Transit
Rolling Stock
Intercity & Heavy Rail

TECHNICAL REPORT

TRILLIUM STAGE 2

Independent Peer Review – Final Report

Client Reference: 19222-91896-P0

SYSTRA Canada Reference: 22024-PQRT-0001_A2

Ligne Trillium Line

Prepared for:
City of Ottawa

Submitted on:
2023-02-06

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ISO 9001:2015 Certified

Revision History

Revision	A1	A2
Date	2022-12-14	2023-02-06
Prepared by	SA-VB-BB	SA
Reviewed by	SD	VB
Approved by	MS	HL

- ☐ Preliminary/internal verification
- ☐ Submitted for approval
- ☐ Submitted for construction/ implementation
- ☐ Submitted for information
- ☐ Issued for proposal
- ☐ Cancelled
- ☑ Issued for revision and comments
- ☐ Submitted for purchasing
- ☐ As built

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Document

IDENTIFICATION

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1. ABBREVIATIONS

Table 1 : List of abbreviations

Abbreviations	
AHJ	Authority Having Jurisdiction
ARP	Aerospace Recommended Practice
CFD	Computational Fluid dynamics
CMMS	Computerized Maintenance Management System
CMP	Construction Management Plan
CTS	Communications Transmission System
CWR	Continuous Welded Rail
DC	Direct Current
DF Track	Direct Fixation Track
DMU	Diesel Multiple Unit
EMC / EMI	Electromagnetic compatibility / interference
FBS	Function Breakdown Structure
FMECA	Failure Mode Effect and Critically Analysis
HFI	Human Factor Integration
ILS	Integrated Logistic Support
ISA	Independent Safety Assessor
LRU	Line Replaceable Unit
LLRU	Lower Line Replaceable Unit
MSF	Maintenance and Storage Facility
MTBF	Mean Time Between Failure
MTFSAF	Mean Time Between Service Affecting Failure
NCR	Non-conformity Report
NMS	Network Management System
TOCC	Transit Operation Control Centre
OCS	Overhead Catenary System
PA	Project Agreement
PHA	Preliminary Hazard Analysis
PMP	Project Management Plan
PSOS	Project Specific Output Specification
RAM	Reliability Availability Maintainability
RAMAR	RAM Apportionment Report
RAMDR	RAM Demonstration Report

Abbreviations	
RAMPP	RAM Program Plan
RAMS	Reliability Availability Maintainability Safety
SAE	Society of Automotive Engineers
SBS	System Breakdown Structure
SCM	Safety Certification Manager
SESA	System Engineering and Safety Assurance
SME	Subject Matter Expert
S&TCS	Signalling & Train Control System
SIL	Safety Integrity Level
TNext	TransiT Next
SSAP	System Safety Assurance Plan
SSCP	System Safety Certification Plan
T&C	Testing & Commissioning
V&V	Verification & Validation

2. INTRODUCTION

2.1 PROJECT INTRODUCTION

O-Train Line 2, Trillium Line, is being extended and upgraded (Stage 2 Project) to provide the City of Ottawa with a safe, efficient, and reliable transit network.

The Trillium Line Extension Project is planned to be an extension south of the existing 8 km single-track system presently in operation. The existing portion is located on the disaffected CN/CP freight line right of way between Bayview and Greenboro and consists of 5 stations with an approximately 750 metres tunnel under Dow's Lake, which is serviced with 6 Alstom 40 metres Diesel Multiple Unit (DMU) vehicles that are being maintained in an existing Maintenance and Storage Facility (MSF) at Walkley Yard.

The new portion of this project comprises an 11 km track extension south of Greenboro and a 4 km spur to the Ottawa McDonald Cartier International Airport, using part of the existing alignment and part green field, with six new stations on the extension lines. The airport spur will have 2 dedicated stations, which will connect to the mainline, and includes a series of new structures, including road and rail overpasses, grade separation, and pedestrian overpasses. The extension project will also add 2 new stations to the existing portion and 4 new stations to the south extensions.

In March 2019, Ottawa City Council approved and awarded the design-build-finance and maintain contract for the Trillium Line Extension Project to TransiTNext (TNext), a wholly owned affiliate of SNC-Lavalin.

SNC-Lavalin was involved in the design and construction of the Stage 1 Line Confederation Line Project. Due to the current operational issues being faced on the Line 1 Confederation Line, questions have been raised about whether the quality of the railway design, construction and installation are contributing factors and about whether challenges being faces on the Stage 1 Confederation Line are going to repeat themselves on the expanded Trillium Line.

The overall goal of this peer review is to assess the quality of the design and construction of the Stage 2 Trillium Line Expansion Project.

2.2 SCOPE

This report summarizes the result of SYSTRA/RATP assessment resulting from the peer review of the documentation provided by the City of Ottawa and interviews with TNext Team. The report provides a list of recommendations that, in the reviewers' opinion, should be applied in order to reduce risks related to the project delivery.

2.3 IMPARTIALITY AND INTENT

The summaries within this document are the professional opinions of the Subject Matter Experts (SME) team. Based on the information and documents provided by the City of Ottawa and Tnext, the analysis provided is impartial and derived from the collective experience of the professionals included in the process and the goal of the assessment.

It is not the intent of the report to provide a definitive judgment on any product, system, or design. The assessment is based on the PA requirements as well as the best practice and industry standards that the SMEs have encountered and applied in their experience. Other professionals may have differing opinions and experiences with the systems and proposed designs.

This report does not provide an opinion on the compliance of the design with the PA requirements and / or the applicable codes and standards.

2.4 METHODOLOGY

This section provides a summary of the assessment methodology used by the SME team :

- SME team members were allocated sections of the PA and PSOS to review based on their area of expertise;
- SME team members were allocated project documentation to review based on their area of expertise;
- SME team members noted clarifications request, questions and comments on a consolidated file;
- Leadership team cross reference all clarification requests, questions and comments to extract the various identified risk areas;
- The SME and Leadership team had meetings with TNEXT team to obtain more information and clarification;
- Recommendations based on the review and meetings with TNEXT are included in this report;
- Recommendations are numbered following the nomenclature below[1]:
  - PM.xx: Project Management;
  - RS.xx: Rolling Stock;
  - TCS.xx:Train Control System;
  - COM.xx: Communication and SCADA Systems;
  - TRK.xx: Trackwork;
  - TVS.xx: Tunnel Ventilation System;

[1] Recommendations that were removed from the report as compared to its initial version has been kept in the annex for traceability.

- SEM.xx: System Engineering Management;
- SA.xx: System Assurance;
- CON.xx: Construction control
- TC.xx: Test & Commissioning;
- OPS.xx: Operation;
- MAI.xx: Maintenance;
- TRA.xx: Training.

Subsequent to the issue of the preliminary report, several rounds of discussions took place with the city and with TNEXT in order to clarify some of the aspects mentioned therein.

The file logging the results of this round of clarifications is provided in Annex to the present report.

The present report considers the latest documents and information received from TNEXT and from the City.

3. DOCUMENTS RECEIVED

The documents received from the City in relation with this peer review are listed in Appendix A.

4. EXECUTIVE SUMMARY

SYSTRA/RATP is performing the role of peer reviewer for the Trillium Line. This role has involved assessing the progress of the Design, Build and Maintain project that TNext is executing for the City of Ottawa.

SYSTRA/RATP began the assessment in May 2022. After review of various documentation from project management, design, construction, testing, operation and maintenance SYSTRA/RATP issued a first discovery report with a list of people to interview from TNext and the City of Ottawa.

In July'22, SYSTRA/RATP conducted a series of interview/workshops and deep dive in the documentation pertaining to the project to provide a third-party professional opinion about the risks of the project and their associated recommendations. The draft recommendations were shared with the City and with TNext, to give the opportunity to provide additional evidence and further clarification as possible.

Through the course of the assessment, TNext and City of Ottawa willingness to engage in open discussion about the progress and the issues of the project was apparent as was their wish to have a third-party opinion.

The process followed by TNext and the team in place is in line with international standards and appropriate for the delivery of a project like Trillium Line. The project management practices are adequate, and tools are in place to ensure control of the progress and address potential risks.

However open issues remain. These weaknesses might be conductive to additional delay in the delivery of the project, safety issues and problems during the operation and maintenance phase. Aside of the recommendations formulated in the present report we would suggest the City to strengthen the control over the commissioning and handover process as well as the first months of revenue operation.

SYSTRA/RATP complete list of recommendations is attached in Appendix B. The main risks can be summarized as follows:

- The ongoing claim between TNext and the City of Ottawa should be resolved quickly. Due to the claim, transparent communication between both parties is reduced which leads to, possibly, a lack of trust and, potentially, an incorrect vision of the actual project progress by the City.
- The information provided to the peer reviewers regarding the new STADLER vehicles tests in an Ottawa winter environment are insufficient to provide confidence that these vehicles' performance is adequate for the intended environmental operation conditions.
- Further to the review of the integration process, the peer reviewers were concerned regarding the lack of clear ownership of the full integration of the new head-end including factory integration tests to mitigate the risk to discover major issues on site.
- The peer reviewers are also concerned that TNext did not perform integration in the factory of all supplier systems before test start on site. There is a major risk to discover integration issues late in the project while they could have been fixed before had such factory integration tests been carried out.
- Further to the review of TNext systems engineering and integration management processes, configuration management and obsolescence management were judged by the peer reviewers to be, respectively, inconsistent and absent. Such processes should be applied by TNext to all their subcontractors, the lack thereof might lead to issues in relation with systems commissioning and/ or operation and maintenance.
- Several discrepancies were identified between CENELEC requirement and TNext system assurance plans and processes. TNext should create a traceability matrix between CENELEC standard and TNext plans to demonstrate compliance and confirm that all CENELEC recommendation is properly applied or adequately mitigated through alternative process and evidence.
- Further to the review of the planned system operations, the peer reviewers were not convinced that the objective of 2048 pphpd can be achieved with the proposed fleet and minimum headway.
- Stochastic simulation should be done with realistic incident scenarios to understand the real capacity of the line and the systems to recover from perturbations and improve operational procedures in place.
- The actual train fleet size is insufficient to allow for a robust operation. It is the peer reviewers' opinion that an additional STADLER train is necessary.
- A Concept of Maintenance is not yet in place from which Maintenance mobilization plan can be prepared. Given the shortage of resources in Canada, it is our opinion that this activity should have already been in place and subsequently be followed closely to ensure that maintenance team and activities are in place before revenue service.
- During the review, we have received updates to previously seen documentation indicating attempts by TNext to rectify some of the issues observed in earlier version of the peer review report; however, several points remain open as indicated in further sections below. It is therefore recommended that further independent review be performed at a point in time closer to the revenue service date when it could be expected that TNext will have taken the necessary actions to close the outstanding issues resulting from the present review.

