieved
Risks in delivering reduced maintenance	Minor		As a direct consequence of lower availability and the amount of equipment involved it is expected that maintenance requirements will actually increase
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		Due to the complex nature of the system, with many interfaces and without a single contractor there is a high probability that the successful implementation of the necessary ATP functions will be at risk

Risks in delivering ATO functions	Major		As this risks is under the control of a single supplier and single subsystem, and as the interfaces to the vehicles is already defined, the risk level is low
Risks in delivering ATS functions	Major		As this risk is under the control of a single supplier, the risk level is medium recognizing that interface details still have to be finalized.
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		While the increased complexity in the secondary train control system is intended to increase failure management capabilities, there is a high probability that this complexity will in fact reduce operational flexibility of the primary ATC system
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		Given current issues and overall risk level, there is a high risk that the schedule will not be achieved
Risks in opening of TYSSE in full ATC	Minor		Given the current TYSSE schedule there is a high probability that opening the line in full ATC could not be achieved
Risks in opening of TYSSE in PM	Critical		It is possible for TYSSE to open in a form of protected manual mode, but even this is not without risk as the resulting solution is unlikely to be "ATC-ready"
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		Given all other risks and known issues, there is a high degree of risk that the capital costs to successfully implement the existing requirements, including TTC costs) will significantly exceed the budget.
Risks in delivering Life Cycle Cost benefits	Major		Given risks to availability and likelihood of increasing maintenance requirements, the life-cycle costs are expected to be higher than anticipated

Comments / Discussion:

There are several key factors for the current risk profile for Alternative A.1.i. These include:

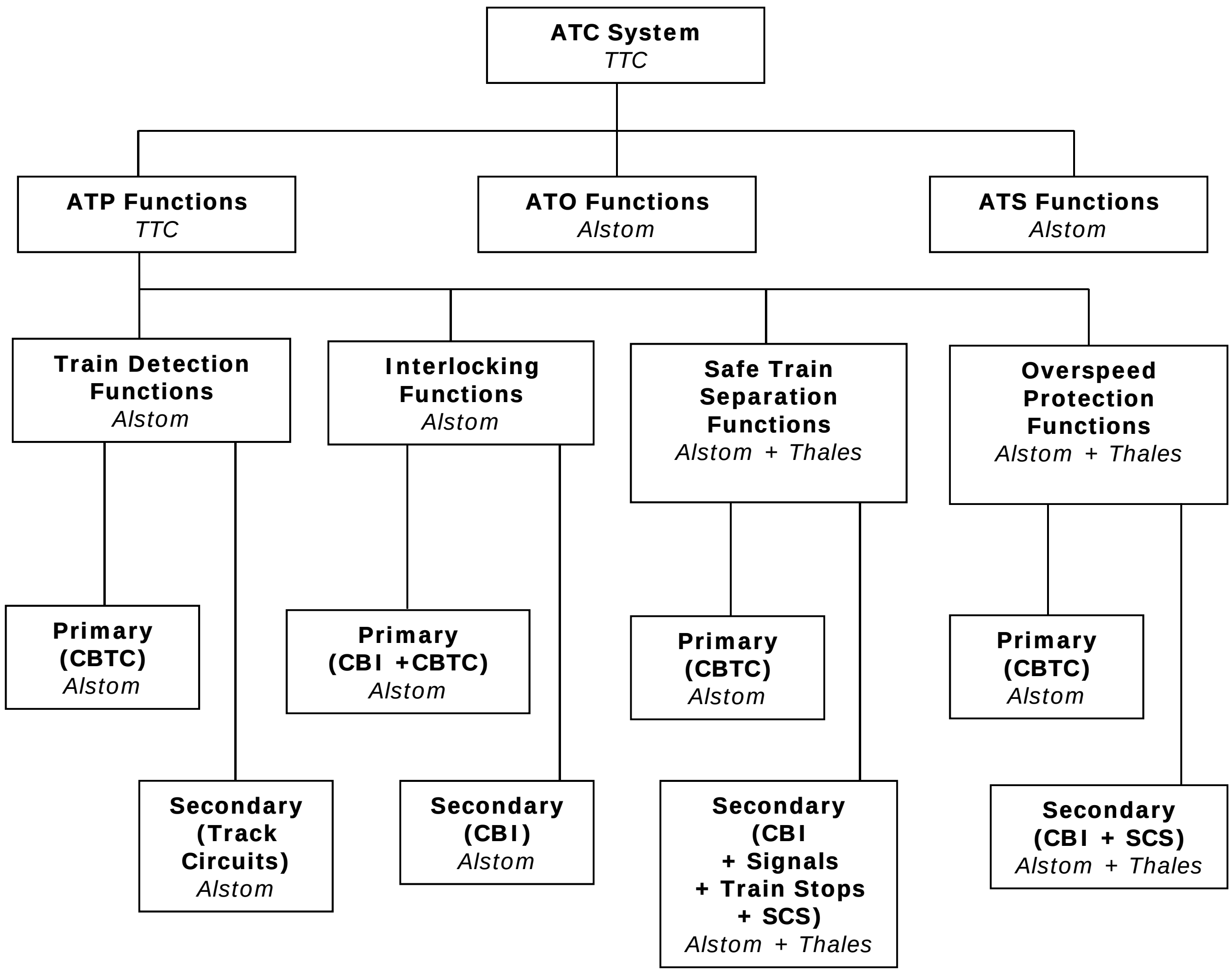
a) The fact that the CBI system selected had not been proven in service with a CBTC system at the time of the award and had only been applied in "Greenfield" environments.

b) The System architecture, including distinct ATC, CBI and SCS subsystems, each from different vendors, is extremely complex, with significant interfaces. The overall requirements remain to be validated and integration issues are a significant risk.

c) The interface between the CBI and ATC systems is highly complex and it will require a distribution of functions between two subsystems with two separate vendors. To establish a safety case for the interface will require significant time and effort, requiring full cooperation between both parties.

5.2 ALTERNATIVE A.1.II

In this alternative, Alstom takes over Ansaldo's scope (with the potential exception of TYSSE).



Reference	A.1.ii
Operating Scenario	A
Alstom Scope	ATC + CBI
Ansaldo Scope	
Thales Scope	SCS
"Supplier X" Scope	
Systems Integrator	TTC

RISKS	**Consequence**	**Level**	**Comments**
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		While there remain some moderate degree of risk, the probability that the desired increase in line capacity will be achieved is improved with a single ATC/CBI supplier and service-proven ATC/CBI interface
Risks in delivering high level of system availability	Major		With a single ATC/CBI supplier, the risk in delivering a high level of system availability is also improved. However the overall system architecture remains complex.
Risks in delivering reduced maintenance	Minor		With a single ATC/CBI supplier, and improved availability, the risk in delivering the maintainability requirements should similarly be reduced. The overall system architecture does however remain complex.
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		Although a single ATC/CBI supplier reduces this risk, given the "brownfield" nature of the system and the complex interfaces to the secondary train control systems, there remains some risk to full implementation of the primary ATP functions.

