Transport Accident Investigation Commission

# Final Report

## *Rail inquiry RO-2019-103*
## *Derailment of Train 626*
## *Palmerston North*
## *4 April 2019*

**April 2020**

## About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas.

The principal purpose of its inquiries is to determine the circumstances and causes of occurrences with a view to avoiding similar occurrences in the future. It is not the Commission's purpose to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. However, the Commission will not refrain from fully reporting on the circumstances and factors contributing to an incident because fault or liability may be inferred from the findings.


**Figure 1: Location of accident**

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# 1 Executive summary

## What happened

1.1. On Thursday 4 April 2019, Train 626, an express freight train consisting of two locomotives and 37 loaded wagons, was travelling north from Palmerston North to Napier.

1.2. Because of the imminent arrival of a southbound train, the train controller routed Train 626 (the train) from the yard onto the Palmerston North-Gisborne line via the north arrival/departure road and number 29 crossover points.

1.3. The train was travelling at the maximum authorised line speed of 25 kilometres per hour when the lead locomotive entered the crossover points. At about the same time, the driver applied more power by selecting power notch five while the train continued to descend the 1-in-120 gradient.

1.4. The train speed had increased to 32 kilometres per hour when there was a sudden loss of brake pipe pressure. A few seconds later the train's brakes were applied automatically, indicating to the driver that the train had parted.

1.5. The driver radioed train control[1] and was told that the traction overhead power line had been brought down. Shortly afterwards the train examiner[2] confirmed that the train had also derailed.

## Why it happened

1.6. The Transport Accident Investigation Commission (Commission) **found** there was insufficient vertical load[3] on the leading bogie[4] of log-carrying wagon UKN143 to prevent it climbing the outer right-hand curved rail on 29B set of points.

1.7. The Commission also **found** that no single factor led to this derailment. Instead, it is very likely that a combination of factors contributed to the wheel climb that resulted in the derailment:

- the track condition and its alignment
- the train travelling above the authorised line speed
- the condition of the wagon's suspension system and its sensitivity to the track conditions
- the multiple cyclic track twists[5] before the point of derailment
- the high, but within limits, centre of gravity of the loaded log wagon.

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[1] The national train control centre housed in the Wellington Railway Station, where train movements and track occupations are authorised by train controllers.
[2] A person qualified to carry out a full terminal brake test – a pre-departure inspection above and below all the wagon decks while a train is stationary – before issuing a certificate to the driver as confirmation that the train is safe to run to its destination.
[3] The downward force on an individual wheel, which can vary as a wagon travels along a track. When the vertical load is low compared to the lateral force, the wheel can climb the rail, potentially leading to a derailment.
[4] A metal frame equipped with twin wheelsets and able to rotate freely, used in pairs under rail vehicles to improve ride quality and better distribute forces to the track.
[5] Variations in cant (the height of one rail relative to another) over a base length of four metres.

## What we can learn

1.8. The Commission identified a **safety issue** where there was no procedure for identifying, evaluating and rectifying track twists of a repetitive cyclic nature. As such, the Commission **recommended** that the Chief Executive of KiwiRail Holdings Limited identify cyclic track conditions on the national rail network and develop a standard that prioritises actions to be taken in order to reduce the likelihood of a derailment.

1.9. Planned and preventive maintenance is a key safety requirement for any transport-related operation.

1.10. A train driver must keep the train under control at all times.

## Who may benefit

1.11. Rail operators may benefit from the key lessons of this inquiry.

# 2 Factual information

## Narrative

2.1. On Thursday 4 April 2019, Train 626, an express freight train, was travelling north from Palmerston North to Napier. The 638-metre (m) long train consisted of two DL-class locomotives hauling 37 loaded wagons, of which the rear 21 wagons carried logs.

2.2. The train had been made up in the Palmerston North freight yard, and its inspection and terminal brake test[6] were underway when the train driver booked on for work at about 2130, approximately 45 minutes before the scheduled start time for the shift. The driver picked up the train documentation[7] and talked to the team leader before boarding and checking the locomotive.

2.3. The driver set up the 'Driver Advisory System (DAS)'[8] then radioed the train examiner at 2145:06[9] to confirm that the train was "all set to go". The train examiner moved to a safe place ahead of the lead locomotive before the train movement started about 10 seconds later. Because of the imminent arrival of a southbound train from the North Island Main Trunk line onto the Branch Main line, the train controller routed the train from the yard onto the Palmerston North-Gisborne line via the north arrival/departure road and number 29 crossover points (see Figure 2).