5. INTERVIEWS WITH TNEXT

The list of interviews with TNEXT and the list of attendees is listed below

Table 2 : List of interviews with TNEXT and the list of attendees

Date	Discipline	TNEXT Attendees	SYSTRA/RATP Attendees
06-Jul-22	SESA	Cesar Palencia, Jane Wilson, Russel Cohen	Benoit Bes, Sameh Aboukricha, Jean-Louis Boulanger, Marc Cattel
06-Jul-22	System Integration	Cesar Palencia, Magdy Ibrahim	Sameh Aboukricha, Eric Marshall, Nicolas Quellec, Marc Cattel, Jean-Louis Boulanger
07-Jul-22	Project Management	Cesar Palencia	Benoit Bes, Marc Seffacene
08-Jul-22	Planning	Ian Baker, Farzad Moosavi	Benoit Bes, Marc Seffacene
11-Jul-22	Maintenance Management	Cesar Palencia, Trefor Ellis	Laurent Jean, Vincent Berducou, Raphaël Argento
12-Jul-22	T&C/Trial Run	Cesar Palencia, Stephen Bassington	Sameh Aboukricha, Vincent Berducou, Ercan Afacan, Marc Cattel, Leonel Carneiro, Eric Marshall, Nicolas Quellec
14-Jul-22	Training	Cesar Palencia, Florica Nye	Laurent Jean, Sameh Aboukricha
19-Jul-22	S&TC - Comms - TVS and RS - Trackwork	Cesar Palencia, Magdy Ibrahim, Jaouani Jihed	Sameh Aboukricha, Ercan Afacan, Eric Marshall, Leonel Carneiro, Romain Bonnet, Federica Danise
20-Jul-22	Technical and Design Management	Cesar Palencia, Frank Kaul	Sameh Aboukricha, Martin Blouin, Marc Seffacene
20-Jul-22	QA/QC and Construction	Cesar Palencia, Eileen Obrien, Duncan Elliott	Sameh Aboukricha, Martin Blouin, Marc Seffacene
29-Jul-22	Operation Modeling	Cesar Palencia, Richard Leslie	Vincent Berducou, Florian Schanzenbacher

6. PROJECT MANAGEMENT

From the review of documentation and interview with TNext the project management practices are sound.

TNext has a risk process in place with monthly reviews. Time chainage diagram is used (Tilos) to follow geographical and timeline progress of construction. The schedule is regularly updated and KPI, CPI and SPI are in place.

Unfortunately, due to the ongoing claim with the City, most of the information is not shared in a transparent way leading to misunderstanding and lack of trust between the City and TNext.

Recommendation PM.01

We recommend the City and TNext to “draw a line in the sand” and openly create a new baseline of the project including new schedule, new monthly report with shared explicit KPIs and potentially some recommendations of this report. An agreement must be reached by both parties on this new baseline that should not interfere with the progress.

The lessons learned from the Confederation line are mainly considered because the TNext team was the one working on Trillium Line. There is no document listing positive and negative lessons learned from the previous project. There is a risk to lose this knowledge if some key personnel from TNext leave the project.

Recommendation PM.02

The lessons learned of the previous and similar project or product should be integrated in the engineering development of the mass transit system. A lessons- learned document relating to the project, system or product should document the lessons learned used for the benefit of the current project.

7. RAIL SYSTEMS

7.1 ROLLING STOCK

Several Rolling Stock documents have been reviewed along with a discussion with TNEXT expert on June 17th. Most of our comments and concerns have been addressed.

Nevertheless, the following points remain a concern.

7.1.1 Interior and Exterior Noise Tests

We requested the Interior and Exterior Noise Tests reports for the FLIRT Ottawa vehicles. We received the test procedures and test reports that were performed by Stadler on the FLIRT platform and on Stadler's existing test tracks.

We were informed that the noise test for the Ottawa project will be performed once the full network is built and commissioned.

This test is critical as the noise performance is dependent on the wheel/rail interface. The wheel/rail interface on the Ottawa project can be different from the wheel/rail interface from Stadler's test track. In addition, the same test must be performed for the ALSTOM train on the new sections of the Trillium Line.

Recommendation RS.01:

For both types of vehicles, we recommend that the vehicles' interior and exterior noise tests are performed as soon as a track length allows to safely reach 85 km/h and brake afterwards to measure the interior noise as well as exterior wayside noise 25 m from the train as required by the PA Schedule 15-2 Part 8, Section 1.8 (a) & (b)

7.1.2 Cold Weather Testing

We obtained confirmation that Stadler had performed additional on-site "Cold Weather" type testing of the Stadler FLIRT, on January 26, 2022, to confirm the performance of the Stadler Flirt heating systems.

We did not receive clear confirmation that the doors were or will be tested in winter condition to ensure the door operators are suitable for the Ottawa environmental conditions (The documents received were not conclusive on this subject, since the test was performed with an external temp of 16°). We concur with TNext that the ALSTOM LINT Train does not need to have new winter test as they are proven in use in the Ottawa environment.

Recommendation RS.02:

For the Stadler vehicles, to simulate the accumulation of freezing rain up to 3mm on the doors to ensure the door operators are properly sized to meet its life expectancy as required by the PA, Schedule 15-2 Part 8, Section 1.18 (d)-(i).

Recommendation RS.03:

To perform cold start, tests of new vehicles (minimum temperature of cold room to meet the environmental conditions of the City of Ottawa) to simulate the vehicles parked overnight outside can start with no problems.

7.1.3 Stability and Safety Against Derailment

We requested all the test reports that have been performed on the stability and safety against derailment of the vehicles prior to putting the vehicles in revenue service. We obtained the vehicle lean test and wheel load equalizations tests reports.

We did not receive documents demonstrating that the bogie rotational resistive tests were performed on this type of vehicle. The bogie rotational resistive test is important to ensure the vehicle is stable at high speeds (hunting effect) and can negotiate a curve with minimal resistance to avoid wheel climbs.

Recommendations RS.04:

The City should request to TNEXT to confirm that Stadler is familiar with this test and whether the bogie rotational resistive test or bogie yaw resistance (EN 14363, section 6.1.5.3.3) test/simulation has been performed.

7.1.4 Vehicle Gauge Clearance

We requested the clearance test procedure that would be performed on the vehicles to ensure the maximum dynamic envelope of the vehicles is within the allowable clearances with tunnels and wayside.

We have obtained additional information stating that, between stations, the network has been designed to comply with Transport Canada TC E-05 Standards Respecting Railway Clearance which outline accommodation for a locomotive. Both the Stadler Flirts and the Alstom-Lint-vehicle-clearance falls well within these regulatory requirements, Also, the clearance tests will be stationed specifically to ensure that platform extenders do not interfere with the vehicle`s envelopes.

Recommendation RS.05:

Removed from the final report further to the latest information received.

In addition, we could not find ALSTOM’s vehicle clearance test procedures for the new section of the track.

We have obtained the information as stated above.

Recommendation RS.06:

Removed from the final report further to the latest information received.

7.1.5 Vehicle Height and Leveling System

We requested to obtain the details on how the leveling system determines the wheel diameter to adjust the air spring height once the vehicle reaches the station platform to meet the platform height requirements within +/- 16 mm. We obtained documents explaining the amount of time required to meet the platform height at a given passenger load but no explanation on how the system determines the wheel diameter.

In addition, the target platform height is 574 mm according to the PA Schedule 15-2, Part 8 section 1.2 (f) but the document BU_3691228 mentions the lowest point of the platform at 565 mm.

Recommendation RS.07:

The City to verify that the wheel compensation is well defined and understood to guarantee that the vehicle height is always within the expected platform height during all operating and passenger loading conditions.

7.2 S&TCS

Documents review and in-person interviews with the City of Ottawa and TNext were used for the peer review of the S&TCS system.

From the document review and the interviews, we observed that TNext scope is aligned and, generally, respects the requirements from the city.

During the interviews we noted that the GEBR (Guaranteed Emergency Brake Rate) used for the design has not been tested on site and we could not find information as to when / if such test will be performed.

Recommendation TCS.01

We recommend that the GEBR test be added in the site test procedures according to the condition required by IEEE1474.1 chapter 6.1.2.1.

7.3 COMS & SCADA

To evaluate the state of the SCADA and Communications systems we performed documents reviews and in-person interviews.

The documentation review and interviews allowed us to verify that the TNext scope is generally managed according to the defined Systems engineering plans.

An area of concern was identified during our meetings with TNext and the City. It concerns the system's integration into the head-end as well as the validation of the head-end and the entire System.

TNext was not able to provide sufficient information regarding the external interface with the head end. After discussing the subject with the City, they confirmed challenges in terms of coordination to handle the entire system (TNext and City scope combined). An example of this situation is the absence of a System "release note" which covers both the TNext and City scope.

From this discussion, we noted that the combined scope for COMS & SCADA (as executed by the City & TNext) does not follow a comprehensive validation and system integration strategy.

We propose the following recommendations to reduce the risk of integration issues with the head end.

Recommendation COM.01

Identify an owner for the head-end system to produce System documentation (e.g., Release notes)

Recommendation COM.02

Establish a test platform for the integration and validation of the system to avoid discovering the first integration issues on site.

Recommendation COM. 03:

Produce a system validation test description document for the head-end System.

Recommendation COM.04

Produce a system integration and validation test description document for the entire system.

7.4 PERMANENT WAY

Following the review of track documentation, we raised several issues / questions. These were discussed with TNext during the interview held on July 19, 2022, and through Q&A excel file, and additional documents sent by the City.

TNext answers helped to close the main topics listed hereafter, however, several of our questions remain without an answer at the date of writing the present report:

- Cross-sections:
  - We noticed that freight clearance, catenary poles, switch heaters and point machines were not represented in all cross-sections, which may eventually lead to space-proofing issues. TNext confirmed that:
    - Switch heaters and point machines have been considered in the space-proofing analysis in every relevant situation, with no residual issue.
    - In case of a future electrification of the line, circulation of freight vehicles won't be possible in several sections.
  - The hazard for passengers in case of evacuation as well as for the maintenance teams, due to the representation of emergency walkway envelope in the ballast between two tracks in narrow sections, has been identified by TNext and the City in all concerned sections and discussed with emergency services. Those configurations (not a best practice in our experience) were accepted by all the parties.

- Different types of vehicles: TNext confirmed that the difference of length between Stadler FLIRT3 trains (80,7 m) and two LINT41 units coupled together (83.6 m) has been fully integrated in the design of the whole system, with no residual issues.