Risks in delivering ATO functions	Major		As this risks is under the control of a single supplier and single subsystem, and as the interfaces to the vehicles is already defined, the risk level is low
Risks in delivering ATS functions	Major		As this risk is under the control of a single supplier, the risk level is medium recognizing that interface details still have to be finalized.
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		In spite of a single supplier for ATC/CBI, the complexity of the interfaces to the secondary train control system will continue to reduce the operational flexibility of the primary ATC system
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		Even with a single supplier providing both ATC and CBI, given the time required to adjust scope and contracts, significant risk remains to the schedule.
Risks in opening of TYSSE in full ATC	Minor		Even with a single supplier, given above, significant risk remains to be able to commission ATC for the TYSSE in time for schedule opening.
Risks in opening of TYSSE in PM	Critical		The risk of not being able to enter revenue service in PM with a single supplier is considered low, and the resulting solution could be "ATC-ready".
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		With the costs incurred to date, even with a single supplier for ATC/CBI the risks of cost overrun remain significant
Risks in delivering Life Cycle Cost benefits	Major		In spite of a single supplier for ATC/CBI, the overall system complexity leads to a significant probability that life cycle cost targets will not be achieved

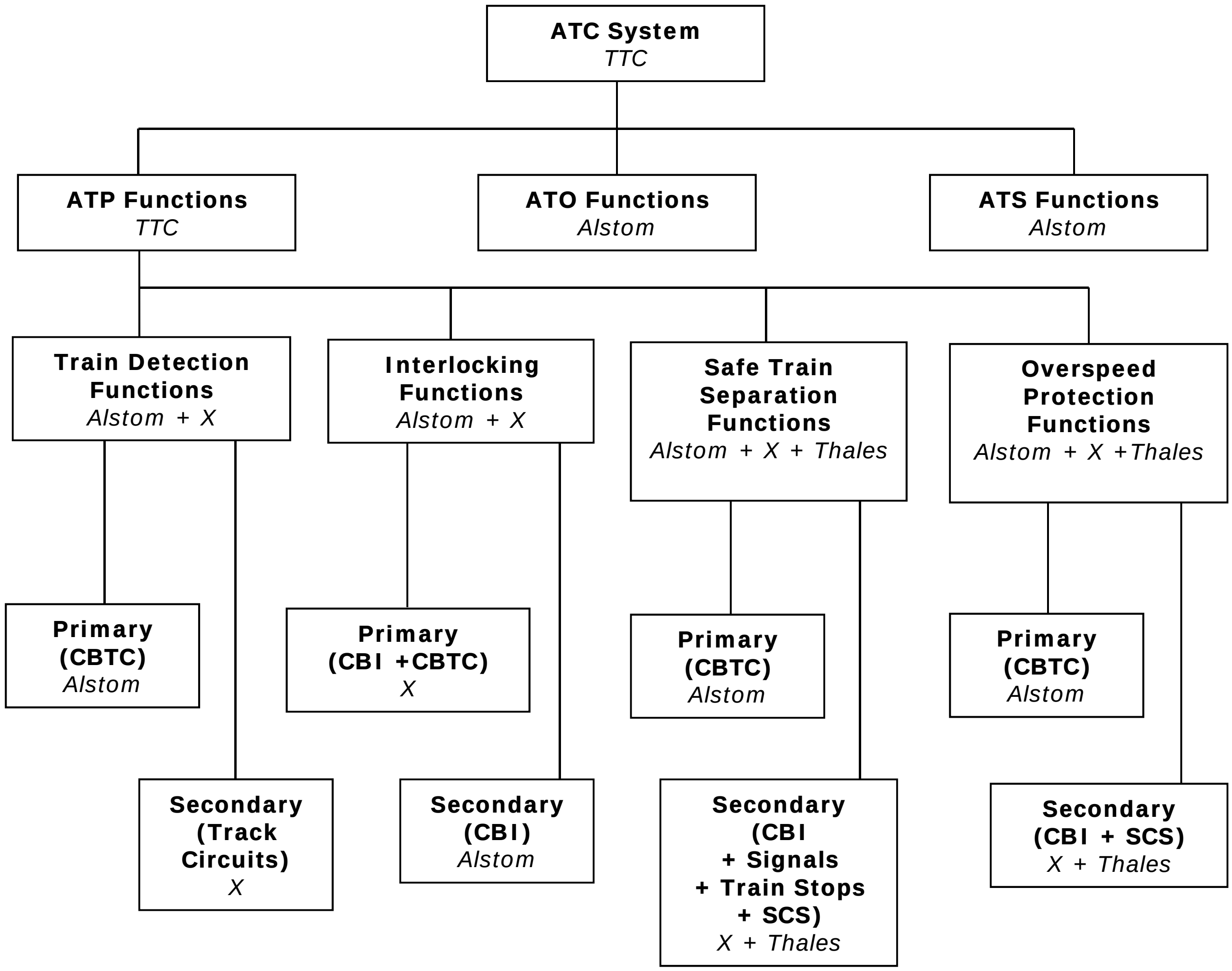
Comments/Discussion:

If Alstom were to take over Ansaldo's CBI scope it is likely that the System Architecture can be simplified with an integrated and service-proven ATC/CBI design. The current risks related to an unproven ATC-CBI interface are therefore removed.

Alstom has implemented their system in "Brownfield" environments, including recently in Santiago Metro. However, cost and schedule risks remain significant with the time taken to transition scope and contracts, and with the costs already incurred.

5.3 ALTERNATIVE A.1.III

In this alternative, "Supplier X" takes over Ansaldo's scope.



Reference	A.1.iii
Operating Scenario	A
Alstom Scope	ATC
Ansaldo Scope	
Thales Scope	SCS
"Supplier X" Scope	CBI
Systems Integrator	TTC

RISKS	Consequence	Level	Comments
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		Given the complexity of the solution, the interfaces necessary to be resolved and likely new issues with supplier 'X' there is a high probability that the target will not be achieved
Risks in delivering high level of system availability	Major		The complexity, numbers of subsystems, interfaces and wayside equipment all lead to a high probability that system availability targets cannot be achieved
Risks in delivering reduced maintenance	Minor		As a direct consequence of lower availability and the amount of equipment involved it is expected that maintenance will actually increase
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		Due to the complex nature of the system, with many interfaces and without a single contractor there is a high probability that the successful implementation of the necessary ATP functions will be at risk

