Findings of Investigation into the Train Derailment Incident on the East-West Line (EWL) on 25 September 2024

Summary of Findings

The East-West Line (EWL) service disruption on 25 September 2024 was caused by the failure of the axle bearings within an axle box of the Kawasaki Heavy Industries (KHI) train involved in the incident ("Incident Train").

The failure of the axle bearings caused extreme heat to be generated while the Incident Train was operating. This ignited and burnt off the rubber layers of the chevron springs which were attached to the axle box, and the chevron springs progressively fell off the Incident Train during the morning of the incident.

Without the supporting chevron springs, the axle box dropped off the Incident Train near Dover station as the train was travelling to Ulu Pandan Depot after passengers had disembarked, and caused the wheels of the front bogie of the third train-car to come off the running rails. The train remained upright after the incident as it was restrained by guard rails installed parallel to the track as a safety feature.

The Incident Train caused severe damage to the running rails, power rail (or third rail), and other trackside equipment as it was travelling to Ulu Pandan Depot. Recovery of the Incident Train and repairs to the damaged track required six days before train services between Buona Vista and Jurong East stations could be resumed.

LTA was assisted in its investigation by an Expert Advisory Panel (EAP) and a commissioned forensic analysis carried out independently by SGS Testing and Control Services Pte Ltd (SGS). The EAP and SGS found that degraded grease was a likely cause of the failure of the axle bearings in the axle box.

Incident Investigation

1. These findings were based on analysis of the damaged components recovered, data captured on the condition of the damaged axle box, and the maintenance records of the Incident Train.

Components Involved in the Incident

2. KHI trains have six train-cars, with each train-car having two undercarriage bogies, and each bogie holding four wheels. An axle box assembly is attached to each wheel. (Please see Figure 1)

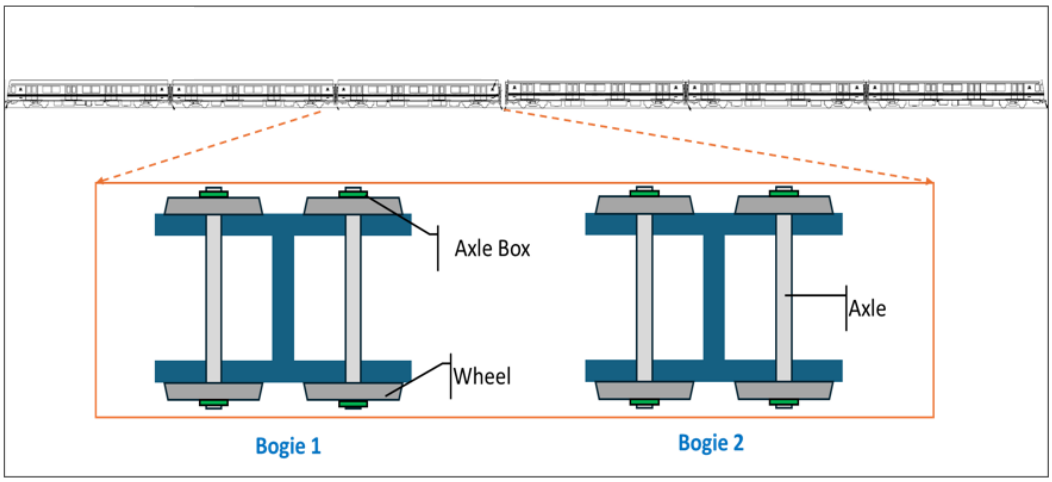


Figure 1: Schematic of the train bogie

3. Axle box assemblies allow the train's wheels and axles to rotate while the weight of the train sits on the axle boxes. An axle box assembly comprises one axle box and two sets of chevron springs. The axle box holds the train wheel to the axle. Within each axle box are greased axle bearings, which allow the axle and wheel of the train to rotate smoothly during operations. The two chevron springs – metal plates interleaved with rubber – connect the axle box and the bogie frame, and absorb shock and vibration during train movement. (Please see Figure 2)