For traceability of the communications between the actors, the full list of Q&A as recorded by the peer reviewers can be found in Appendix C

7.4.1 Ballasted Track and Turnouts

We had questions concerning the CWR design and destressing work method statement, to avoid tracking stability issues (track buckling risk, with high temperatures) and the potential for a rail to break (with cold temperatures).

Considering the following elements:

- Technical information mentioned in the *Design Brief Trackwork 660373-0000-003-4REB-0001_02* and in the *Track installation track charts* (in particular: tie spacing, ballast shoulder width, destressing design),
- The positive feedback of the 17-year operating Trillium Line, confirmed by TNext as well as by the City,
- The principle of strictly renewing the existing Trillium Line design for the Trillium Line extension.

We consider that this topic can be closed.

The zero thermal stress temperature considered for ballasted tracks (32°C +/- 4°C) is high, in comparison with the coldest air temperature (-40 °C). It has been defined to reduce the possibility of rail buckling at high temperatures but may lead to high tensile stresses in the rail with cold temperatures and a higher potential for a rail to break, and/or track transversal displacement in sharp curves. However, as indicated during the meetings with TNext and with the City, neither rail break nor any need to frequently maintain the ballast side slope in the inner side of the curves occurred in the previously operated Trillium Line.

Recommendation TRK.01

Produce a system integration and validation test description document for the entire system.

7.4.2 Ballast fewer Tracks and Turnouts

We had questions regarding the assurance that civil tolerances won't have any impact on track tolerances and will not degrade the possibility for the maintenance teams to implement track geometry adjustments if needed (using shims).

During the interview, TNext introduced the notion of "best fit alignment" and clarified this notion through the Q&A file : "Best fit of the track is usually done to accommodate a small amount of structure settlement during construction, or a consistently lower/higher as-built top of plinths due to a higher construction tolerance for concrete finishing than for tracks. For instance, when the as-built top of plinths are too low by 15 mm across the entire bridge, best fitting the alignment by lowering the track would avoid shimming up every single DF fastener by 15 mm on the bridge. On the opposite, best fitting the alignment by raising the track would avoid excessive grinding in the event of plinths getting poured higher than theoretical. Please note that this is not meant to correct localized areas."

Following an additional interview with the City on September 28, 2022, we understood that:

- The Civil team oversees the construction of the viaduct spans, including positioning the shear connectors to connect the viaduct to the track plinths or track slabs, followed up by a survey.
- The Track team oversees the construction of the ballast-less tracks through a bottom-up-construction process, with a survey performed after each step of the construction process:
  - In-situ poured concrete, construction of the track plinths or slabs, followed up by the survey,
  - Track plinth / track slab drilling and female inserts embedding,
  - Installation of an adequate number of shims for each fastening system, and rail, followed up by the survey.

Although the bottom-up construction process for DF Track appears to be complex, in comparison with a top-down construction method, we understand that this construction process has been chosen in relation to the type of rail fastener. The DF Track construction process proposed by TNext seems to be secured by a survey performed after each step of the construction process. This should prevent any deviation of the track tolerances specified in the contract.

In addition, the "best fit alignment" should not lead to a modification of the parameters specified in the Alignment Design Criteria.

Finally, we recommend having confirmation that the mechanical tests performed for the qualification of the fasteners have been done in extreme positions (with maximum shimming) and will not imply any restriction of any kind.

Recommendation TRK.02

Check during the construction of the DF tracks that the different surveys mentioned in the work method statement is carried out as planned.

Confirm the mechanical tests performed on the fasteners of the DF tracks have been done in extreme positions (with maximum shimming) and will not imply any restriction of any kind.

7.4.3 Diamond crossover at Limebank station

As represented in the track installation track charts for Segments 1 & 5 reference 660373-4TBL-003-4RDD - ICC-0066, half of the diamond crossover before Limebank station S17+211 will be laid in the elevated guideway, the other half being laid in the abutment.

Usually, efforts are made to avoid this configuration that may induce structural displacements with potential consequences on the geometry of the diamond crossover.

We understand this choice has been made due to alignment constraints, and to optimize the operation (crossover as close as possible to the station's platform).

We recommend having confirmation that this diamond crossover has been considered in the rail-structure interaction analysis and the girder is fixed in the abutment zone to restrain movements.

Recommendation TRK.03

Confirm the diamond crossover at Limebank station has been considered in the rail-structure interaction analysis, and the girder is fixed in the abutment zone to restrain movements.

Furthermore, with reference to AREMA chapter 9 Seismic Design for Railway Structures and based on the information received from TNext that they do comply with AREMA, we suggest that for the post-seismic inspection plan, in a level 2 or 3 event as classified by AREMA, on top of AREMA`s recommendations, close inspection of rails and rail anchors be done at the junction of structural spans.

7.5 TUNNEL MECHANICAL EQUIPMENT DESIGN

During the review of the documents and the interviews with TNext, we noted several issues and inconsistencies in the documentation provided regarding TVS and mechanical design.

For example:

- Document 660373-3DLP-003-45VEG-0001_03 - Tunnel Ventilation Fan Technical Specification:
  - **Table 1:** The number of required jet fans is not in compliance with the requirement stated in the document No. 660373-3DLP-003-45VER-0001_00 & drawing No. 660373-3DLP-003-45VDD-1001_PD. The discrepancy should be clarified.
  - **Appendix C:** Jet fan nominal thrust is not in compliance with the requirement stated in the document No. 660373-3DLP-003-45VER-0001_00 & drawing No. 660373-3DLP-003-45VDD-1001_PD. The discrepancy should be clarified.
  - **Appendix C:** Jet fan design temperature is not in compliance with the requirement stated in the document No. 660373-3DLP-003-45VER-0001_00 & drawing No. 660373-3DLP-003-45VDD-1001_PD. The discrepancy should be clarified.
  - **Appendix C:** Jet fan motor power should be defined to avoid trouble in electrical design; it should follow the requirement stated in drawing No. 660373-3DLP-003-45VDD-1001_PD.
- Document 660373-0000-003-45VEA-0001_01 - Basis of Dow's Lake Tunnel – Mechanical Design:
  - **Item 3.2.3.2:** As per NFPA 14 – 2019 section 6.4.4, in areas subject to freezing, a listed automatic drip valve that is arranged to allow drainage without causing water damage shall be installed in the piping between the check valve and the fire department connection.
  - **Item 3.2.3.2:** (As per NFPA 14 – 2019 section 6.3.2, valves shall be provided on all standpipes, including manual dry standpipes and horizontal standpipes, to allow isolation of a standpipe without interrupting the supply to other standpipes from the same source of supply.
  - **Item 3.2.3.2:** As per NFPA 14 – 2019 section 7.10.1.1, where a horizontal standpipe on a Class I or Class III system supplies three or more hose connections on any floor, the minimum flow rate for the hydraulically most demanding horizontal standpipe shall be 750 GPM (2840 L/min), and the calculation procedure shall be in accordance with 7.10.1.2.2.) which is not matching with TNext design flow of 500 GPM.
  - The interval distance between fire hose valves (standpipe class I) is not clearly provided.
  - **Item 3.2.4.1.2:** Indoor design temperature doesn't match with other document (660373-0000-003-40SER-1005 Station Electrical & Mechanical Systems Design System Safety Case table 9).
  - **Item 3.2.4.1.2:** Air filtration was not mentioned, as required by Trillium Lina PA – schedule 15-2 Part 4 station, table 4-5-1 HVAC indoor design conditions.
  - **Item 3.2.4.2.2:** The information and documents provided do not give enough confidence to the peer reviewers that outdoor VRF units are capable of working with outdoor design conditions in winter and

in summer. Considering that even in winter there may be a need to provide cooling due to the heat dissipation from equipment.

- **Item 3.2.4.2.2:** The information and documents provided do not give enough confidence to the peer reviewers that free cooling methodology with mechanical cooling/heating has been considered in the design as required by Trillium Lina PA – schedule 15-2 Part 4 station, item 5.5.N.

- Document 660373-3DLP-003-45VER-0001_00 Emergency Ventilation System and Egress Evaluation:
  - **General:** Some discrepancies have been noted in terms of Fire Design Size (HRR) in the different sections of the report. For example: § 5.1.2.1 defines 49.2 MW, § 5.1.2.3 defines 33.6 or 48 MW, etc. This aspect should be clarified by TNext with reference to a final design document.
  - **§ 4.3 – Table 4:** It is noted that Pollution control mode does not include "Exhaust direction". Normally it is more efficient to push the air in the same direction as the running train, so this mode should also be included. This aspect should be clarified by TNext.
  - **§ 5.1.3 – Table 8:** For the sake of clarity, it should be clarified that the values in the table represent the critical velocity in the tunnel cross section and not in the annulus cross section.
  - **§ 6:** It is noted that there is no mention to the locomotive cooling requirements and calculations to define minimum bulk airflow to ensure that temperature at locomotive radiator inlet is less than maximum permissible limit.
  - **§ 6.2.1:** Since SES 4.1 is not intrinsically allowing the evaluation of pollutant emissions, it is suggested to endorse the provided model with analytical calculations to demonstrate that the piston effect and longitudinal ventilation are able to provide sufficient air flow to dilute the pollutant and purge the tunnel before next train enters the tunnel.
  - **§ 6.3 – table 29:** It is noted that Stadler train has been considered for the non-emergency simulations. Our understanding is that the smallest train that can circulate in the tunnel is Alstom LINT which is smaller than the Stadler Train. Normally the smallest train should be used for calculation to be conservative in terms of piston effect.
  - **Appendix A:** The slope in the fire schematic should be checked because it seems not to be in compliance with the tunnel elevation presented in Figure 5.
- Document 660373-3DLP-003-45VEE-0001_PA Emergency Ventilation System – Computational Fluid Dynamics Study:
  - We found that Fire design size seems not to be in line with other TVS documents. The discrepancies should be clarified. This aspect should be checked and the HRR value should be aligned between all the TVS documents and simulations.
  - The document states that the simulation conducted to assess the pre-ventilation smoke spread is based on the most onerous scenario. This statement seems to be incorrect considering the fire HRR provided in the Heat Release Reports. According to the values summarized in the table below, it can be noted that the design fire parameters considered for the pre-ventilation assessment are not the critical ones either in terms of fire size nor growth rate/time to reach the peak HRR (which is significantly lower). This aspect should be clarified.