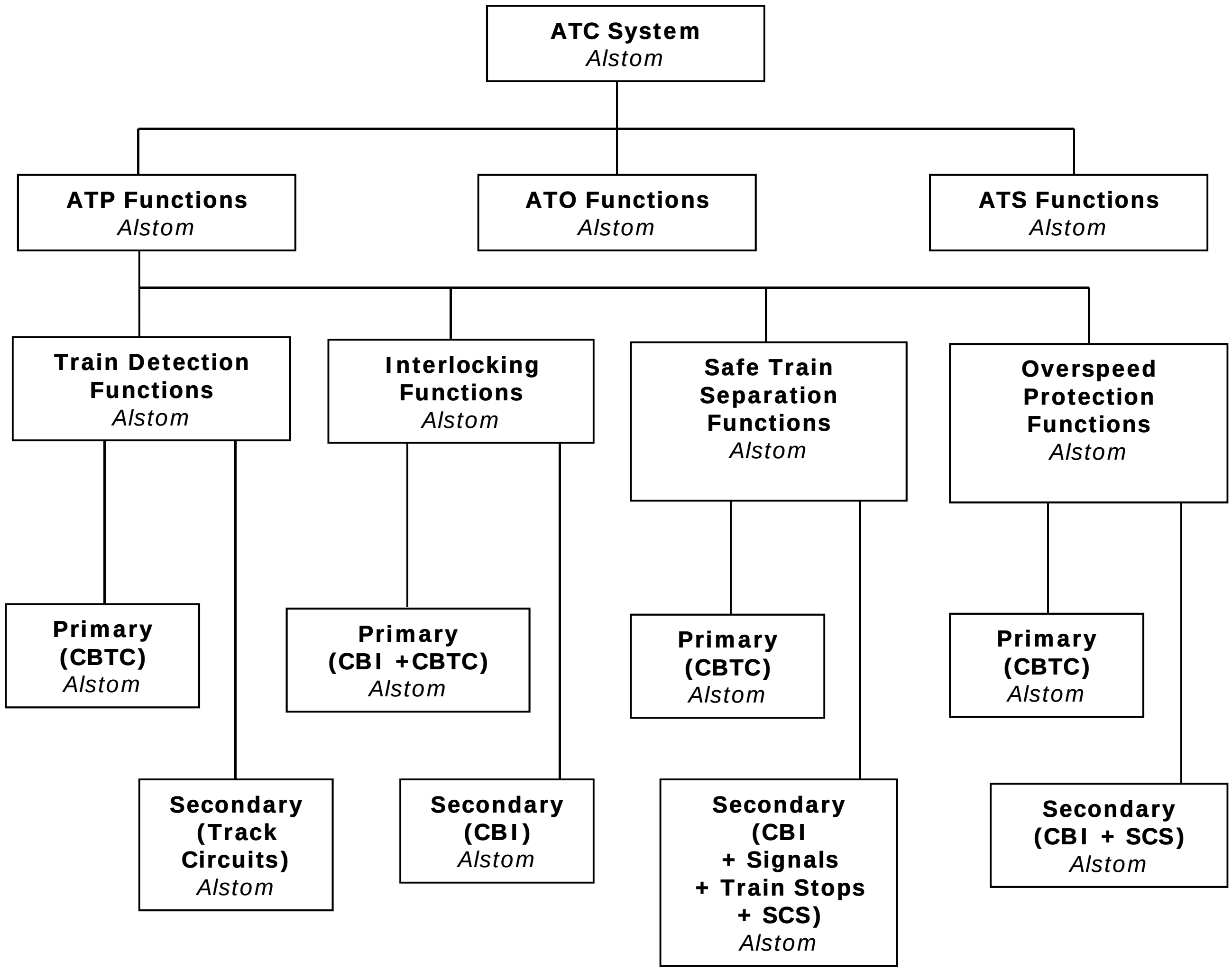
Risks in delivering ATO functions	Major		As this risk is under the control of a single supplier and single subsystem, and as the interfaces to the vehicles is already defined, the risk level is low
Risks in delivering ATS functions	Major		As this risk is under the control of a single supplier, the risk level is medium recognizing that interface details still have to be finalized
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		While the increased complexity in the secondary train control system is intended to increase failure management capabilities, there is a high probability that the complexity will reduce operational flexibility of the primary ATC system under normal operations.
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		Given that a new supplier would need to be introduced with a new contract, and given the overall risk level, there is a high risk that the schedule will not be achieved
Risks in opening of TYSSE in full ATC	Minor		Given current TYSSE schedule there is a high probability that opening the line in full ATC could not be achieved
Risks in opening of TYSSE in PM	Critical		Assuming the CBI for TYSSE were to be replaced, then there is a high risk that this could not be contracted and implemented in time
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		Given all other risks and known issues, there is a high degree of risk that the capital costs to successfully implement the existing requirements will significantly exceed the budget even with a new supplier 'X'.
Risks in delivering Life Cycle Cost benefits	Major		Given risks to availability and likelihood of increasing maintenance requirements, the lifecycle costs are expected to be higher than anticipated

Comments/Discussion:

The risks to successful completion of the project on time and to budget remain high, since a new supplier would have to be qualified with contracts negotiated and then deliver in a comparatively short timescale considering this is “Brownfield”. The only potential exception could be if supplier ‘X’ were Thales, since they have “Brownfield” experience, they are local and they are already delivering the SCS.

5.4 ALTERNATIVE A.2.I

In this alternative, Alstom take over total project scope.



Reference	A.2.i
Operating Scenario	A
Alstom Scope	Total Scope
Ansaldo Scope	
Thales Scope	
"Supplier X" Scope	
Systems Integrator	Alstom

RISKS	**Consequence**	**Level**	**Comments**
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		While the risk level is reduced with a single supplier, due to the overall complexity of the total system the risk level remains moderate
Risks in delivering high level of system availability	Major		The improved system architecture, with service-proven subsystem interfaces, should increase availability, and this risk is reduced.
Risks in delivering reduced maintenance	Minor		Improvements in system architecture and availability should reduce maintenance, and this risk is further reduced.
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		Given the complex nature of the system and interfaces to the secondary train control systems, there remains some risk to full implementation of ATP functions.
Risks in delivering ATO functions	Major		As this risk is under the control of a single supplier and single subsystem, and as the interfaces to the vehicles is already defined, the risk level is low

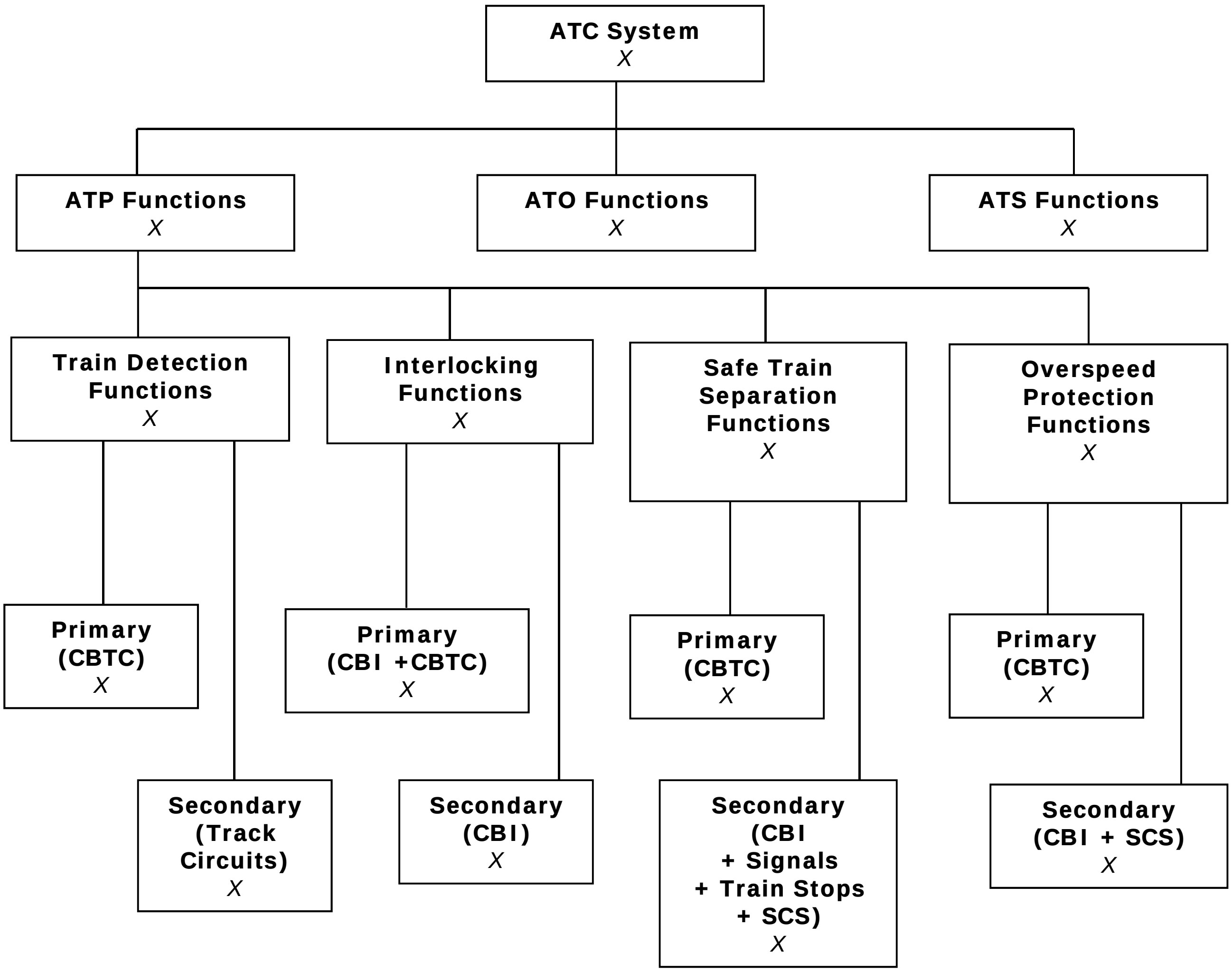
Risks in delivering ATS functions	Major		As this risk is under the control of a single supplier, the risk level is medium recognizing that interface details still have to be finalized
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		Even with a single supplier, the complexity in the secondary train control system will likely reduce operational flexibility of the primary ATC system under normal operations
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		Even with a single supplier providing ATC and AWS, given the time required to adjust scope and contracts, significant risk remains to the overall schedule.
Risks in opening of TYSSE in full ATC	Minor		Even with a single supplier, given above, significant risk remains to be able to commission ATC for the TYSSE in time for schedule opening.
Risks in opening of TYSSE in PM	Critical		The risk of not being able to enter revenue service in PM with a single supplier is assessed as low probability.
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		With the costs incurred to date, even with a single supplier the risks of cost overrun remain significant
Risks in delivering Life Cycle Cost benefits	Major		In spite of a single supplier, the complexity leads to a significant probability that life cycle cost targets will not be achieved

Comments/Discussion:

In this option, there is now a single supplier with an existing contract. While some integration is possible, the system architecture remains complex with the additional AWS. All the integration risks and challenges can now to be managed by a single supplier which while a benefit to the TTC may be a challenge to a single supplier. The risks therefore to schedule and costs in particular remain high; especially given the costs already incurred and the need to renegotiate scope and price which becomes more difficult in a sole source arrangement.

