

Subject: LRT Disruption – Root Cause Review

File Number: ACS2023-TSD-ENG-0020

Report to Transit Commission on 12 October 2023

Submitted on September 29, 2023 by Renée Amilcar, General Manager, Transit Services Department

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Ward: Citywide

Objet : Perturbation du service du TLR – Examen des causes profondes

Numéro de dossier : ACS2023-TSD-ENG-0020

Rapport présenté au Commission du transport en commun

Rapport soumis le 12 octobre 2023

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Quartier : À l'échelle de la ville

REPORT RECOMMENDATION

That the Transit Commission receive this report for information.

RECOMMANDATION DU RAPPORT

Que la Commission du transport en commun reçoive ce rapport pour information.

BACKGROUND

The purpose of this report is to review the incidents and investigations undertaken by the City and RTG/Alstom since 2021 to manage and resolve ongoing issues related to axle bearings on O-Train light rail vehicles.

The report reviews the findings of the current investigations, outlines where further findings are expected to complete the root cause analysis, and sets out short-, medium- and long-term actions to permanently resolve the axle bearing issue and increase rail service reliability.

DISCUSSION

1. Axle Hub Issues leading to Suspension of Service

There have been three events related to the axle issue that have led to full or partial shutdowns. The events are summarized below:

#	Date	Event
1	August 8, 2021	On return to the Maintenance and Storage Facility (MSF), and with no passengers on-board, light rail vehicle number 19 (LRV19) derailed outside of Tunney's Pasture Station due to an axle issue. Alstom introduced a revised inspection regime every 7,500 kilometres.
2	July 21, 2022	Unusual vibrations reported on LRV27. Subsequent investigation found a severely degraded axle hub. Alstom released a safety note that reduced periodic inspection of axle hubs from 7,500 kilometres to 3,750 kilometres. Additionally, leading/trailing bogie axles were now replaced every 175,000 kilometres.
3	July 17, 2023	Service suspended due to grease found following a routine inspection on LRV32, which later led to discovery of a failed bearing. The LRV fleet was inspected, and Alstom released a new safety note. Periodic inspection for all LRVs was reduced to 3,750 kilometres and leading/trailing bogie axles were now due to be replaced every 60,000 kilometres.

2. Investigations and Reports Undertaken

There have been multiple studies undertaken to date to investigate the ongoing axle hub issue. Reports include several by external organizations (e.g., National Research Council (NRC), Transportation Safety Board (TSB), MxV Rail) to evaluate the wheel/rail interface, friction management, train speed (particularly in tight curves), track condition and vehicle dynamics. These studies are described in more detail in the following subsections.

2.1 Wheel Rail Interface Study

In December 2021, NRC released a report of their review of wheel/rail interaction for the Confederation Line Wheel/Rail Interaction Report. The report examined the following:

- Interaction between wheel profile (B12) and rail profile (RE115);
 - The designation RE115 refers to the nominal weight of the rail, which is 115 pounds per yard and 8-inch head radius. B12 is the Alstom wheel profile for the Citadis vehicle. These represent some of the parameters used by the NRC in their analysis.
- The material properties of the wheels/rail;
- The impact of wheel/rail lubrication; and
- The impact of vehicle dynamics (particularly in tight curves).

Recommendations from the report included:

- Performing rail grinding to restore the original contour or making a new profile;
- Optimizing the wheel profile to current track geometry; and
- Reducing friction in curves.

2.2 TTCI/MxV Report

MxV Rail (formerly TTCI) inspected the Ottawa Line Rail Transit Confederation Line in August and September 2022 during a maintenance shutdown. The purpose of the inspection was to assess and document issues that may be resulting in a high level of maintenance to both infrastructure and rolling stock. MxV Rail has analyzed vehicle-track interaction on many systems and found that it is essential to evaluate both sides of the wheel-rail interface.