Table 3 : discrepancies in fire loads

Scenario	Fire size	Fire growth	Reference document
Pre-ventilation assessment	33.6MW	423s	660373-3DLP-003-45VEE-0001_PA
Stadler scenario 1a – Catastrophic fuel	32.6MW	<50s	660373-3DLP-003-40FER-0003_00
Stadler scenario 2 – Passenger compartment	35.4MW	96s	660373-3DLP-003-40FER-0003_00
Alstom scenario 1a – Catastrophic fuel	40.3MW	<50s	660373-3DLP-003-40FER-0004_00
Alstom scenario 2 – Passenger compartment	49.2MW	264s	660373-3DLP-003-40FER-0004_00

- Document 660373-3DLP-003-45VDD_PD TVS Drawings Dow's Lake Tunnel Drw. No. 1005:
  - We did not find the deflectors on any drawing and believe these could be missing from the installation drawings even if they appear in the design.

Recommendation TVS.01

A detailed design review of all Tunnel Ventilation documentation should be conducted to correct any inconsistency and / or discrepancy and ensure that the correct design will be implemented in accordance with the PA requirements.

In addition, we noted that there is no mention of temperature control if a train is idle in the tunnel, where the tunnel temperature rises due to locomotive engine heat dissipation. As a general note, in most TVS systems designs, a « comfort mode » is provided to keep the tunnel temperature at a given level in compliance with the train HVAC tripping temperatures.

We have discussed this issue both in meetings with the City and with TNext but this requirement does not exist. It may not be an issue if tunnel temperature never reaches trains HVAC tripping temperature, however, it needs to be demonstrated. TNext stated that it is generally quite unusual to have temperature measurements inside the tunnels. We have received several clarifications from TNext through the city in late November early December 2022 with regards to this issue but could not find any information addressing the original concern.

Recommendation TVS.02

We recommend performing an analysis to ensure that the tunnel temperature never reaches the train HVAC tripping temperature.

8. SYSTEMS ENGINEERING & SYSTEM ASSURANCE

8.1 SYSTEMS ENGINEERING

The Systems Engineering Management Plan (SEMP) defines all the systems engineering processes and tools as called for by the IEEE 15288:2015 standard. The plan covers the following activities:

- Requirements Management – covered by the Requirement Management Plan (RMP);
- Configuration Management – covered by the Configuration Management Plan (COMP);
- Systems Integration – covered by the Systems Integration Management Plan (SIMP);
- Validation and Verification – covered by the Verification and Validation Plan.

These activities are also covered by the SEMP but are described in sections 7.1 and 7.2:

- Electromagnetic Compatibility;
- Human Factors;
- Systems Safety Assurance;
- Systems Security;
- Reliability, Availability and Maintainability (RAM).

The RMP follows accepted practices as described in the IEEE 15288 and 12207 and 24198 standards.

The COMP follows accepted practices as described in the IEEE 15288, 12207 and 828 standards.

The SIMP and V&V plan also follow accepted best practices. The plans, however, do not contain measurable criteria to indicate when a System or System element is ready for the next step in its life cycle.

We noted that TNext does not have any obsolescence management plan. Given the fast pace of technology development, it is more and more difficult to maintain information and communication equipment, therefore, an obsolescence management plan is usually put in place for rail projects to mitigate this risk. This concern is further developed in chapter 10.2.7.

We reviewed several documents from the TNext subcontractors, and we noted that they are not endorsed by TNext and could not conclude that TNext fully reviews, integrates and approves all constraints from the subcontractors.

For example, the received Stadler's document related to the Wheel/Rail Interface BU_4141634 and noticed it does not bear any sign of review nor endorsement by TNext who is responsible for the overall system integration. We have obtained the confirmation from TNext that all documents are reviewed by them prior to transmission to the city. However we could not confirm such TNext statement as seen on several of their documents.

In addition, we did not see the plans for ALSTOM LINT trains tests on the new section of the track. Integration tests of ALSTOM LINT trains must take place on any section of the track that is new or modified.

Recommendations SEM.01

All documents received from TNext subcontractors should be reviewed and signed by TNext. Documents from Alstom' Lint Vehicles should also be reviewed and approved for operability (Gauge, platform length/height, braking performance, etc..) of the current vehicles on the extension lines.

Regarding Configuration management, we are concerned that configuration items are identified at high level and do not allow for the management of software, hardware, and firmware configurations. According to TNext this is left to each vendor and subcontractor to manage.

Recommendation SEM.02

We recommend putting in place a high-level configuration management plan as a guideline to be followed by all project actors (including the scope under the city) and participants in order to have a consistent holistic view of all configuration items including software, hardware and firmware.

System Breakdown Structure (SBS) and Functional Breakdown Structure (FBS) were not communicated to the peer reviewers and seem to be missing. It is common practice that SBS and FBS are developed through the

successive level of hierarchy and down to the LRUs (LRU as per the RAM Program Plan) of the mass transit system. Both must be initiated at the definition phase and updated when needed for the next phases and is the basis of all the engineering activities.

Recommendation SEM.03

The definition of what is a system, a sub-system, and equipment from the mass transit system (Project) point of view should be stated and aligned with a System Breakdown Structure and a Functional Breakdown Structure, to get a common view between all the stakeholders and co-partners of the project.

8.2 EMC / EMI , E&B, Stray Currents Mitigation & Provisions for Future Electrification

The EMC/EMI, Earthing/Bonding/Grounding and Corrosion Control standards address the different aspects to be considered for implementing the Basic Design documents (specifications and drawings).

8.2.1 Future Electrification Clearance

In the document EMC Control (Ref: 660373-0000-003-40SAG-0012), chapter 1.4 (i), the defined clearance means that the undergoing project shall already integrate the OCS constraints X/Y/Z in such a way that electrification works will not interfere with the single-track operations. Nevertheless, it does not define the action/recommendation to consider in order to ensure this clearance is guaranteed.

Recommendation SEM.04

We recommend clarifying the list of actions to be considered in order to guarantee the clearance for future electrification of the line along with test procedure ensuring that actions have been completed.

8.2.2 EMC/EMI impact on Human Health

In the document EMC Control (Ref: 660373-0000-003-40SAG-0012, chapter 1.9.3 the standard EN 50500 related to the EMC/EMI impact on human health in railway environment is missing. It is the key reference for defining the way to control and measure the EMC-EMI impact versus the reference values defined on this standard for protecting the human health.

In addition, no reference is made to the ICNIRP and their standards;

- ICNIRP 1998: guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz);
- ICNIRP 2010: guidelines on limits of exposure to static magnetic fields.

Recommendation SEM.05

We recommend adding EN50500 standard and ICNIRP standard to the EMC Control Plan to guarantee that EMC/EMI impact on human health in railway environment is measured and within the standard specifications.

8.2.3 Stray Current Control

In the document Basis of Design Corrosion control approach (Ref: 660373-4SYS-003-47SEA-0006), chapter 5.4, the measures regarding corrosion control for the bridge structure are well-defined but the ones regarding the

tracks (including the interface with the bridge structure) are missing. As the Track structure is a key component of the stray current collector system, these measures, in line with the Track specification document and the Grounding and Bounding document, need to be defined.

Recommendation SEM.06

The Basis of Design Corrosion control document should be updated to take into account the measure concerning corrosion control on the bridge including the track design.

8.3 SYSTEM ASSURANCE

8.3.1 General

The peer reviewers found it difficult to understand the TNext SA processes through the documentation received. For the RAMS processes, it is a good practice as per our experience to develop flow charts to help in the understanding of / and ensure buy-in from all stakeholders. It would be relevant to see if TNext has such a graphical representation of their processes and to which extent these are disseminated and understood across the entire project organization. The reviewers acknowledge SIL determination to have seen some charts in some of TNext documents (e.g., SIL Determination process in the document System Safety Assurance Plan) however it was not possible to assert that such figures comply with EN 50126:2017.

Furthermore, the review reveals that, potentially, some RAM activities are not expected to be performed, at the right phase with respect to the V-cycle. For instance, the RAM requirements integration report for RAM requirements at the stage 8-Integration, the RAM specification to subcontractors at the stage 7-Manufacture should take place earlier in the system development life cycle to ensure continuous system integration, particularly the interaction between RAMS engineering and design and maintenance engineering.

Recommendation SA.01

An overall review of the RAMS activities along the V-Model lifecycle should be executed to ensure that activities are performed at the correct phase of the project. TNext should also describe the way the RAMS findings are addressed in the design and maintenance.

Through the review of the hazard log of the Stadler vehicles, in few instances, Residual Severity was found lower than Initial Severity without additional protection or prevention or mitigation being mentioned, such as, RST-B-B-004, RST-E-B-004.1 and RST-E-B-004.3 ID of the Stadler PHA.

When it is considered not to assess equipment such as an “escalator for Bayview”, detailed justifications should be provided. (Although TNext clarified that the Bayview station does not have an escalator under their scope of the works, the issue is about clarity and rigour in the documentation not about the specific example)

For the Safety Integrity Level determination, we understand that SIL 0 is no longer presented in the EN 50126-2:2017 standards referred to by TNext. (SIL 0 is simply referred to as non-safety-related). Therefore, the harmonization of TNext terminology should be performed with the relevant standards.

Other findings are related to the hazard analysis of wrong side door opening. The hazard analysis describes the scenarios and the mitigation associated to wrong door side opening in the station, but we did not find the analysis about the same scenario between stations. We are concerned that hazard analysis is incomplete, and some scenarios might be missing.

Recommendation SA.02

TNext should revise the PHA to align with the terminology of EN 50126-2:2017 and have a complete review of all hazards and mitigation considering all scenarios, justifying downgrading of severity level, justifying non-assessment of certain equipment. If it is not done, it can conduct to a safety hazard not being mitigated. The hazard severity matrix, hazard probability matrix as well as the hazard criticality matrix should be presented in the Safety Assurance Plan rather than in the PHA report.

The principles adopted by TNext in terms of RAMS organisation and process implementation require further clarifications with regards to the aspects of RAMS team`s autonomy, authority, and independence as well as skills. For example, the Safety Lead should not report to the SESA but directly to the Deputy Director of the project-related. It is not clear how the two parts of the SESA organization come together to integrate all the System Engineering and RAMS activities for all the subsystems forming the Trillium transit system. The independence of these two organisations and the RAMS activities under their remit are part of the fundamental elements necessary to provide confidence that final product & service meets the specified RAMS performance levels. The management of the RAMS skills and competences of the RAMS team also needs further clarifications from TNext.

Recommendation SA.03

TNext should show the autonomy, authority and independence as well as the management of the skills of the RAMS team. A change and / or an update to the organization presented may be needed to fully comply with EN 50126-1:2017.