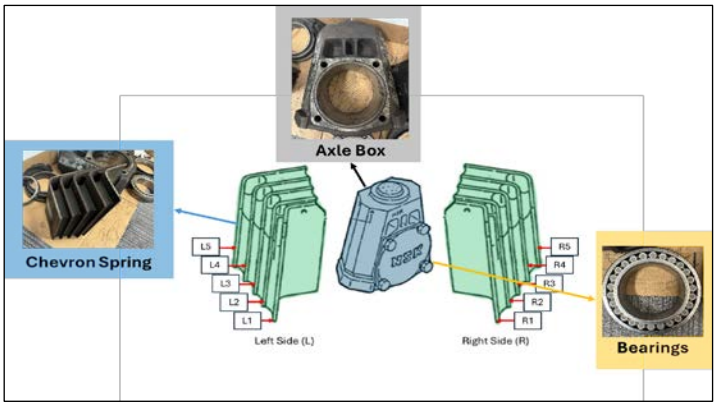
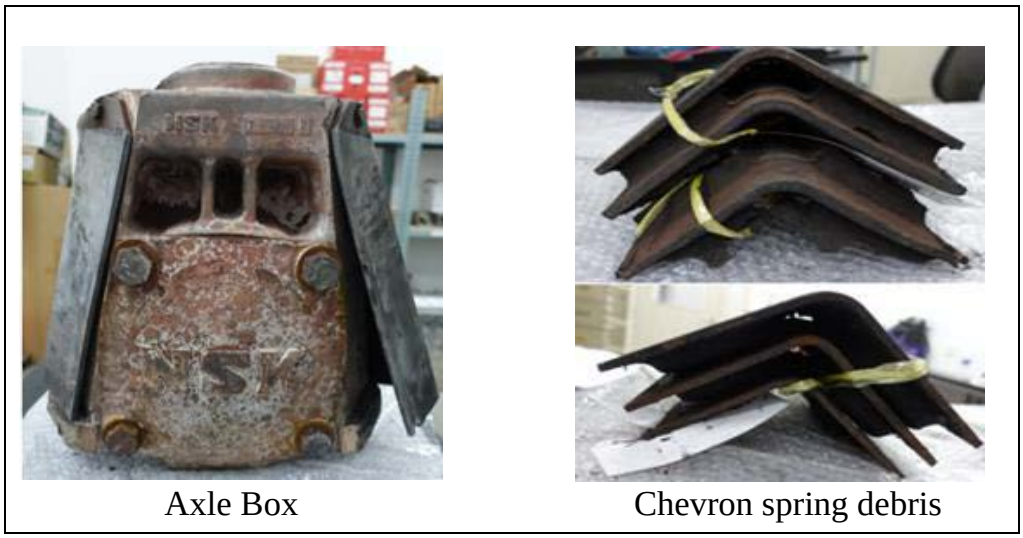


Figure 2: Schematic of the axle box assembly of a KHI train.

Analysis of Recovered Components

4. Chevron spring debris was found at the eastbound track before Jurong East station, and at both eastbound and westbound tracks near Queenstown station where the Incident Train had turned around to return to Ulu Pandan Depot, the nearest depot.[1] The dislodged axle box with chevron spring debris attached was found along the westbound track after Dover station. These were sent for forensic tests, together with control samples of grease and axle bearings (from other axle boxes of the Incident Train) for comparison. (Please see Figure 3)



Axle Box Chevron spring debris

Figure 3: Recovered axle box and chevron spring debris.

5. The recovered axle box and axle bearings were badly damaged, and the grease in the axle box had completely burnt off. The recovered chevron spring debris was also

[1] The nearest turnaround track, where the train could change from the eastbound track to the westbound track, was located at Queenstown station.

too badly damaged for any tests to be done to identify any initial damage prior to the incident. It was therefore not possible to establish a definitive root cause.

6. The same components were taken from other sections of the Incident Train for tests and examination. These tests found nothing significant that would have required replacement or corrective maintenance of the chevron springs. However, grease samples from other axle boxes of the Incident Train showed degradation. Degraded grease can cause increased wear and tear of the axle bearings, eventually causing overheating and failure.

7. The locations of the damaged components recovered also supported the above findings that this was a likely failure mode. Burnt rubber and pieces of the chevron springs were found along the Incident Train's path of movement, which suggested that an overheated axle box due to the failure of the axle bearings had generated sufficient heat to ignite the rubber layers between the chevron springs, causing them to disintegrate. The chevron springs then progressively dropped off, which eventually resulted in the axle box becoming dislodged near Dover station.