The findings are broken out into the following priority issues:

- Wheel/rail interface and profiles
- Excessive wheel/rail lubrication
- Restraining rails
- Track buckling/lateral alignment, rail neutral temperature and lack of broken rail detection system
- Soft rail
- Sub-standard ballast, questions about subgrade

The report provided the following recommendations:

- Perform a vehicle-track interaction analysis to optimize the wheel-rail interface that is the focal point for most of the problems observed. This may include development of new wheel and rail profiles.
- Reduce lubrication to target only the gage face of the high rail in curves.
- Re-evaluate the need for and placement of restraining rails, including clearance tolerances and effects on back-of-flange contact during normal operations.
- Implement a broken rail detection system so the rail neutral temperature can be optimized.

2.3 TSB Rail Safety Advisory Letter

The Transportation Safety Board of Canada (TSB) released a Rail Safety Advisory Letter in February 2023, which contains a summary of the derailments and axle bearing issues (including the TSB examination of three axle bearing assemblies).

The report included the following:

- Summary of the derailments and unusual vibration reported on LRV27.
- Summary of the axle issue and the development of the Citadis Spirit for Ottawa.
- Statement that the derailment was due to a catastrophic failure of an axle bearing.
- Results of TSB examination of 3 failed axles:
 - Materials were found to meet specifications;
 - Multiple failure modes were found (fatigue, overstress, heat, etc.);
 - Failures are more prominent in motor bogies; and
 - Mileage of failed components was well below industry standards.

2.4 Instrumented Bogie Testing

2.4.1 November/December 2022 Testing Campaign

The purpose of the instrumented axle test campaign performed in November and December of 2022 was to investigate the impact of the short-term actions recommended in the preliminary LRV19 Derailment Investigation Report (no. DED0002013535) issued on May 12, 2022 on the loads of the hub. These actions include:

- Friction Coefficient management through application of Top-of-Rail (TOR) Friction Modifier.
- Temporary Speed Restrictions (TSRs) and general impact of speed on the lateral loads on the hub.
- Investigation on the B17 Wheel profile about potential effect on the loads on the hub.

An additional aspect that was investigated was the impact of the restraining rail contact on the loads on the hub, as an adverse effect was anticipated in the mainline curves where restraining rail are installed.

2.4.2 July 2023 Testing Campaign

The goals of this test were to:

- Investigate the difference between tunnel and non-tunnel areas in terms of wheel/rail lubrication.
- Investigate the track cleaning process in the tunnel.
- Validate the use of Top-of-Rail (TOR) friction management.
- Further evaluate the impact of restraining rail contact.
- Evaluate impact of hot temperatures.

The report for this Instrumented Bogie Test is being prepared by Alstom.

2.5 Alstom's Recommendations for a Sustainable Solution

This report is prepared by Alstom, the vehicle manufacturer, and contains recommendations, validated by testing and investigations, for a sustainable solution to the Ottawa LRT System.

As noted in the report, "A Sustainable Solution is one in which the System can safely return to the passenger capacity requirements set out in the Project Agreement for Service Level 1, employing the planned maintenance levels, without the need for continuing periodic axial play inspections."

The report provided recommendations to address the root cause by reducing the lateral forces imposed on the wheelset during operation and the option to reinforce the axle hub assembly design to sustain lateral load cases that are above and beyond the ones prescribed in EN 13979-1.

The recommendations listed in the report include: Introduce Top-Of-Rail Friction Modifier; Changes to track Infrastructure; Changes to Wheel/ Rail Profile; Axle Hub Assembly Recommendations; Continued Monitoring; and Further Investigation.

This report is currently under review by RTG who will provide their own system-level report that will provide a status and remedial assessment to the City and RTG's next steps in relation to the axle bearing assembly issue.

3. Containment Plan – Short Term

3.1 Return To Service Plans

After each suspension of service due to an axle bearing assembly issue, a Return to Service Plan is agreed upon between RTG and the City. The Return to Service Plan details the containment program necessary for resumption of service and includes an updated Safety Note from Alstom. On each occasion, Transportation Resource Associates (TRA), the City's Rail Safety Advisor, assists with the vetting, approval, evaluation, and oversight of the safe delivery of the Return to Service Program. The City and TRA have maintained lists and status updates of return to service commitments (including those by RTG) and have reviewed their status regularly.

3.2 Alstom Safety Notes

The Alstom Safety Note describes the conditions for safe operation of the Citadis fleet of vehicles and validates that the hazards associated with service are, at a minimum, acceptable with review.