8.3.2 Railway RAMS and Quality of Service

The “Service Availability”, the “Service Reliability” and the “Availability” wordings seem to be used interchangeably throughout the reviewed documentation. It is necessary to provide clear definitions of these performance indicators, this will help avoid confusion between different RAM performances and will direct to the usage of the right mathematical formulae for the computation of each. As a matter of fact, the “Availability” definition provided in the documentation is related, as per our interpretation, to the intrinsic Availability of the system/subsystem/equipment and cannot be viewed as a “service Availability”

In addition, MTBF and MTBSAF are used in various documents which could lead to a lack of clarity regarding the objectives of the RAM activities. For example, there seems to be a confusion in the RAM Demonstration Plan between availability allocation and the related Mean Time Between Service Affecting Failures. This last parameter seems to be related to the Service Reliability performance while the availability is related to the Intrinsic Availability as per EN 50126:2017.

We have concerns that the RAM analysis and demonstration are not conducted in a consistent way by all TNext subcontractors due to the lack of clarity of the RAM high level documentation.

Recommendation SA.04

RAMS terms like MTBF and MTBSAF or “Service Availability”. “Availability” shall be defined and used consistently across all TNext documentation including their subcontractors’ ones to avoid misunderstanding. Documents should present clearly how the MTBSAF of each sub-system has been determined, with which reliability database or return of experience was used in its calculation.

The parameters for the measurement of the quality of revenue service should be established with their definition and related mathematical formulae. The four dimensions of RAMS: Reliability, Availability, Maintainability and Safety, highly contribute to the revenue service performance. The approach about their contribution should be better stated in the RAM program plan. The specific reliability and availability formulae relating to each system/subsystem should be stated depending on the way each system works or its mission profile, for example continuous or intermittent function. This will support a robust demonstration of the achievement of the RAM targets in revenue service.

With regards to the reliability allocation and its apportionment from top level down to the LRU, the service reliability requirements stated in the PA should be analyzed in detail. The deductions and interpretations should be performed according to the needs, the requirements and the constraints, thus allowing to perform a correct apportionment of the reliability performance down to the system/subsystem/equipment and to define and optimize the architecture. This apportionment should also be consistent with the RAM capabilities of the suppliers.

Recommendation SA.05

The reliability and availability formulae should be stated and tailored to the mission profile or working mode of each system/subsystem/equipment. The RAM apportionment should be performed down to the LRU and appear in the RAM apportionment report.

TNext should clarify in the failure analysis the failure categorization as well as the associated operational or non-operational phases, the mission profile of the transit system, the operating conditions, maintenance conditions and human factors, as per EN 50126 -1, -2 and EN 50129. A common cause failure analysis is required as per these standards, including the analysis of the effects of design implementation, manufacturing errors and failures of system components that could interfere with redundant design principles.

Recommendation SA.06

TNext should conduct a common cause failure analysis into a specific report addressing the systematic failures to verify that events in a fault tree analysis are truly independent.

The peer reviewers have not seen sufficient information and documentation confirming the existence of a plan to monitor RAMS performance after the start of revenue service. The collection of field data to measure the RAMS performance is critical to ensure its continuous monitoring, confirm the required performance is achieved, analyze failures and support the overall reliability growth, through an ad hoc action plan if needed.

Recommendation SA.07

TNext should clarify the process for collecting and analysing the field RAMS data by explaining which information will be collected, monitored, and how, and then detailing the process of analysis and action plan definition and implementation.

8.3.3 Risk reduction strategy

The control of risk can be achieved by the execution of mitigations or by the elimination of the risk and follows a systematic analysis of the cases.

In the framework of risk reduction or resolution, the RAMS processes, methodologies and techniques can be used for:

- identifying the potential mitigations which can eliminate the hazards linked to barriers of developing a safety-related design;
- eliminating the safety related procedural barriers;
- identifying the safety related maintenance periodic tasks;
- Mitigating any possible decrease of system performances for example by increasing the reliability.

Those types of mitigations are one of the means for achieving the improvement of the system safety, the service reliability and the availability of the systems / sub-systems / equipment's. The various types of mitigations can be combined in the framework of an overall risk reduction strategy.

Recommendation SA.08

TNext should clarify the approach taken for the risk reduction for safety-related risks and for the RAM related risks by referring to EN 50126:2017.

8.3.4 Re-use or adaptation of a system with previous certification

As the Trillium mass transit system includes altered sub-systems for which functional updates and / or changes are implemented, RAMS activities should include gap analyses. However, no supporting documentation of such activity was communicated to the reviewers in this respect. In general, the gap analysis should be performed when a previous product is re-used and / or adapted for a different system with different environmental and / or operating conditions; it should be based on the guidelines of the EN 50126:2017.

A safety gap analysis as related to the re-use and/or the adaptation of an existing system/sub-system/equipment (e.g., Alstom LINTs trains) based on the guidelines of EN 50126:2017 should have been performed by TNext, no supporting documentation that this was the case has been communicated to the peer reviewers till the time of drafting the present report.

For the existing Vehicle fleet re-used and/or adapted, TNext should have clarified in the Safety Certification Plan whether there is or not a mutual acceptance or recognition of the previous safety acceptance of the existing (original) Vehicle fleet (Alstom LINTs). In case of recognition of the previous safety acceptance of the existing (original) Vehicle fleet (Alstom LINTs), this may limit the effort of the RAMS activities for the recertification to re-enter in revenue service of the vehicle fleet re-used and/or adapted.

Additional documentation was provided by TNext through the City of Ottawa in Late November and early December 2022, specifically, the reviewers received the Siemens S&TCS safety case and the S&TCS Safety Assessment report by TUV SUD. These documents raise additional concerns with regards to TNext system assurance process. As per the PSOS, the S&TCS shall be compliant with EN 50126:2017. However, the Siemens safety case received from the City is developed based on EN 50126:1999 and the Safety assessment report clearly states that TUV SUD is not certified for this version of the standard. The peer reviewers are, therefore, not confident that this aspect of the safety process is well under control by TNext.

Recommendation SA.09

TNext should present, in a specific document, the gap analysis principle and process for re-used products, already certified or not. As part of this document, TNext should clarify how they manage the functional boundaries and functional interfaces between the original vehicle fleet and the vehicle fleet adapted/tailored to the project (if applicable). Such recommendation is also applicable to the S&TCS which is not compliant with the PSOS requirements in terms of code compliance.

8.3.5 Compliance with CENELEC Standards

CENELEC standards request, at a minimum, that all entities involved in the project comply with ISO 9001 or equivalent and this must be demonstrated by audits and traceable evidence. Currently TNext system assurance plans do not clearly address this point.

After a review of the TNext SESA documents, and notwithstanding the additional organization information provided by TNext during and after the meeting with them regarding this subject, it appears quite difficult to understand the actual project team organization and to confirm the independencies as requested by EN 50126 /50129 and 50128. For example, the Safety Lead should not report to the SESA but directly to the Deputy Director of the project.

It is also not clear how the two parts of the SESA organization come together to integrate all the System Engineering and RAMS activities for all the subsystems forming the Trillium transit system. The independence of these two organizations and the RAMS activities under their remit are part of the fundamental elements necessary to provide confidence that final product and service meet the specified RAMS performance levels and no risks related to the safety demonstration is introduced.

As per EN 50126, and in relation with independency, some plans are requested

- Safety plan;
- RAM plan;
- Verification plan (that covers testing);
- Validation plan.

Currently Verification and Validation are in the same plan. According to CENELEC the VALIDATOR is independent from the VERIFIER, hence these cannot be grouped under the same plan.

To illustrate this point, during our review it appeared that TNext mixes validation and verification, and it is explained in their documents that the validator will provide a requirement matrix. However, this is noncompliance with EN 50126 – parts 1 & 2 which clearly stipulate the requirements as in, for instance:

- Part 1 section 6.7.3, the structure of validation plan;
- Part 1 section 7.5.4, the validation tasks;
- Part 2 – section G.3, responsibilities and competencies of the VALIDATOR are defined.

The VALIDATOR is a key person for the project and this possible non-compliance by TNext is a risk that does not seem to be addressed as per the information we obtained at the date of drafting the present report.

The peer reviewers have been given further updated documentation from TNext through the City by the end of November and early December 2022, specifically the revised V&V plan and the revised System Safety

Certification Plan, in both documents it is still clear that V&V is not carried out independently in particular for phases 1 to 4 of EN 50126:2017. Furthermore, according to EN 50126:2017 Appendix G which is referenced in both above mentioned TNext documents, verification and validation are distinct in terms of responsibilities and key competencies, this does not seem to have been clearly addressed by TNext. This issue has been previously discussed and closed by the ATKINS ISA[2] report dated May 2021 which was communicated to the reviewers also by late November 2022, therefore it is not newly pointed out to TNext through the present report and should have been subject to more attention. It is important to note that the reviewer has no means to verify whether TNext is applying the revised plans given they were communicated at a very late stage in the review process. The impact of this potential TNext non-compliance is unknown and should be subject to further investigations, gap analysis and mitigation plan which are beyond the scope of the present report. Finally, if TNext considers the organisation is acceptable for SIL2 and below subsystems according to EN50126-2:2017 section 7.3 case B, the following two questions are then raised: what about the interfaces with SIL4 subsystems and the overall system integration? these fall directly under TNext responsibility and it is not clear how they address this given the existing organisation. And what about phases 1 to 4 for which this clause does not apply, why aren't these addressed in the TNext documentation?

Furthermore, the received current versions of TNext plans do not explain how, based on the job descriptions, the competencies are assessed and demonstrated. Additionally, the peer reviewers did not receive (despite request) sufficient information and documentation confirming that people are being (or have been) trained in relation with CENELEC standards and specifically no formal competence management plan by TNext was communicated. However, TNext has verbally stated that their safety personnel receive regular internal training to perform their duties. Such information could not be verified by the peer reviewers in documents communicated from TNext through the City.

In the safety Assurance Plan, some CENELEC standards appeared but some are missing such as EN50159 and EN50155. It is an issue because, at project level, it is important to manage the integration between different actors and it's very important to verify that the product is EN 50155 compliant when embedded in a train (in addition to EN 50129 compliance). If this integration activity is not correctly managed, it is possible to anticipate issues during commissioning and / or commercial service.

Additionally, in TNext Safety Assurance Plan some other standards such IEC 61508 are quoted but there is no explanation how these standards are used for the safety demonstration. The risk is the incompatibility between different standards. Some activities required by IEC 61508 are different in comparison with CENELEC standards. How each of the standards are used and for which exact purpose should be described in the plan.