2.4. The train was travelling at 22 kilometres per hour (km/h) when the train examiner radioed the driver to say that the complete train had passed and the terminal roll-by train inspection[10] was complete, and there were no issues with the train. At the end of the radio communication the driver applied additional locomotive power by moving the throttle handle from power setting notch one to notch three of the eight power-setting notches available.

2.5. A few seconds later the train controller authorised the train to traverse number 29 crossover points by changing the indication on Signal 28RC/30RB (see Figure 2) to 'proceed', and changing the setting of the crossover points from normal to reverse. Although the train was nearly 900 m from the signal at that time, the driver saw the signal aspect change to green then applied more power by moving the throttle control from notch three to notch four.

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[6] A terminal brake test must be carried out when any locomotive hauled train is made up or any wagon added to a train. The test involves checking both sides of each wagon on the train to ensure the braking system is connected correctly and functioning in both application and release.

[7] Documentation that includes speed restriction advice for the route, train work orders, details of locomotive numbers, a list of wagons in standing order, the train-end monitor number, train weight and length graphs and the train inspection certificate.

[8] A computer touch-screen mounted in the locomotive cab that is connected to the locomotive power supply, global positioning system and cellular antennae. It provides a visual output of topographical and network data along with suggested speeds and operating modes.

[9] Times and speeds relating to the train operation have been downloaded from the locomotive's event recorder.

[10] An inspection intended to detect rail vehicle irregularities that are not so apparent when the vehicle is stationary. Potential irregularities include wheels derailed during the loading process, loose backing rings or hot bearings, skids or flat spots on wheels, and dragging equipment.

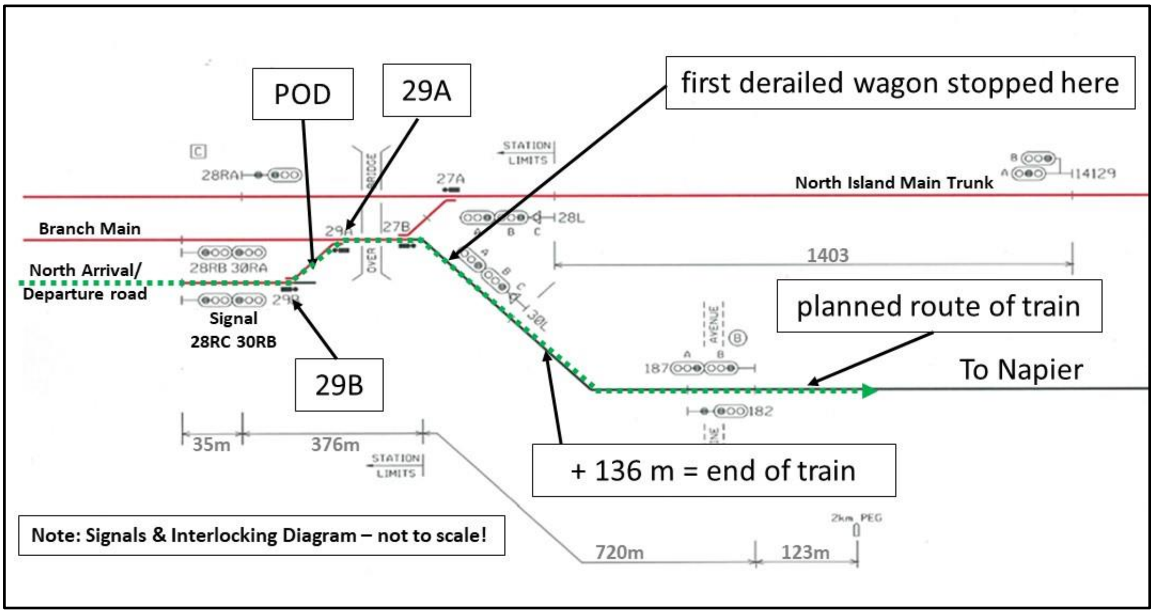


**Figure 2: Planned route for the freight train**

2.6. The train was travelling at the maximum authorised line speed of 25 km/h when the lead locomotive entered the crossover points. At about the same time the driver applied more power by selecting power notch five while the train continued to descend a 1-in-120 gradient.