Temperature Data of Damaged Axle Box

8. This sequence of events is consistent with the data captured by the Hot Axle Box Detection System (HABDS). The HABDS is a trackside system put in place by SMRT as an additional monitoring tool on their own initiative (i.e. it was not part of the equipment provided by LTA and was not a regulatory requirement for the operator). The HABDS detects high temperatures on axle boxes of passing trains. The system alerts maintenance staff to potential issues on the axle boxes, so that further inspections can be carried out.

9. On 25 September 2024, based on temperature logs from the HABDS, a temperature of 118℃ on the incident axle box was recorded at 7.23am when the Incident Train was making its first westbound trip. This was significantly higher than the typical operating temperature of up to 65℃. Due to a system issue, the system could not identify the Incident Train at the time and action could not be taken promptly. Post-incident, the temperature logs were also examined from the HABDS in the days prior to the incident, and it was found that while the temperature of the incident axle box was slightly elevated compared to other axle boxes on the Incident Train, it remained within typical operating thresholds and therefore had not triggered any alerts before 25 September 2024.

Assessment of Incident Management

10. In LTA's review of SMRT's incident management practices, LTA found that SMRT's staff had responded to the situation appropriately based on the information they possessed at the time and according to their SOPs. By reviewing CCTV footage based on initial reports of a burning smell, SMRT staff had narrowed down the probable train responsible for the burning smell to the Incident Train, which at that time was travelling from Jurong East station towards Clementi station. The station manager of Clementi station confirmed a burning smell and smoke in the train cabin. In accordance with SMRT's SOP, the controllers instructed the train captain to take the Incident Train out of service at Clementi station and disembarked passengers safely.

11. SMRT then withdrew the train towards the nearest depot, Ulu Pandan Depot, to diagnose and resolve the issue. On-site inspection of potentially damaged trains, for example at MRT stations, is not feasible due to insufficient space on the platform and viaduct. In addition, carrying out such an on-site inspection during operating hours would require shutting down the traction power for the line for safety reasons, which would affect service on the entire line and cause other trains with commuters to be stranded. SMRT's SOP was therefore to withdraw trains towards the nearest depot (Ulu Pandan Depot in this case) to diagnose and resolve the issue.

Assessment of Maintenance Regime for Incident Train

12. The Incident Train was part of the KHI fleet that was progressively being replaced by new Movia trains (Contract R151). The contract was awarded by LTA in 2018, for 106 new Movia trains to replace the 66 KHI trains, 21 Kawasaki Heavy Industries & Nippon Sharyo (KNS) trains and 19 Siemens trains. Initially, 66 Movia trains were to be handed over to SMRT by March 2024, with the first trains to be handed over in October 2021. The remaining 40 trains would be fully handed over by February 2026. However, due to the COVID-19 pandemic, there were changes in the delivery timeline and the first Movia trains were only handed over to SMRT in May 2023, a delay of 1.5 years. Upon receiving the first Movia trains, SMRT began decommissioning the KHI trains. Nonetheless, as the operator for the EWL, SMRT was required to continue regular maintenance for the KHI trains that were still in service, including conducting Preventive Maintenance and Overhaul.

(i) Preventive Maintenance

13. LTA examined the maintenance records for the Incident Train. SMRT conducts checks on the axle boxes and chevron springs as part of its 3-weekly and 6-monthly

Preventive Maintenance (PM) on KHI trains. During the PM, SMRT would carry out tasks such as visually inspecting the axle boxes and chevron springs for signs of damage, and checking the temperature stickers on each axle box. These temperature stickers would blacken irreversibly if exposed to high temperatures, to alert maintenance staff to conduct more detailed checks.

14. Prior to the incident on 25 September 2024, SMRT last carried out the 3-weekly and 6-monthly PM on the Incident Train on 10 September 2024 and 15 July 2024 respectively. SMRT's visual checks did not find any anomaly with the axle box assemblies and the temperature stickers.