The main issue in Safety Assurance Plan is related to the THR/TFFR (Tolerable Hazard Rate/Tolerable Functional Failure Rate) management. EN 50126:2017 changed the approach with respect to previous revisions. First TNEXT shall identify hazards and associated THR then allocate the hazards to functions and finally allocate them to subsystems. When the THR is allocated, it is possible to introduce TFFR; based on THR/TFFR it is possible to compute the SIL for functions and support of functions (subsystem, equipment). Current version of the TNext Safety Assurance Plan focuses only on SIL that means systematics failure management, but THR/TFFR should also be identified for random failure management. During the latest discussions that took place during late November 2022, TNext stated that they needed not follow such process as they "already knew the SIL levels for each

[2] The peer reviewers noted that SNC selected ATKINS as ISA and assumed that, both companies being affiliated, does not undermine the independence of the review.

subsystem" before process initiation, this statement is not aligned with EN 50126:2017. Furthermore, the latest related document received from TNext through the City during November 2022 (System Safety Assurance Plan) does not allow the reviewers to infer that the process described by EN50126-2 :2017 section 10.2 was followed. It also appears that such issue was pointed out by SENER report dated 22 September 2022 but subsequently closed. It is not possible at this stage for the peer reviewer to know and understand the discussions that took place leading to the closure of this issue from the SENER report, the consequences resulting therefrom are unknown to the reviewer, however, they may be well-being of a significant impact. Such issue requires further detailed analysis of TNext documents and processes that is beyond the scope of the present peer review. We also underline that, as per EN 50126:2017 section 10.2.7 the use of a qualitative approach does not waive TFFR requirement as TNext have stated during the meeting held late November 2022.

CENELEC standards also introduced the notion of generic product, generic application and specific application that are helpful to break down the system and for the iterative deployment, currently it is not clearly explained how it is managed by TNext.

Regarding TNext current Certification Plan, the relationship between the project teams and the ISA is not clearly explained. In addition, the objective of the Certification Plan, which is to explain how the different assessment will be performed, is not achieved from the peer reviewer's point of view.

One final issue that appeared in the plan is the responsibility related to the integration: some equipment from contractor X are assembled in equipment of contractor Y, but it is unclear who is ultimately responsible. Therefore, it is not possible to conclude that the integration responsibilities are clearly allocated and understood among all the stakeholders involved.

In conclusion, it appeared to the peer reviewers that the compliance with CENELEC standards EN 50126:2017 and EN 50129:2018 is not fully demonstrated by TNext as per the documents received and interviews conducted.

Recommendation SA.10

TNext should provide formal traceability between the CENELEC standards and their plans and other SA deliverables and activities with the objective to demonstrate compliance. This is essential to provide confidence in both the process and the deliverables.

9. CONSTRUCTION VERIFICATION AND TEST & COMMISSIONING

9.1 CONSTRUCTION CONTROL

A key factor to achieve the required durability, particularly considering the Canadian weather, is to control the concrete coverage of the structure reinforcement steel. Experience has shown that rebar cages move during the pouring process, because of either insufficient spacers or abrupt maneuvers. Mitigation would be to have a non-destructive (e.g., georadar) testing after concrete is set. The reviewers did not find any such control in the documentation and therefore consider this as a potential long-term risk of deterioration of the structures.

Recommendation CON.01

TNext should develop a method to verify after pouring the adequate positioning and concrete coverage of the structure reinforcement steel.

9.2 T&C PROCESSES

We have reviewed the T&C plan; many questions were open as the plan is quite preliminary and does not address the testing strategy, plans and processes in detail.

We could not find a comprehensive off-site testing plan. It is our understanding that TNext vendors and suppliers are left without a clear strategy and no in-factory interfaces and integration tests are done between contractors.

It is not clear neither to which extent the integration was performed between SIEMENS and STADLER in the factory test track.

In our opinion the absence of factory integration for SCADA & Telecom systems is also a risk to the project.

Furthermore, there does not seem to be a procedure to define the criteria to ascertain that a subsystem or equipment is ready for site testing.

Recommendation TC.01

A clear factory integration test plan should be put in place with an exhaustive list of tests to be performed in factory and clear criteria of success to reduce the number of issues to be discovered on site.

We are also concerned regarding the adequacy of the T&C management tools such as defects management and configuration management (hardware, software, firmware versions, etc.) as we could not see that such tools exist, are in use and are adequate. See recommendation SEM.02.

Also, in relation with the T&C management process, we could not see a comprehensive integrated time schedule showing all the interdependencies and interfaces between systems. Such a time schedule is key in T&C success.

Recommendation TC.02

TNext should build a comprehensive and integrated time schedule showing all the interdependencies and interfaces between systems and a clear way forward for the performance of system integration tests. This schedule should be coupled with a set of KPIs and a dashboard allowing to closely monitor on a weekly or biweekly basis at most the test progress for each discipline and identify the blocking points and escalate them for swift resolution.

Another issue with regards to T&C is the absence of a clear plan to verify system performance during wintertime before placing the system into commercial service.

Recommendation TC.03

TNext should provide a test plan to verify global system performance during wintertime.

We have also noted that the system's minimum operating requirements (MOR) or operating standards are not clearly defined. According to TNext verbal statement, this exercise has started only for the RSK vehicles. This issue is linked to the lack of clear criteria for the success of the system's operation demonstration tests as TNext interpretation is that, as long as failures do not affect train departures from terminals, then performance is demonstrated.

However, we believe a clear set of MOR needs to be defined. The Service Reliability performance required by the PA Schedule 15-2, Part 1, is 98.5%. This is the only requirement in the PA; but it implies a lot of RAMS activities, to demonstrate the achievement of this target of Service Reliability. Apportionment of this

requirement Service Reliability 98.5% from the top-level mass transit system to lower level of the System Breakdown Structure (SBS) including functions, subsystems and equipment should be carried out by TNext.

Recommendation TC.04

TNext should have a set of minimum of operating requirements derived from the 98.5% performance requirement and revise their RAM analysis to allocate proper performance requirement to each of the systems, subsystems, functions and equipment.

10. OPERATION & MAINTENANCE

10.1 OPERATION

The following conclusions are based on the documents made available to SYSTRA/RATP and on interviews with the City of Ottawa and TNext.

The main documents of interest for the operations are:

- Project Agreement – Schedule 15-2, Part 1, Execution Version;
- Project Agreement – Schedule 15-2, Part 4, Execution Version;
- RCP-ORM-TL2-CON-0003 - Concept of Operations;
- Operational Modelling – Systemwide & MSF (SNC LAVALIN).

We have identified some risks which could potentially affect operations. These risks are mainly related to infrastructure and rolling stock dimensioning but also to the Concept of Operations.

10.1.1 PPHPD Forecasted and Operational Design

As it is mentioned in the PA the Ridership forecasted is:

- 2031: PPHPD of 1950 at Walkley station;
- 2048: PPHPD of 2450 at Greenboro station.

We couldn't find the exact capacity of the refurbished Alstom trains in the project documents. For the main line operated with the Stadler trains the demonstration that the demand forecasted (PPHPD) in 2048 can be met is not done considering the minimum headway of 12 minutes.

To reach a PPHPD of 2450, it is our opinion that more trains and/or a lower headway is/are necessary.

Recommendation OPS.01:

Review the analysis for the PPHPD forecasted in 2031 and 2048, taking into account the minimum headway and the actual train fleet to see if some improvements are necessary to achieve 2048 PPHPD.

10.1.2 Stadler Fleet Size

SYSTRA/RATP have identified a risk of an insufficient Stadler fleet size. This has been confirmed by the modelling experts of TNext during the interview.

With respect to a cycle time (terminus north – terminus south – reversing – terminus south – terminus north – reversing) of 84 minutes on the mainline and 24 minutes on the airport link and the headway of twelve minutes, the minimum fleet size for operations are of:

- 7 trains Stadler on the mainline (capacity of 420 passengers);
- 2 trains (Alstom) on the airport link.

The headway of 12 minutes is scheduled for almost all operational hours.

As of today, the City of Ottawa and TNext have ordered and received seven Stadler trains and the Alstom fleet size consists of 6 trains. We see a risk that depending on the necessary maintenance (planned and unplanned) of the new Stadler trains, between one and two of such trains could simultaneously be immobilized.

In the worst case, two Stadler trains would have to be replaced by the spare trains (2x2 Lint trains) and two Lint trains are necessary for operations on the airport link. This scenario will leave no more spare train to operations and in case a Lint train is undergoing maintenance. Operations will be impacted because the required capacity cannot be offered due to an insufficient amount of rolling stock.

Finally, two Lint trains have fewer doors than one Stadler train which might lead to dwell time problems during passenger boarding / alighting particularly on the main line at the peak hours.

Recommendation OPS.02:

The option to order an 8th Stadler train should be considered to reduce the risk of degraded operations due to unplanned maintenance on the new Stadler trains.

10.1.3 Infrastructure Capacity

Large sections of the Trillium line are single-track lines. Single-track lines are difficult to operate especially if the frequency is low as it generates a high risk of delay propagation and degradation of service quality. As of today, all simulations have been performed with a minimum headway of 12 minutes which is the normal operational headway.

No simulations have been performed with a headway lower than 12mn to understand what margin exists in case of disruption. It is therefore difficult to understand with the actual fleet and the infrastructure constraints what is the minimum achievable headway . This information is critical to be able to have accurate operating procedure in case of disruption.

Recommendation OPS.03:

Considering the forecasted ridership, simulate what is the minimum headway achievable on the line to have a comprehensive understanding of the margin available in case of disruption.

The turnaround time of 3 minutes at South Keys of trains on the Airport Link is relatively short for suburban traffic. Benchmarks from other lines, for example in Europe, are around 8 minutes for a minimum turnaround (which is the turnaround time chosen for the other terminus stations of Trillium line).

Recommendation OPS.04:

Use a turnaround time of at least 5 minutes at South Key for the trains of the Airport Link.

10.1.4 Traffic Control Concept to Limit Delay Propagation

The deterministic simulations made by TNext seem to be sound. However, we have been surprised by the stochastic modelling of only small delays and an increase of dwelling time of less than 2 minutes. To prove reliability and resilience of traffic on this very specific line, stochastic simulations of bigger incidents (based on the failure rate of infrastructure, rolling stock and passenger incident) would be helpful, as per market practices.

During the interviews with the City of Ottawa, OCT and TNext, we have understood the reason why only small train delays have been simulated. The current operational strategy in case of delays equal or bigger than 6 minutes (half the headway) consists in holding all the trains on the line at the next station until the next scheduled departure time.

Recommendation OPS.05

To improve the accuracy of operating procedures and have a better understanding of the line operation robustness, we recommend making stochastic simulations with incidents closer to reality, for example:

- Doors technical issue at the station in the main line (train blocked 10 to 15 minutes)
- Passenger sick and unconscious in a train (20 minutes for waiting emergency services)
- Etc.

10.1.5 Traffic Control Concept to Limit Delay Propagation

Many other documents could have been interesting to read but at this stage of the project they were not available and therefore could not be reviewed, such as:

- Operations service plan;
- O&M manuals;
- Operating procedures;
- Security training program for O&M personnel;
- Safety training program for O&M personnel.