5.5 ALTERNATIVE A.2.II

In this alternative, "Supplier X" takes over total project scope.



Reference	A.2.ii
Operating Scenario	A
Alstom Scope	
Ansaldo Scope	
Thales Scope	
"Supplier X" Scope	Total Scope
Systems Integrator	X

RISKS	Consequence	Level	Comments
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		While the risk level is reduced with a single supplier, due to the overall complexity of the total system the risk level remains moderate
Risks in delivering high level of system availability	Major		The improved system architecture, with service-proven subsystem interfaces, should increase availability, and this risk is reduced.
Risks in delivering reduced maintenance	Minor		Improvements in system architecture and availability should reduce maintenance, and this risk is further reduced.
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		Given the complex nature of the system and interfaces to the secondary train control systems, there remains some risk to full implementation of ATP functions.
Risks in delivering ATO functions	Major		Although this risk is under the control of a single supplier, with supplier "X" the risk level is high given the amount of rework required compared to work already done by Alstom

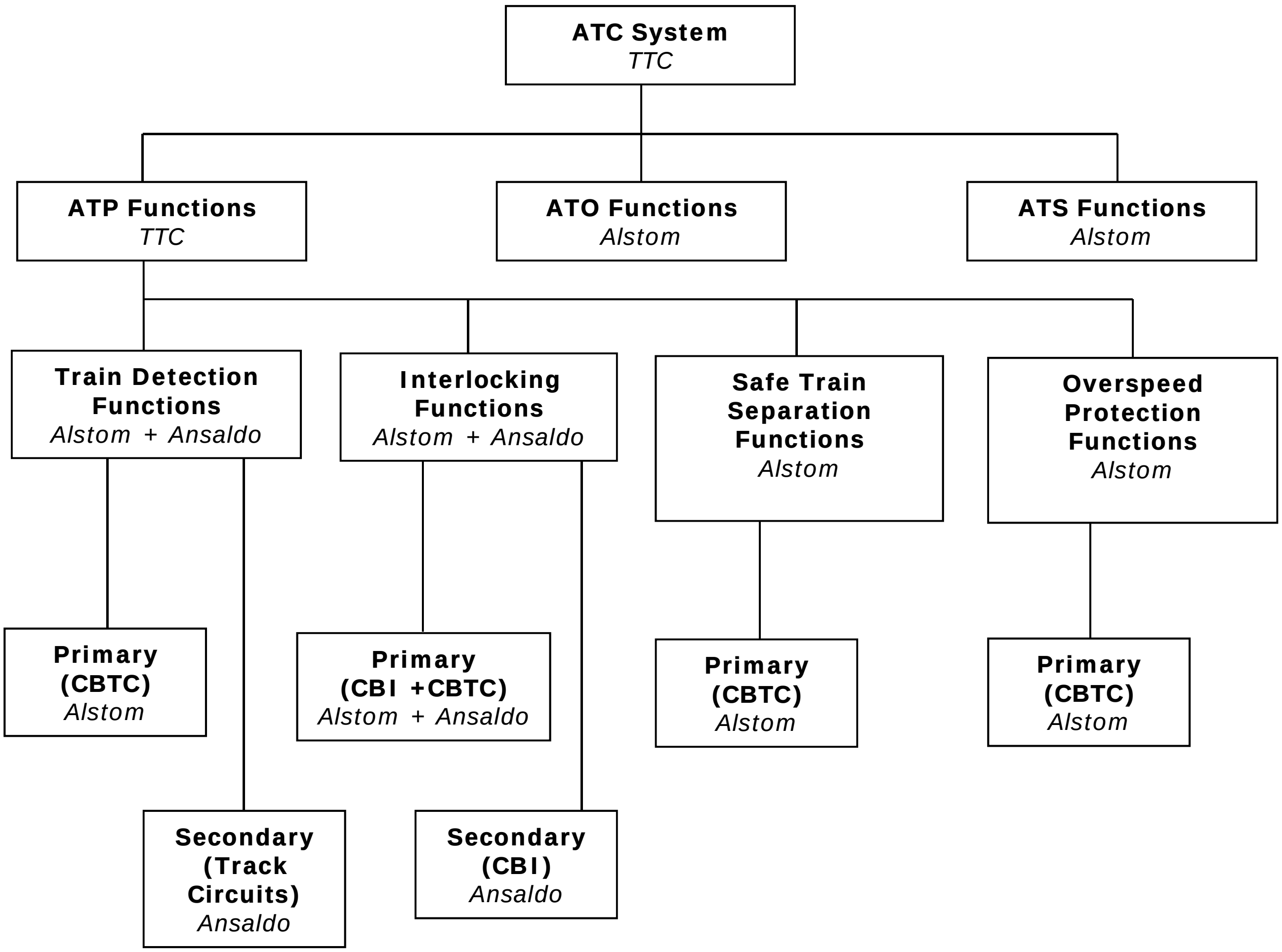
Risks in delivering ATS functions	Major		Although this risk is under the control of a single supplier, with supplier "X" the risk level is high given the amount of rework required compared to work already done by Alstom
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		Even with a single supplier, the complexity in the secondary train control system will likely reduce operational flexibility of the primary ATC system under normal operations
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		Even with a single supplier providing ATC and AWS, given the time required to tender and negotiate a new contract, risk to the project schedule is high.
Risks in opening of TYSSE in full ATC	Minor		The time taken to tender and negotiate a new contract put this at high risk.
Risks in opening of TYSSE in PM	Critical		The time taken to tender and negotiate a new contract put this at high risk.
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		With the costs incurred to date, even with a single supplier, as yet unknown, the risks of cost overruns are high
Risks in delivering Life Cycle Cost benefits	Major		In spite of a single supplier, the complexity leads to a significant probability that life cycle cost targets will not be achieved

Comments/Discussion:

The risk level for this alternative, with complete scope assigned to a new supplier 'X' would be higher than that for assigning full scope to Alstom A.2.i, since Alstom have already done significant work, they have a mature team, contract and local presence.

5.6 ALTERNATIVE B.1.I

In this alternative, Thales scope is eliminated and Ansaldo's scope is reduced.