The containment recommendations include:

- Inspection regime of the axles;
- Axle replacement regime;
- Track conditions such as restraining rail positioning; and,
- Temporary speed reductions.

The Alstom Safety Note has been revised multiple times since first published. At this point, ongoing revisions to the Safety Note are expected every 30 days, until the bearing assembly issue is resolved.

3.3 Axle Inspections and replacement program

After the first derailment in August 2021, an axle inspection was implemented every 7,500 kilometres to mitigate the risk of axle failure. The axle inspection includes an axle

clearance check, backlash measurement (one wheel is lifted off the rail and turned and the relative rotation compared to the other wheel on the rail is measured.), and wheel back-to-back measurement.

Following the results of the July 2022 investigation into unusual vibrations reported on LRV27, Alstom issued a revised Safety Note, which included an update to the frequency of the axle inspections increasing the frequency from every 7,500 kilometres to every 3,750 kilometres. Failure of any of the axle inspection checks or severe leaks results in replacement of the axle.

Additionally, after grease leaks were found during the most recent shutdown in July 2023, the axle inspections have been updated to include monitoring and categorization of visible grease. Replacement of the leading and trailing motor bogies axles is now required after every 60,000 kilometres; this is compared to 90,000 kilometres after the July 2022 incident and 175,000 kilometres after the July 2021 incident.

Each LRV has five bogies; one leading and one trailing and three intermediate bogies. Statistics from July 2021 to July 2023 show a much lower occurrence of axle hub failure on the intermediate bogies which is consistent with lower lateral forces on these three bogies.

3.4 TSRs in Curves

Temporary Speed Restrictions (TSRs) are put in place as a safety factor in parts of the guideway where there are precautions about either the vehicle or track conditions. A TSR is the speed at which it has been determined it is safe to navigate a certain curve or section of rail.

As per the latest Alstom Safety Note, a 20 per cent speed reduction has been applied to all curves with a radius less than 250 metres until further notice.

3.5 Restraining Rail Adjustments

The restraining rail is a passive safety device that prevents derailing in the event of wheel climb within a curve. The design of the Confederation Line track is consistent with the Track Design Handbook for Light Rail Transit, published in 2012 by the Transportation Research Board. In relation to the restraining rail, the track is designed in accordance with Philosophy III, with a track geometry preventing no routine restraining rail contact. Due to various factors, such as rail flange face wear, track gauge tolerances and temperature induced track movement, there has been evidence of contact between the restraining rail and the back of wheel.

After the July 23 event, Alstom indicated that no contact was permissible between the restraining rail and the back of wheel and RTM implemented a program of restraining rail

adjustment. In order to validate the increase of the maximum allowable gap between the low rail and restraining rail, RTM engaged SNC Lavalin Rail and Transit Ltd. to evaluate the current criteria for establishing the position of the restraining rail and to propose new criteria to achieve the Alstom requirement of having no contact between the back of the LRV wheel flange and the restraining rail during normal operation. The new criteria for the maximum gap between the low rail and restraining rail was set at 54 millimetres.

The setting of the restraining rails has been achieved either by adjusting to the limits of the existing bracket tolerances or in some cases providing new brackets.

3.6 Ongoing Oversight

The TSD Rail Systems team, as part of Engineering Services, continues to monitor and provide oversight of RTM. The Rail Systems team regularly reviews axle replacement documentation to ensure that checks and replacements are occurring at the appropriate frequencies. The Rail Systems team also reviews any reports related to the axle issue and provide their comments and/or recommendations. Additional external oversight is also provided by TRA as was recommended as part of the Ottawa Light Rail Transit Public Inquiry recommendations.

4. Mitigation Plan – Medium Term

4.1 TOR Lubrication

A friction modifier will be added to the top of the rail to reduce the friction between the train wheels and the rail at specific curves. This reduces noise and vibration as the wheels round the curve and the reduced friction helps prevent wheel climb on outer rails. A reduced coefficient of friction will also reduce the amount of lateral (i.e., sideways) force applied to the axle bearing which is a contributory factor in the axle bearing assembly failures.