As a result, the assessor cannot provide an opinion on the traffic control concept to limit delay propagation.

10.2 MAINTENANCE AND REHABILITATION

Findings are based on the documents provided to us in addition to the interviews that were organized with the TNext maintenance teams.

10.2.1 General

10.2.1.1 Staffing and Organization

The following information regarding the team was provided by TNext during the interviews:

- The maintenance director has been appointed since 2020. His resume outlines significant experience on different projects (New metro line in Brazil, PPP project in London (Piccadilly line), etc.) and in different positions (T&C Manager, Maintenance Director, etc.)
- Another maintenance director oversaw the maintenance six months before him.

- Since 2020, a vehicle maintenance manager is part of the maintenance team.
- A wayside manager has been recruited from the construction team.
- There are also 6 technicians, former employees from Bombardier / Alstom, with extensive experience on the Alstom Lint. Other members of the maintenance teams are or will be recruited from the construction team.
- The Preliminary maintenance plan provides limited information on the staffing and the mobilization. However we were not provided a specific document, such as a mobilization plan which defines policies, the organization and explain how they would be applied. Such document would have been expected at this stage of the project.
- TNext strategy consists of maximizing recruitment from the construction team.
- TNext expects that the migrations (from construction to maintenance) of such employees would be done "as soon as it is possible" and seems to be confident about the staffing.

Recommendation MAI.01

Given the shortage of qualified resources in Canada, we recommend that TNext produce a Maintenance mobilization plan with a clear schedule and KPIs to follow to anticipate any future issues.

10.2.1.2 Maintenance Policy

In July 2022, the concept of maintenance has been changed where several maintenance tasks will be done in-house instead of being subcontracted out.

We were not provided the Concept of Maintenance document: " O-Train Line 2660373-0000-003-80AG-0001_PA" (In development by TNext) as TNext informed us that the Concept of Maintenance was a document written in 2019. As per TNext, the Concept of Maintenance document has been superseded by the M&R plan, open comments on the Concept of Maintenance have been addressed in the M&R plan and all but one has subsequently been closed. However, we have not been provided with the M&R plan.

Without this document we were unable to assess if the time estimate for maintenance, the size and the organization of the maintenance team is adequate.

Since most of the maintenance tasks will be done in-house, it is essential to have the appropriate skilled staff, especially considering that there is only one vehicle as a reserve.

TNext told us (verbally) that the Concept of Maintenance was a document written in 2019.

Recommendation MAI.02

Removed from the final report further to the latest information received from the City.

10.2.2 Maintenance Team Implication

Our interviews have confirmed that the maintenance team interfaces with the Design and Construction team, The City of Ottawa and the Operator, including workshops on the following topics:

For example:

- Operation and Maintenance workshops involving the city;
- Maintenance committee;

- REX phase 1 – Confederation Line;
- Safety;
- Writing of operation manuals;
- Etc.

The Maintenance and Rehabilitation team are working hand in hand with the Design and Construction Team.

This active collaboration between the teams is reflected in regular meetings, such as the monthly interface meeting, to discuss major items (for example maintenance area) or the weekly meeting to discuss key design issues and finding mutually agreeable solutions.

The Maintenance and Rehabilitation team is also involved into all the design review package.

The Maintenance and Rehabilitation team is not responsible for maintenance during the construction phase, which is performed by the Construction with the exception of Rolling Stock stored and maintained by Alstom at the old MSF.

The organization of regular meetings, the involvement of the Maintenance Team in different phases of the project sis in line with good industry practice.

10.2.3 Schedule

As part of the interviews with TNext, we were informed that the City's maintenance schedule identified the details of the Alstom trains rehabilitation , the delivery of the Stadler trains, the trial runs, the readiness of the MSF, the burn-in period, etc.

Work Schedule PBS-2 did not provide such information, or the information was too diluted to understand the status of each task. We were therefore unable to assess the duration of each task and more important, what would be the impact of delays. Such information should be shared with TNext as this is key to several steps leading to the start of revenue service.

Recommendation MAI.03

The City must ensure that a dedicated maintenance schedule exists and is available to TNext, including all the major milestones in the deployment of the maintenance activities and that such schedule is integrated within the project schedule with clear milestones.

10.2.4 Maintenance and Rehabilitation Plan

The six Alstom trains were stopped in May 2020, parked, and maintained by Alstom at the old MSF, following an SMP (Standstill Maintenance Procedure).

We did not have access to this SMP and could not check if the performed tasks, the date of control, the list of issues, were adequate or not.

Rehabilitation work was also done on the Alstom trains and is now completed. We did not receive information regarding the completion of the rehabilitation, nor validation document showing that the required specifications are met.

Stadler maintenance document has been received and is under review by the TNext maintenance team. We did not have access to this maintenance document.

During the interview, TNext confirmed that all maintenance and rehabilitation activities for the ALSTOM and STADLER Trains are in place but we were not provided enough information and documentation to gain enough confidence that this is actually the case.

10.2.5 Rolling Stock & Associated Maintenance

The interval between 2 maintenance steps can be defined according to the number of kilometres or to the amount of time whichever comes first. The interval is generally defined by the OEM and must be strictly respected to avoid safety risks and can only be modified after conducting an analysis of operating conditions and obtaining technical advice from experts.

We were informed of only one overdue maintenance: axle bearings every 600,000 km or 4 years. We were informed there is no report on the past performance of the Alstom Lint 41 trains. (MTBFS, Availability, Punctuality, Reliability issues), and that

there is no document (maintenance traceability, repair report) showing that the past reliability issues have been addressed. This prevents TNext from ensuring that Alstom trains will be in good condition for the start of revenue service.

We reviewed maintenance reports from Alstom with no indication of the mileage of the trains, except on one document dated 17 Oct 2019.

TNext specified that the Alstom LINT 41 vehicle history books are at the existing MSF and are updated to reflect the work being undertaken daily. They also specified that the ongoing maintenance data are also being inputted into the developing Maintenance Management System to test this interface.

Extract of reliability issues are listed below (from Bombardier reports).

Table 4 : Extract of reliability issues (information as of October 17, 2019)

Vehicle	C4	C5	C6	C7	C8	C9
Vehicle km	410,295	363,582	395,484	367,058	401,177	398,350

Table 5 : Alstom Lint 41 – Bombardier reports

Equipment	Report	Issues
Air system	2017 to 2020	Failure of the brake system, air dryer…due to contamination with water/oil emulsification coming from the air compressor. Alstom / Knorr answer: install additional separators/ filters. Overhaul of brakes.
Engine	2020	Fuel dilution, leaking injectors.
Axle gearboxes	2020	Long lead time for repair in Germany.
HVAC	2020	Repetitive failure of pre-heaters leaks of hoses, clamps. Complete rebuild of the system.
Electrical issues	2020	Unreliable relays, fuse holders, nodes, etc.
Power pack		

Equipment	Report	Issues
Transmission cooler	2017	Aluminum cooler being corroded due to copper contamination in the coolant. Future failure to be anticipated. A stainless-steel cooler will resolve this issue.
Train body	2017 to 2020	Salt damage, with corrosion of aluminum trim, damaged engine hatch causing electrical shorts. Paint peeling off the roof.
Train interior	2017 to 2020	Salt damage, floor sealing damaged, corrosion on seat frames, cabinets, bottom of stanchions, paint damaged near the bicycle racks or wheelchair spots. Damaged seats, foam gone, bolts falling out at the back of the seat.

Recommendation MAI.04 Removed from the final report further to the latest information received.

Regarding the Stadler trains, we did not see any specific measures to create a difference of mileage to avoid having all the Stadler trains in maintenance at the same time. Considering the tight operation schedule and the limited amount of spare trains, it is essential to have a substantial difference of kilometres between each Stadler train. (Maintenance leveling, spacing requirements) to ensure sufficient trains are available for service.

The trial run program is comprised of several phases to demonstrate that the complete system is ready for service. Some trains could be used more than others to create the difference of mileage. For the different phase of the trial run program, it is recommended to identify which train shall be used with the forecasted number of kilometres to be achieved, in a manner to achieve the difference of mileage for each train of the fleet.

As the trial run period is short, a special timetable with some specific trains can be used to start revenue service.

Recommendation MAI.05

In the Trial Run program prepare a plan to create a difference of mileage between the STADLER trains thus avoiding having all Stadler trains in maintenance at the same time later on.

10.2.6 CMMS and Management System

A tailor-made software developed by SSG Insight Ltd is under development (software name: Agility).

Development monitoring is carried out by a working group with the city.

We have no information regarding the readiness of this software. This software is critical to schedule the maintenance tasks and to manage spare parts & consumables. Training of the staff is also essential. In case of delay, there is no back-up.

TNext is confident about the software development and stated that the risk of the software being delayed is low. The development is behind schedule (originally completed by May 2022) as the development was slowed down to align with System Interface availability and trial running. TNext experts consider that the CMMS should be ready for the training period. This software is also used on the Confederation Line.

Recommendation MAI.06

The City should ensure that the development of the maintenance software (Agility) is included in the schedule along with the training of the personnel. Clear milestone should be followed with KPI. As of today, there is no backup solution. Consequently, we recommend that the City works with the different stakeholders (provider, construction teams, and final users) for a backup solution in the event that the CMMS system is not ready on time.

10.2.7 Obsolescence

We were provided with no information regarding the obsolescence management.

In light of our interviews, it appears that there is no obsolescence management plan on the maintenance team side as the management of obsolescence is expected to be under the responsibility of the suppliers.

The risk of unidentified obsolescence and impacts on the performance is can become critical on the longer term.

Recommendation MAI.06

TNext should prepare a holistic obsolescence management plan including policy and processes that should be followed by all their suppliers.

10.3 TRAINING

The training starts mid August 2022 with the maintenance training for STADLER trains.

The implementation of the training plan is in progress at the time of the interview. The training coordinator has been mobilized by TNext. The training manuals are being submitted to the client, monthly workshops with the city and bi-weekly meeting with key suppliers are in place.

Despite regular exchanges and the start of training, some points still remain open such as the training schedule which is in a draft version under validation by the city.

Reaching a consensus promptly is key to ensuring a successful mobilization. According to our discussions with TNext, the identified subjects are:

- The definition of the perimeters, responsibilities, expectations of all stakeholders (City, OCT and TNext);
- Validation of the training schedule (including the hours associated with each training session);
- The definition and implementation of a certification plan;
- The availability of the operating rules to be respected for their integration into the training sessions.

Recommendation TRA.01

We recommend that the City and TNext quickly reach an agreement on the training schedule and content to avoid delay on the revenue service date.