Reference	B.1.i
Operating Scenario	B
Alstom Scope	ATC
Ansaldo Scope	CBI
Thales Scope	
"Supplier X" Scope	
Systems Integrator	TTC

RISKS	**Consequence**	**Level**	**Comments**
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		With CBI scope reduced/simplified the probability of achieving headway is increased, although risk remains significant given the unproven ATC-CBI interface
Risks in delivering high level of system availability	Critical		Reduction in complexity with SCS also eliminated should improve availability although overall complexity still presents risk
Risks in delivering reduced maintenance	Minor		This risk is reduced with the reduced onboard and wayside equipment
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		The system remains somewhat complex, with significant ATC/CBI interfaces and without a single contractor there is a high probability that the successful implementation of the necessary ATP functions will be at risk. Also with Operating Scenario B, full ATP protection is not provided for non-ATC trains.
Risks in delivering ATO functions	Major		As this risk is under the control of a single supplier and single subsystem, and as the interfaces to the vehicles is

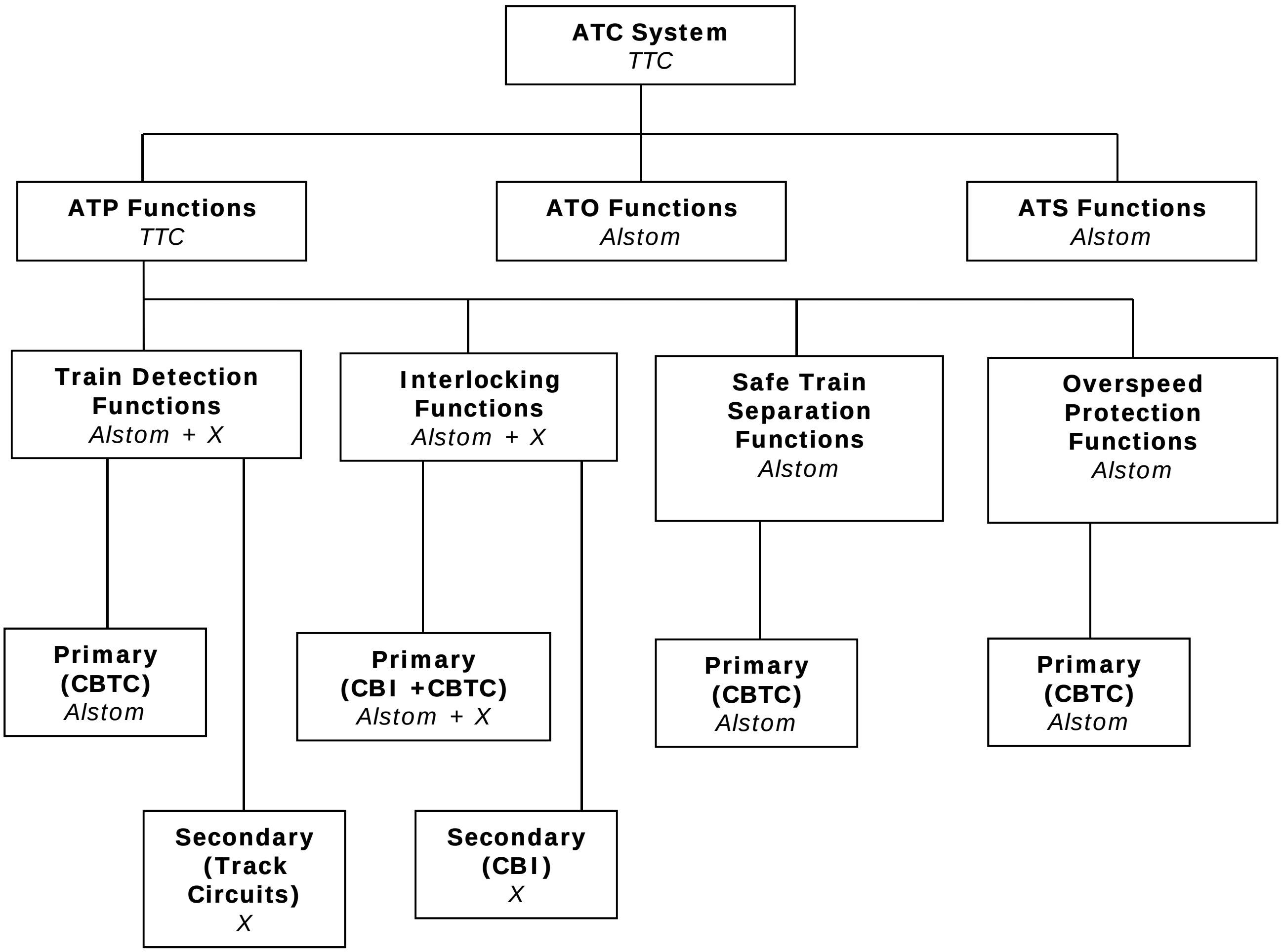
			already defined, the risk level is low
Risks in delivering ATS functions	Major		As this risk is under the control of a single supplier, the risk level is medium recognizing that interface details still have to be finalized
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		With the reduction in complexity of the CBI and elimination of secondary train protection systems, this risk is reduced
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		There is still a significant probability that the full system may not be in service by 2020
Risks in opening of TYSSE in full ATC	Minor		There is a high probability that TYSSE will not be able open with full ATC
Risks in opening of TYSSE in PM	Critical		There remains the possibility that TYSSE may not be able to open in PM, however it should be possible to mitigate this risk.
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		There remains a significant risk to the capital costs in spite of reduction in CBI scope and elimination of SCS.
Risks in delivering Life Cycle Cost benefits	Major		This risk is reduced with the reduced onboard/wayside equipment, increased availability, etc.

Comments/Discussion:

The reduction in Ansaldo's scope and simplification of the AWS with removal of the SCS should benefit the program and reduce risk levels. Availability may also be improved, with reduced maintenance and life-cycle costs. However many costs already committed and changes to scope must be negotiated.

5.7 ALTERNATIVE B.1.II

In this alternative, Thales scope is eliminated, and "Supplier X" takes over Ansaldo's scope.



Reference	B.1.ii
Operating Scenario	B
Alstom Scope	ATC
Ansaldo Scope	
Thales Scope	
"Supplier X" Scope	CBI
Systems Integrator	TTC

RISKS	**Consequence**	**Level**	**Comments**
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		Selecting an alternative CBI supplier and even with a simplified CBI, the risk to achieving the headway will remain significant
Risks in delivering high level of system availability	Critical		The resulting system architecture should be able to meet the availability targets, however the risk remains
Risks in delivering reduced maintenance	Minor		As a result of the simplifications, this risk should be reduced.
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		Even with the simplifications in architecture and requirements, the ATP functions must be allocated between two system suppliers and so this remains a high risk. Also with Operating Scenario B, full ATP protection is not provided for non-ATC trains.
Risks in delivering ATO functions	Major		As this risk is under the control of a single supplier and single subsystem, and as the interfaces to the vehicles is already defined, the risk level is low