At this time, RTM has engaged a vendor and is planning the implementation of wayside applicators before the end of 2023.

4.2 Bearing Condition Detectors – “Smart Bugs”

The TSB report recommended the deployment of equipment capable of monitoring the condition of the axle hub assembly to provide early warning of a potential failure. Alstom has outfitted four LRVs with accelerometers (Smart Bugs) that measure vibration within the axle bearing assembly. The goal is to capture the vibrational data from at least one event where an axle hub progresses from an in-tolerance state to an out-of-tolerance state. This would then identify the unique vibrational signature that signals an impending failure. Monitoring the in-service vehicles has so far been unsuccessful in identifying this vibration signature. An alternative approach is being pursued with the NRC in Ottawa and

a “Bench Test” experiment will allow additional testing in a controlled laboratory environment. By testing different axles with varying levels of failure it is expected that a critical failure signature for the axle hub will be identified. A reliable detection of a vibrational signature like this would allow for a reduction in manual measurements and provide better overall visibility on axles requiring corrective action.

5. Mitigation Plan – long term

5.1 Redesign of axle bearing assembly

RTG has committed to the City that Alstom has commenced a redesign of the axle bearing assembly and expects that an approved design will be in place by the end of 2024.

The axle bearing assembly redesign will focus on strengthening the assembly to better withstand the lateral forces experienced on the Confederation Line and ultimately deliver an axle bearing assembly that meets expectations from a safety, service and maintenance perspective.

Coupled with the adjustments to the restraining rail and implementation of TOR lubrication, the axle bearing assembly redesign will address the issues currently experienced on the Confederation Line and improve the overall reliability of the system.

In parallel, RTG continues to consolidate the results and recommendations of all the reports and studies undertaken to date and will provide their analysis, conclusions and next steps in a comprehensive report.

6. Conclusion

The issues with the axle bearings have had a significant effect on the reliability of rail service. Fixing this issue permanently will allow for the removal of temporary mitigations currently in place, as well as further increasing the safety of the light rail system. While the timelines to design and implement the new axle bearing system are long, solid plans are in place to monitor and manage the current axle configuration until the solution can be implemented. This work should result in Ottawa being one major step closer to having the reliable and dependable rail system that it deserves.

FINANCIAL IMPLICATIONS

There is no financial implication to receiving this report for information.

LEGAL IMPLICATIONS

There are no legal impediments to receiving this report for information.

CONSULTATION

As part of the ongoing review and analysis of the issues identified in this report, Transit Services has continued to work closely with RTG, RTM and Alstom. Additionally, experts have been consulted to provide reports and recommendations. Those experts include the National Research Council (NRC), Transportation Safety Board (TSB), MxV Rail, Transportation Resource Associates (TRA) and JBA.

ACCESSIBILITY IMPACTS

One of OC Transpo's mission statements, as outlined in the Five-Year Roadmap is: We promise to deliver safe, clean, dependable and accessible public transit. All components of the transit system, including O-Train Line 1 adhere to the *Accessibility for Ontarians with Disabilities Act (AODA)*.

Staff will continue to engage persons with disabilities and accessibility stakeholders to ensure that their perspectives are considered and incorporated, and to promote inclusion. The vehicles identified in this report are fully accessible light rail vehicles.

ASSET MANAGEMENT IMPLICATIONS

OC Transpo's assets are identified as one of the five pillars in the 5-Year Roadmap. In the coming years, OC Transpo will be adding all the Stage 2 O-Train extensions and their associated properties, vehicles, infrastructure and technologies required to operate these new systems. OC Transpo's new and existing assets will be maintained and managed through systematized departmental administrative processes. As noted in the Roadmap, one initiative, the Core Business Review, will identify all key assets to ensure that Transit Services is making the best use of each of them.

RISK MANAGEMENT IMPLICATIONS

Risk management implications are outlined in the report.

TERM OF COUNCIL PRIORITIES

This report supports the following Term of Council Priorities:

- A city that is more connected with reliable, safe and accessible mobility options.
- A city that is green and resilient.

DISPOSITION

Transit Services will continue to provide progress updates for Transit Commission and Council.