TRILLIUM STAGE 2

Independent Peer Review – Final Report

APPENDICES

SYSTRA CANADA • RATP DEV

APPENDIX A

Input Documentation

Disclaimer:

The Attached list of documents were communicated by the City to the peer reviewers. These documents were not entirely checked, reviewed, verified nor validated by the peer reviewers, rather the peer reviewers have searched these documents for specific information necessary to the performance of the peer review tasks.

APPENDIX B

Recommendations List

Reference	Recommendation[3]
PM.01	We recommend the City and TNext to "draw a line in the sand" and openly create a new baseline of the project including new schedule, new monthly report with shared explicit KPIs and potentially some recommendation of this report. There must be an agreement that the claim from both parties of what conducted to this new baseline will be treated by a different team than the one delivering the new baseline project and it will not interfere with the progress.
PM.02	The lessons learned of the previous and similar project or product should be integrated in the engineering development of the mass transit system. A lessons-learned document relating to the project, system or product should document the lessons learned used for the benefit of the current project.
RS.01	For both types of vehicles, we recommend that the vehicles' interior and exterior noise tests are performed as soon as a track length allows to safely reach 85 km/h and brake afterwards to measure the interior noise as well as exterior wayside noise 25 m from the train as required by the PA Schedule 15-2 Part 8, Section 1.8 (a) & (b).
RS.02	For the Stadler vehicles, to simulate the accumulation of freezing rain up to 3 mm on the doors to ensure the door operators are properly sized to meet its life expectancy as required by the PA, Schedule 15-2 Part 8, Section 1.18 (d)-(i).
RS.03	To perform cold start tests of the vehicles (minimum temperature of cold room to meet the environmental conditions of the City of Ottawa) to simulate the vehicles parked overnight outside can start with no problem.
RS.04	The City should request TNEXT to confirm that Stadler is familiar with this test and whether the bogie rotational resistive test or bogie yaw resistance test/simulation have been performed.
RS.05	To change the gauge clearance test procedure in order to take into account the installation of cameras and real-time position tracking system on the vehicle to identify the exact point of impact between the vehicle and any obstacle that is in the vicinity. (removed)
RS.06	To schedule Alstom's vehicle's gauge tests on the new and modified section of the line to ensure there is no risk of interference between the LINT vehicles and the clearance envelopes. (removed)
RS.07	The City to verify that the wheel compensation is well defined and understood to guarantee that the vehicle height is always within the expected platform height during all operating and passenger loading conditions.
TCS.01	We recommend that the GEBR test be added in the site test procedures according to the condition required by IEEE1474.1 chapter 6.1.2.1.
COM.01	Identify an owner for the head-end system to produce System documentation (e.g., release notes).
COM.02	Establish a test platform for the integration and validation of the System.to avoid discovering the first integration issue on site.
COM.03	Produce a system validation test description document for the head-end System.
COM.04	Produce a system integration and validation test description documents for the entire system.
TRK.01	The City should verify that the following documents have been submitted by TNext and approved by the City or its representative, in compliance with the applicable standards and local state of the art: Track equipment diagram and CWR destressing work method statement. (removed)

[3] The recommendations list includes recommendations that were removed from the body of the document further to the receipt of clarifications from TNext through the city after the issuance of the first version of the present report. These recommendations are shown in light grey color in the table.

Reference	Recommendation[3]
TRK.02	The notion of "best fit alignment" must be clarified by TNext, to confirm that civil tolerance issues won't have any impact on track tolerances, including keeping the possibility for the maintenance teams to implement track geometry adjustments if needed (using shims for example). Check during construction of the DF tracks that the different surveys mentioned in the work method statement is carried out as planned. Confirm the mechanical tests performed on the fasteners of the DF tracks have been done in extreme positions (with maximum shimming) and will not imply any restriction of any kind.
TRK.03	Confirm the diamond crossover at Limebank station has been considered in the rail-structure interaction analysis, and the girder is fixed in the abutment zone to restrain movements.
TVS.01	A detailed design review of all Tunnel Ventilation documentation should be conducted to correct any inconsistency and/or discrepancy and ensure that the correct design will be implemented in accordance with the PA requirements.
TVS.02	We recommend performing an analysis to ensure that the tunnel temperature never reaches trains HVAC tripping temperature.
SEM.01	All documents received from TNext subcontractors should be reviewed and signed by TNext. Documents from Alstom's Lint Vehicles should also be reviewed and approved for operability (Gauge, platform length/height, braking performance, etc.) of the current vehicles on the extension lines.
SEM.02	We recommend putting in place a high-level configuration management plan as a guideline to be followed by all project actors and participants (including the scope under the City) in order to have a consistent holistic view of all configuration items including software, hardware and firm wares.
SEM.03	The definition of what is a system, a sub-system and equipment from the mass transit system (Project) point of view should be stated and aligned with a System Breakdown Structure and a Functional Breakdown Structure, to get a common view between all the stakeholders and co-partners of the project.
SEM.04	We recommend clarifying the list of actions to be taken into account in order to guarantee the clearance for future electrification of the line along with test procedure to ensure that actions have been completed.
SEM.05	We recommend adding EN50500 standard and ICNIRP standard to the EMC Control Plan to guarantee that EMC/EMI impact on human health in railway environment is measured and within the standard specifications.
SEM.06	The Basis of Design Corrosion control document should be updated to take into account the measure concerning corrosion control on the bridge including the track design.
SA.01	An overall review of the RAMS activities along the V-Model lifecycle should be executed to ensure that activities are performed at the correct phase of the project. TNext should also describe the way the RAMS findings are addresses in the design and maintenance.
SA.02	TNext should revise the PHA to align with the terminology of EN 50126-2:2017 and have a complete review of all hazards and mitigation taking into account all scenarios, justifying downgrading of severity level, justifying non-assessment of certain equipment. If it is not done, it can conduct to a safety hazard not being mitigated. The hazard severity matrix, hazard probability matrix as well as the hazard criticality matrix should be presented in the Safety Assurance Plan rather than in the PHA report.
SA.03	TNext should show the autonomy, authority and independence as well as the management of the skills of the RAMS team. An update of the organization presented may be needed to comply with EN 50126-1:2017.
SA.04	RAMS terms like MTBF and MTBSAF or "Service Availability". "Availability" shall be defined and used consistently across all TNext documentation including their subcontractors' one to avoid misunderstanding. It should also be presented how the MTBSAF of each sub-system has been determined, with which reliability database or return of experience.

Reference	Recommendation[3]
SA.05	The reliability and availability formulae should be stated and tailored to the mission profile or working mode of each system/subsystem/equipment. The RAM apportionment should be performed down to the LRU and appear in the RAM apportionment report.
SA.06	TNext should conduct a common cause failure analysis into a specific report addressing the systematic failures to verify that events in a fault tree analysis are truly independent.
SA.07	TNext should clarify the process for collecting and analysing the field RAMS data by explaining which information will be collected, monitored and how, and then detailing the process of analysis and action plan definition and implementation.
SA.08	TNext should clarify the approach taken for the risk reduction for safety-related risks and for the RAM related risks by referring to EN 50126:2017.
SA.09	TNext should present in a specific document the gap analysis principle and process for re-used products, already certified or not. As part of this document, TNext should clarify how they manage the functional boundaries and functional interfaces between the original vehicle fleet and the vehicle fleet adapted/tailored to the project. Such recommendation is also applicable to the S&TCS which is not compliant with the PSOS requirements in terms of code compliance.
SA.10	TNext should provide a formal traceability between the CENELEC standards and their plans and other deliverables with the objective to demonstrating compliance. This is essential to provide confidence in both the process and the deliverables.
CON.01	TNext should develop a method to verify after pouring the adequate positioning and concrete coverage of the structure reinforcement steel.
TC.01	A clear in-factory integration plan should be put in place with an exhaustive list of tests to be performed in factory and clear criteria of success to reduce the number of issues to be discovered on site.
TC.02	TNext should build a comprehensive and integrated time schedule showing all the interdependencies and interfaces between systems and a clear way forward for the performance of End-to-End tests. This schedule should be coupled with a set of KPIs and a dashboard allowing to closely monitor on a weekly or biweekly basis at most the test progress for each discipline and identify the blocking points and escalate them for swift resolution.
TC.03	TNext should provide a test plan to verify global system performance during wintertime.
TC.04	TNext should have a set of minimum operating requirements derived from the 98.5% performance requirement and revise their RAM analysis to allocate proper performance requirement to each of the systems, subsystems, functions and equipment.
OPS.01	Review the analysis for the PPHPD forecasted in 2031 and 2048, taking into account the minimum headway and the actual train fleet to see if improvements are necessary to achieve 2048 PPHPD.
OPS.02	The option to order an 8th Stadler train should seriously be considered to reduce the risk of degraded operations due to an unplanned maintenance on the new Stadler trains.
OPS.03	Considering the ridership forecasted, simulate what is the minimum headway achievable on the line to have a comprehensive understanding of the margin available in case of disruption.
OPS.04	Use a turnaround time of at least 5 minutes at South Key for the trains of the Airport Link.
OPS.05	To improve the accuracy of operating procedure and have a better understanding of the line operation robustness, we recommend making stochastic simulation with incidents closer to reality, for example: Doors technical issue at the station in the main line (train blocked 10 to 15 minutes) Passenger sick and unconscious in a train (20 minutes for waiting emergency services) Etc.

Reference	Recommendation[3]
MAI.01	Given the shortage of qualified resources in Canada, we recommend that TNext produce a Maintenance mobilization plan with a clear schedule and KPIs to follow to anticipate any future issues.
MAI.02	The Concept of Maintenance document should be issued quickly to make sure that the maintenance team mobilization and training are in line with the needs for Trillium Line before the revenue service date. (removed)
MAI.03	The City should ensure that a dedicated maintenance schedule exists and is available to TNext, including all the major milestones in the deployment of the maintenance activities and that such schedule is integrated within the project schedule with clear milestones.
MAI.04	In the Trial Run program prepare a plan to create a difference of mileage between the STADLER trains in to avoid having them all in maintenance at the same time later on. (removed)
MAI.05	The City should ensure that the development of the maintenance software (Agility) is included in the schedule along with the training of the personnel. Clear milestone should be followed with KPI. As of today, there is no backup solution. As a consequence, we recommend that the City works with the different stakeholders (provider, construction teams, and final users) for a backup solution in the event that the CMMS system is not ready on time.
MAI.06	TNext should prepare a holistic obsolescence management plan including policy and processes that should be followed by all their suppliers.
TRA.01	We recommend that the City and TNext quickly reach an agreement on the training schedule and content to avoid delay on the revenue service date.

APPENDIX C

List of residual questions and answers.

Disclaimer:

This table is a working tool of the peer review team and is appended to the peer review report for traceability purposes only.

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