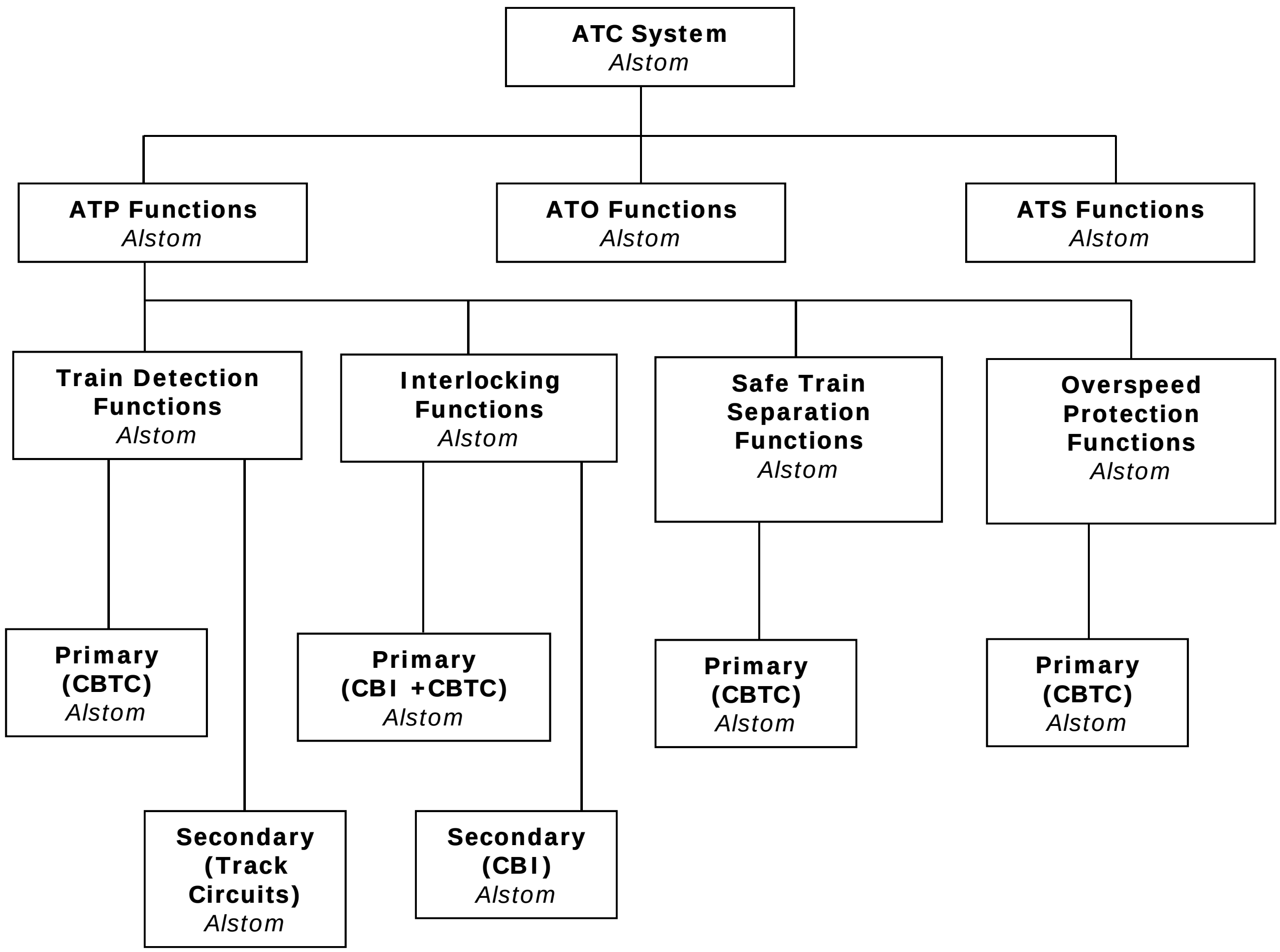
Risks in delivering ATS functions	Major		As this risk is under the control of a single supplier, the risk level is medium recognizing that interface details still have to be finalized
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		The simplifications to the architecture and reduction in scope should result in minimal risk to operational flexibility
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		The introduction of a new supplier and changes to scope/contracts will still put the overall schedule at high risk.
Risks in opening of TYSSE in full ATC	Minor		The risk to opening TYSSE on schedule with ATC and a new CBI supplier is significant.
Risks in opening of TYSSE in PM	Critical		The risk to opening the TYSSE on schedule in PM with a new CBI supplier is high
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		There remains a high risk to the capital costs in spite of reduction in CBI scope and elimination of SCS.
Risks in delivering Life Cycle Cost benefits	Major		This risk is reduced with reduced onboard/wayside equipment, increased availability, etc.

Comments/Discussion:

Replacing Ansaldo with another supplier, even with simplified requirements and the elimination of the SCS presents significant risk unless the new supplier can be guaranteed to be qualified and can demonstrate prior “brownfield” experience in similar circumstances.

5.8 ALTERNATIVE B.2.I

In this alternative, Thales scope is eliminated and Alstom takes over complete project scope.



Reference	B.2.i
Operating Scenario	B
Alstom Scope	Total Scope
Ansaldo Scope	
Thales Scope	
"Supplier X" Scope	
Systems Integrator	Alstom

RISKS	**Consequence**	**Level**	**Comments**
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		With a single supplier, providing a service-proven solution, and with the reduction in complexity of the secondary train control system, this risk is considered low
Risks in delivering high level of system availability	Critical		With a single supplier, providing a service-proven solution, and with the reduction in complexity of the secondary train control system, this risk is considered low
Risks in delivering reduced maintenance	Minor		The risk to achieving maintenance targets is considered low based on reduction of wayside and vehicle borne equipment
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		With a single supplier, providing a service-proven solution, and with the reduction in complexity of the secondary train control system, this risk is considered low. However, with Operating Scenario B, full ATP protection is not provided for non-ATC trains.
Risks in delivering ATO functions	Major		As this risk is under the control of a single supplier and single subsystem, and as the interfaces to the vehicles is already defined, the risk level is low

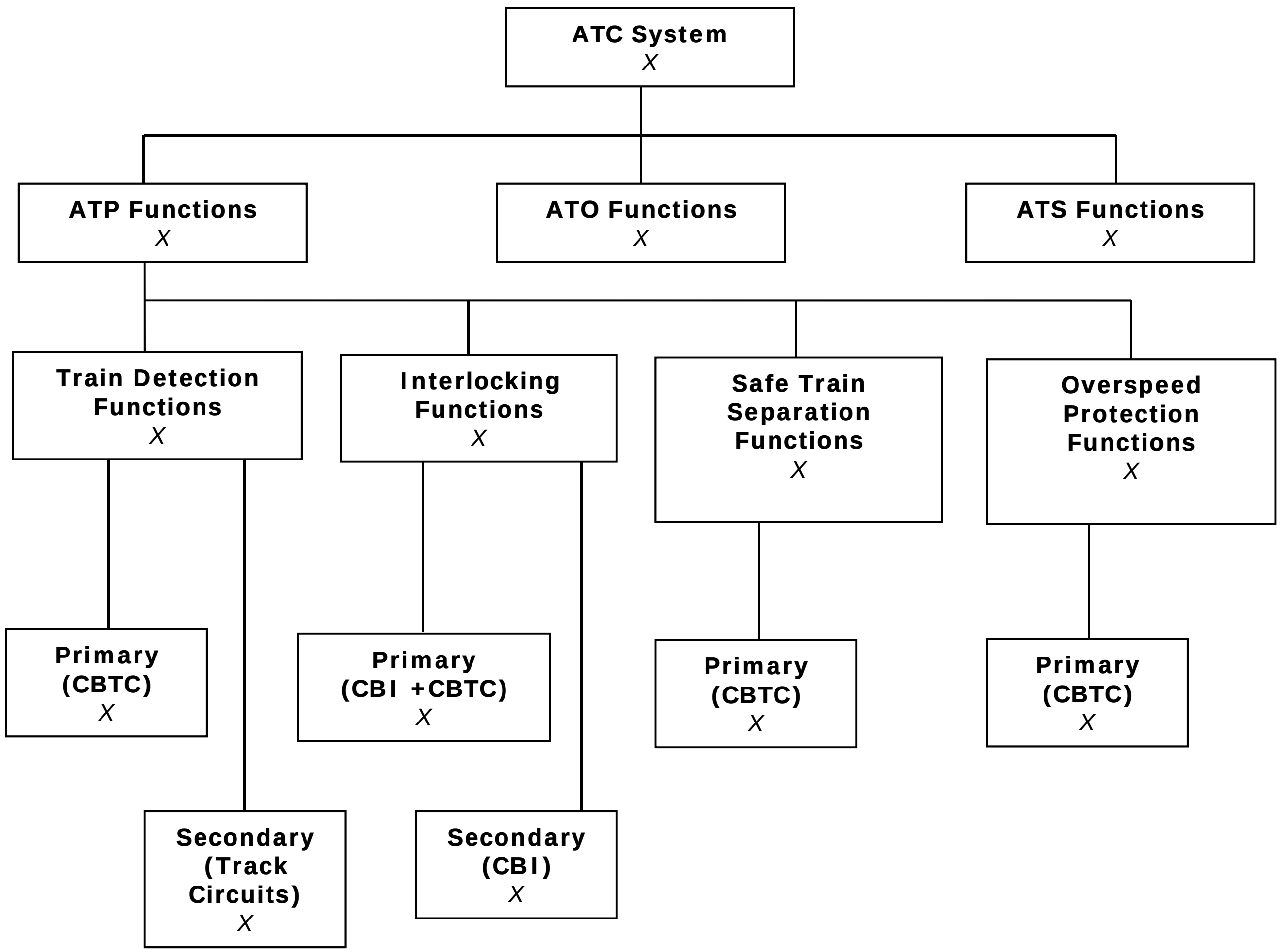
Risks in delivering ATS functions	Major		As this risk is under the control of a single supplier, the risk level is medium recognizing that interface details still have to be finalized
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		With a single supplier, providing a service-proven solution, and with the reduction in complexity of the secondary train control system, this risk is considered low
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		Since the supplier is existing with much work already done the risk to schedule is reduced, though some risk remains
Risks in opening of TYSSE in full ATC	Minor		The risk to TYSSE opened with full ATC remains significant
Risks in opening of TYSSE in PM	Critical		The risk of not being able to enter revenue service in PM with a single supplier is considered low, and the resulting solution should be “ATC-ready”.
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		The reduction in scope and consolidation of supply should result in reduction in risk, however some risk remains to cost
Risks in delivering Life Cycle Cost benefits	Major		The simplification of requirements and architecture should result in less risk of increase in life cycle costs