(ii) Overhaul

15. LTA also examined the overhaul records for the Incident Train. Between 2015 and 2020, SMRT had replaced the bogie frames of all KHI trains. As for the components of the axle box assembly, SMRT's stipulated maintenance requirement is to overhaul the axle box and chevron springs after every 500,000 km run by the KHI trains. During this overhaul, the axle box assemblies would be dismantled, cleaned and checked to ensure that they remain in good working condition. The axle box, axle bearings, and chevron springs would be replaced based on their condition, where necessary. Fresh grease would also be reapplied on the axle bearings.

16. The Incident Train was last overhauled in July 2018. Based on the updated timeline for the replacement of KHI trains, in December 2023, SMRT commenced a cycle of modular overhaul for 38 KHI trains that were still in service and which required overhaul of their safety-critical components, including the axle box assembly. The Incident Train was one of the 38 trains identified for overhaul. By the time of the incident on 25 September 2024, 18 had been overhauled, but the Incident Train had not.

17. LTA found that SMRT had extended the overhaul interval for the Incident Train on two separate occasions, to 575,000 km (in August 2022) and 750,000 km (in August 2024) respectively, based on SMRT's internal procedures. While LTA was aware of SMRT's internal procedures to vary its overhaul activities, SMRT was not required to inform LTA when these procedures were activated. LTA noted that SMRT had relied on analysis of the performance of the KHI train fleet and their continued reliability in deciding on these extensions of the overhaul interval for the Incident Train. As axle box failures are not common, SMRT did not undertake a detailed engineering and risk assessment on extending the axle box overhaul interval. The incident train had logged 690,000 km by the time of the incident. Had the Incident Train been overhauled in a

more timely manner, the condition of its axle box assemblies would have been checked and any degraded grease could have been replaced earlier.

Assessment of Service Recovery

18. Despite the initial confusion during the first hours of the incident, SMRT managed the service disruption satisfactorily. SMRT activated free boarding of public buses and bridging shuttle bus services promptly when they understood that train services would take some time to resume. SMRT also took quick action to limit the affected sector to between Jurong East and Buona Vista stations once it assessed that it was safe to do so. The shuttle trains between Boon Lay and Jurong East stations, and between Queenstown and Buona Vista stations, allowed the bridging shuttle bus services to be further optimised and reduced the additional journey time for those affected.

19. The repair and restoration works were extensive, and involved round-the-clock efforts by SMRT, supported by LTA's trackwork contractors drawn from other ongoing rail projects. All required works were completed on 30 September 2024, and after safety runs, normal train services resumed on 1 October 2024.

Follow-up Actions

a) Ensure safe operation of the KHI trains

20. After the incident, SMRT withdrew all KHI trains that had exceeded 500,000 km mileage since their last overhaul from service to undergo the overhaul activities specifically for axle boxes before they were put back into service. This was completed by October 2024.

b) Strengthen operational procedures

21. In consultation with LTA, SMRT has implemented the use of data analytics to detect emergent abnormal axle box temperatures, so that pre-emptive action can be taken before problems occur. SMRT also rectified the system issue in the HABDS and strengthened its SOP for staff to raise high-temperature alerts to the OCC in a timely manner.

22. From the experience of this incident, SMRT has instituted withdrawal of trains back to depot under such scenarios at a lower speed of 35 km/h to limit any potential damage to the tracks and trackside equipment.

c) Strengthen engineering and risk assessment

23. Given that component failures can also happen on any train, including both new and older trains, SMRT is undertaking a comprehensive review of its methodology for approving deviations in maintenance regimes, with a focus on strengthening its engineering principles and risk assessment framework.

24. As asset owner, LTA has also strengthened its oversight of operators' management of assets, including operators' internal procedures to adjust maintenance schedules. LTA has enhanced its tracking of major maintenance for operating assets and review of waivers or extensions of scheduled maintenance of key systems/components. This includes LTA and operators working together for future overhaul decisions. LTA is also engaging independent advisors to provide advice on operations and maintenance strategies and reliability improvements.

25. SMRT, LTA, and the National Transport Workers' Union have set up a tripartite Rail Safety and Reliability Review Workgroup to review and enhance systems in areas such as life cycle management, asset renewal, system enhancements, and maintenance practices across the rail ecosystem. As part of the review, the workgroup has also engaged overseas metro operators in Guangzhou and Taipei for mutual learning.