Comments / Discussion:

In this alternative, the scope and functionality is reduced to the ATC system with simplified secondary train detection and protection. The CBI can be integrated with the ATC. The SCS is eliminated and the integration risks are borne by a single supplier, Alstom, who is already under contract to the TTC. The Project remains "brownfield" so risks are still significant.

5.9 ALTERNATIVE B.2.II

In this alternative, Thales scope is eliminated and "Supplier X" takes over total scope



Reference	B.2.ii
Operating Scenario	B
Alstom Scope	
Ansaldo Scope	
Thales Scope	
"Supplier X" Scope	Total Scope
Systems Integrator	X

RISKS	**Consequence**	**Level**	**Comments**
Risks in delivering the ATC Project Performance Requirements			
Risks in delivering a step-change increase in line capacity	Critical		With a single supplier, providing a service-proven solution, and with the reduction in complexity of the secondary train control system, this risk is considered low
Risks in delivering high level of system availability	Critical		With a single supplier, providing a service-proven solution, and with the reduction in complexity of the secondary train control system, this risk is considered low
Risks in delivering reduced maintenance	Minor		The risk to achieving maintenance targets is considered low based on reduction of wayside and vehicle borne equipment
Risks in delivering the ATC Project Functional Requirements			
Risks in delivering ATP functions	Critical		With a single supplier, providing a service-proven solution, and with the reduction in complexity of the secondary train control system, this risk is considered low. However, with Operating Scenario B, full ATP protection is not provided for non-ATC trains.

Risks in delivering ATO functions	Major		Although this risk is under the control of a single supplier, with supplier "X" the risk level is high given the amount of rework required compared to work already done by Alstom
Risks in delivering ATS34 functions	Major		Although this risk is under the control of a single supplier, with supplier "X" the risk level is high given the amount of rework required compared to work already done by Alstom
Risks in delivering the ATC Project Operational Requirements			
Risks in delivering operational flexibility	Minor		Under the control of a single supplier and with a simplified architecture the risks to operational flexibility are low
Risks in delivering the ATC Project Schedule Requirements			
Risks in delivering project by 2020	Critical		With the need to tender and negotiate a new contract the risk to the overall schedule is high
Risks in opening of TYSSE in full ATC	Minor		With a new supplier starting from scratch the risk to opening with ATC is high
Risks in opening of TYSSE in PM	Critical		With a new supplier starting from scratch the risk to opening in PM is high
Risks in delivering the ATC Project Cost Requirements			
Risks in delivering project within budget (including TTC costs)	Critical		With costs already incurred, even with reduction in scope and simplification in architecture there will be significant risk to costs.
Risks in delivering Life Cycle Cost benefits	Major		The simplification of requirements and architecture should result in less risk of increase in life cycle costs

Comments/Discussion:

In this alternative, the scope and functionality is reduced to the ATC system with simplified back-up for train detection and protection. The CBI can be integrated with the ATC. The SCS is eliminated and the integration risks are borne by a single supplier, 'X" who is to be selected with an agreement to be reached. The Project remains "brownfield" so risks are still significant. This alternative would increase schedule risks due to the additional tender process and the project budget would also be at risk, with much of the work already done and costs incurred by Alstom and possibly the TTC of no benefit to the new contract.

5.10 SUMMARY

Table 2: Alternatives Assessment by Individual Risk

Delivery Alternative Reference	A.1.i	A.1.ii	A.1.iii	A.2.i	A.2.ii	B.1.i	B.1.ii	B.2.i	B.2.ii
Operating Scenario Alternative	A	A	A	A	A	B	B	B	B
Alstom Scope	ATC	ATC, CBI	ATC	ATC,AWS		ATC	ATC	ATC,CBI	
Ansaldo Scope	CBI					CBI			
Thales Scope	SCS	SCS	SCS						
"Supplier X" Scope			CBI		ATC,AWS		CBI		ATC,CBI
Systems Integrator	TTC	TTC	TTC	Alstom	Supplier X	TTC	TTC	Alstom	Supplier X
RISKS									
Risks in delivering the ATC Project Performance Requirements									
Risks in delivering a step-change increase in capacity (Critical)	5	4	5	4	4	4	4	3	3
Risks in delivering high system availability (A:Major; B:Critical)	4	3	4	3	3	4	4	3	3
Risks in delivering reduced maintenance (Minor)	3	3	3	2	2	1	1	1	1
Risks in delivering the ATC Project Functional Requirements									
Risks in delivering ATP functions (Critical)	5	4	5	4	4	5	5	3	3
Risks in delivering ATO functions (Major)	2	2	2	2	4	2	2	2	4
Risks in delivering ATS functions (Major)	3	3	3	3	4	3	3	3	4
Risks in delivering the ATC Project Operational Requirements									
Risks in delivering operational flexibility (Minor)	3	3	3	3	3	1	1	1	1
Risks in delivering the ATC Project Schedule Requirements									
Risks in delivering project by 2020 (Critical)	5	4	5	4	5	4	5	3	5
Risks in opening of TYSSE in full ATC (Minor)	3	3	3	3	3	3	3	3	3
Risks in opening of TYSSE in PM (Critical)	3	3	5	3	5	3	5	3	5
Risks in delivering the ATC Project Cost Requirements									
Risks in delivering project within budget (Critical)	5	4	5	4	5	4	5	3	4
Risks in delivering Life Cycle Cost benefits (Major)	4	3	3	3	3	2	2	2	2
RISK SCORE (OVERALL RANKING)	45 (8)	39 (5)	46 (9)	38 (4)	45 (8)	36 (2)	40 (6)	30 (1)	38 (4)

5.11 ALTERNATIVE EVALUATION APPROACH

As an alternative evaluation approach, for each identified risk, each alternative was ranked in order based on a qualitative risk assessment, from lowest risk (1) to highest risk (9).

For this alternative approach, the following colour coding was adopted.

Overall Ranking	Colour Coding
1,2,3	
4,5,6	
7,8,9	

Table 3 below shows the overall assessment with the ranks for each risk added for each alternative. The alternative with the lowest aggregate score would offer the least risk alternative.

Table 4 provides a comparison of the assessments from the two approaches.

The assessment of risks - first individually (Section 5.10) and then by comparison (this Section 5.11) - allows some cross comparison and although some subjectivity remains, provides a more robust assessment.

Table 3: Alternative Assessment by Ranking

Delivery Alternative Reference	A.1.i	A.1.ii	A.1.iii	A.2.i	A.2.ii	B.1.i	B.1.ii	B.2.i	B.2.ii
Operating Scenario Alternative	A	A	A	A	A	B	B	B	B
Alstom Scope	ATC	ATC, CBI	ATC	ATC,AWS		ATC	ATC	ATC,CBI	
Ansaldo Scope	CBI					CBI			
Thales Scope	SCS	SCS	SCS						
“Supplier X” Scope			CBI		ATC,AWS		CBI		ATC,CBI
Systems Integrator	TTC	TTC	TTC	Alstom	Supplier X	TTC	TTC	Alstom	Supplier X
RISKS									
Risks in delivering the ATC Project Performance Requirements									
Risks in delivering a step-change increase in capacity (Critical)	8	7	9	5	6	3	4	1	2
Risks in delivering high level of availability (A:Major; B:Critical)	8	7	9	5	6	3	4	1	2
Risks in delivering reduced maintenance (Minor)	8	7	9	5	6	3	4	1	2
Risks in delivering the ATC Project Functional Requirements									
Risks in delivering ATP functions (Critical)	8	4	9	3	5	6	7	1	2
Risks in delivering ATO functions (Major)	6	5	7	4	9	2	3	1	8
Risks in delivering ATS functions (Major)	6	5	7	4	9	2	3	1	8
Risks in delivering the ATC Project Operational Requirements									
Risks in delivering operational flexibility (Minor)	8	7	9	5	6	3	4	1	2
Risks in delivering the ATC Project Schedule Requirements									
Risks in delivering project by 2020 (Critical)	8	3	9	2	7	4	5	1	6
Risks in opening of TYSSE in full ATC (Minor)	8	3	9	2	7	4	5	1	6
Risks in opening of TYSSE in PM (Critical)	2	5	8	4	9	1	6	3	7
Risks in delivering the ATC Project Cost Requirements									
Risks in delivering project within budget (Critical)	8	7	9	5	6	3	4	1	2
Risks in delivering Life Cycle Cost benefits (Major)	8	7	9	5	6	3	4	1	2
RISK SCORE (OVERALL RANKING)	94 (8)	60 (6)	103 (9)	49 (4)	82 (7)	37 (2)	53 (5)	14 (1)	49 (4)

Table 4: Comparison between Table 2 and Table 3

Delivery Alternative Reference	A.1.i	A.1.ii	A.1.iii	A.2.i	A.2.ii	B.1.i	B.1.ii	B.2.i	B.2.ii
Operating Scenario Alternative	A	A	A	A	A	B	B	B	B
Alstom Scope	ATC	ATC, CBI	ATC	ATC,AWS		ATC	ATC	ATC,CBI	
Ansaldo Scope	CBI					CBI			
Thales Scope	SCS	SCS	SCS						
"Supplier X" Scope			CBI		ATC,AWS		CBI		ATC,CBI
Systems Integrator	TTC	TTC	TTC	Alstom	Supplier X	TTC	TTC	Alstom	Supplier X
TABLE 2 SUMMARY	45 (8)	39 (5)	46 (9)	38 (4)	45 (8)	36 (2)	40 (6)	30 (1)	38 (4)
TABLE 3 SUMMARY	94 (8)	60 (6)	103 (9)	49 (4)	82 (7)	37 (2)	53 (5)	14 (1)	49(4)

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 GENERAL CONCLUSIONS

Conclusion #1:

It is perhaps self-evident that project delivery risks can be reduced by simplifying the project scope and reducing the number of contracts and contractual interfaces required to deliver that scope.

This Alternatives Analysis confirms this conclusion and identifies Alternative B.2.i as the least-risk solution, specifically:

- The secondary train control system is significantly simplified (revised Operating Concept and ATC System Specifications), with emphasis placed on the delivery of a highly available primary ATC system; and

- Delivery of the total ATC project scope is the contractual responsibility of a single contractor, Alstom (revised Delivery Method).

This Alternative provides the highest level of confidence of delivering the Project Requirements on schedule and within budget.

Acceptance of this Alternative does however also require acceptance by TTC of:

a) Operating Scenario Alternative B) being an appropriate and acceptable operating strategy for TTC, in which the likelihood of non-ATC trains operating on the line is minimized (all passenger trains/work trains that are likely to operate on the line are ATC-equipped), such that the independent speed control system (SCS) can be eliminated and the number of wayside signals/train stops significantly reduced;

b) Moving to a single-contractor delivery strategy can be accomplished contractually, within a reasonable time frame; and without placing at-risk the opening of TYSSE, at least in a fixed-block, protected manual (PM) mode.

Conclusion #2:

If a) above is acceptable to TTC, but b) is not acceptable to TTC, then this Alternatives Analysis identifies Alternative B.1.i as the next least-risk solution, specifically:

- The secondary train control system is significantly simplified (revised Operating Concept and ATC System Specifications), with emphasis placed on the delivery of a highly available primary ATC system; and

- Delivery of the total scope remains the contractual responsibility of two contractors, Alstom and Ansaldo (with modified scope), with TTC acting in the role of Systems Integrator with respect to the interfaces between these two contracts (revised Delivery Method).

Conclusion #3

If a) above is not acceptable to TTC, but b) is acceptable to TTC, then this Alternatives Analysis identifies Alternative A.2.i as the next least-risk solution, specifically:

- A complex secondary train control system is retained providing secondary train protection for non-ATC trains; under this alternative, it would not be necessary to equip work trains with ATC equipment (no change to existing ATC System Specifications); and

- A single contractor, Alstom, is responsible for delivering the total scope, ATC + AWS (revised Delivery Method).

Conclusion #4

If both a) and b) above are not acceptable to TTC, then this Alternatives Analysis identifies Alternative A.1.ii as the next least-risk solution:

- A complex secondary train control system is retained providing secondary train protection for non-ATC trains; under this alternative, it would not be necessary to equip work trains with ATC equipment (no change to existing ATC System Specifications); and

- Delivery of the total scope remains the contractual responsibility of two contractors, Alstom (ATC + CBI) and Thales (SCS), with TTC acting in the role of Systems Integrator with respect to the interfaces between these two contracts (revised Delivery Method).

The above conclusions are summarized in the following table:

	Operating Scenario A Selected	**Operating Scenario B Selected**
Multi-Supplier Alternative Selected	A.1.ii: Alstom + Thales (Conclusion #4)	B.2.i: Alstom + Ansaldo (Conclusion #2)
Single-Supplier Alternative Selected	A.2.i: Alstom (Conclusion #3)	B.2.i: Alstom (Conclusion #1)

6.2 SPECIFIC RECOMMENDATIONS

The Alternatives Analysis addressed in this report focuses on the ATC System Configuration and ATC Delivery Method for the end-state railway.

Recognizing that time is of the essence, and the transition from the current delivery plan to any new delivery plan must be accomplished as expeditiously as possible, then regardless of the Alternative adopted by TTC, it is recommend that as a next step, TTC establish two interrelated and coordinated "tiger teams" – one engineering/operations – the other commercial.

Both teams should include appropriate representation not only from the ATC project, but also the TYSSE project, the Wilson Yard project, and any other relevant interfacing projects.

The engineering/operations tiger team should have the mandate to develop:

1) A Concept of Operations (ConOps) document reflecting the selected Operating Scenario (A or B);

2) A revised ATC project Technical Specification – specifically the Operating Requirements, Performance Requirements and Functional Requirements consistent with this ConOps document but also reflecting the capabilities of service-proven CBTC and CBI products;

3) A revised ATC System Configuration Summary, reflecting the high-level System Architecture for the revised ATC project;

4) A high-level Migration Plan/Schedule defining the cut-over of the ATC system on the line, including TYSSE; and

5) A Project Management Plan defining the management of the revised ATC project through hand-over to Operations.

The commercial tiger team should have the mandate to:

1) Take whatever immediate procurement action is necessary to minimize continued expenditure on the design, delivery and installation of equipment/subsystems/systems that will not form part of the final ATC System Architecture and are not required on an interim basis to support the defined Migration Plan;

2) Develop a procurement strategy to transition to the new project delivery method (e.g. sole-source negotiations or competitive procurement); and

3) Negotiate with appropriate suppliers the cost and schedule impacts of any required changes in their contract scope to comply with the revised Technical Specification, Configuration Summary, Migration Plan and Project Management Plan.