2.7. The downloaded data from the train's event recorder[11] showed the train speed had increased to 32 km/h when there was a sudden loss of brake pipe pressure further back on the train. The train brakes were applied automatically after the train parted. The driver moved the power control handle back to idle before the train movement stopped at 2152:07. The train's vigilance system[12] detected the sudden loss of brake pipe pressure and initiated an emergency radio call to inform train control.

2.8. Once the train had come to a stop, the driver radioed train control and reported that the train had parted. The train controller told the driver to stay inside the locomotive cab because the traction overhead power line had been brought down near the Railway Road overbridge (see Figure 3). The driver radioed the train examiner and told them that the train had derailed. The driver stayed in the locomotive cab for nearly two hours until traction staff confirmed that the traction overhead power line had been earthed and isolated. A relief driver then arrived to take the front portion of the train on to Napier.

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[11] A device that continuously captures and stores train systems' data. The data stored typically includes location, speed, brake pressure, dynamic brake, whistle activation, vigilance activation and cancellation. The data is used to evaluate incidents and accidents.

[12] A system fitted to locomotives for the protection of crew. The system can carry out a number of functions, including applying the brakes automatically when a train separates.


**Figure 3: Derailed wagons (photograph provided by KiwiRail)**

## *Site examination*

2.9. The point of derailment[13] (POD) was on the outer rail of the rail for 29B crossover points in the direction of travel (see Figure 4).

2.10. The 29B set of points had been laid in 1984, using heavyweight rail fixed to treated *Pinus radiata* sleepers with standard fastenings. The timber sleepers and fastenings were in fair condition, with signs of some sleeper deterioration.

2.11. A witness mark[14] on the rail indicated that the leading bogie of wagon UKN143, 28 wagons behind the locomotives, climbed the right-hand-side curved rail, in the direction of travel, and dropped into the ballast on the outside of the rail. The derailed wagon was dragged through two more sets of points before it came to rest on its side about 155 m past the POD. During the derailment sequence, the three wagons immediately behind wagon UKN143 also derailed (see Figure 5). There was a separation of about 136 metres between the last wagon of the front portion of the train and wagon UKN143.

[13] The exact location where the first wheel flange loses guidance from the rail.
[14] A physical mark that is made when a wheel flange climbs up and across a railhead (the bulbous upper part of a rail section).


**Figure 4: 29B set of points**


**Figure 5: Derailed wagons**

## Track inspections

2.12. Track inspections are carried out to ensure a track is safe for the passage of rail vehicles at the authorised line speed until the next scheduled inspection. Elements of the multi-tiered inspection regime for an arrival/departure road are carried out at defined intervals that include:

- a visual and detailed inspection, either by foot or from a slow-moving hi-rail vehicle, every 13 weeks
- a track evaluation car[15] run annually to measure, record and analyse defined geometric parameters such as cant[16], cyclic lines[17], gauge[18], line[19], top[20] and twist
- a detailed engineering inspection of the track asset condition annually.

2.13. KiwiRail had no record to show that it had inspected the north arrival/departure road at 13-week intervals. The most recent recorded combined visual/detailed track inspection of the north arrival/departure road had been carried out in April 2018, nearly 12 months before the derailment. The work order created from that inspection had required the tightening of loose bolts on 29B set of points. The service request had been reported closed on 28 June 2018. There were no other open service requests for the set of 29B points at the time of the derailment.

2.14. The track evaluation car had last recorded the north arrival/departure road on 16 August 2018. Three maintenance work orders within the 29B set of points had been created following that recording, including two line exceedances and a 20-millimetre (mm) track twist on approach to the set of points.

2.15. The KiwiRail Holdings Limited (KiwiRail) Track Geometry Standard T-ST-AM-5120 required these exceedances to be fixed within six months. The three work orders had not been reported closed at the time of the derailment.

## Wagon UKN143

2.16. The fleet of six UKN-class wagons had been operating on the rail network since 2011. The wagons are permitted to carry three bundles of logs weighing up to 11 tonnes each. The wagon class is fitted with Type 14 bogies and restricted to a maximum gross laden weight of 55 tonnes. The distance between bogie centres is 12.192 m.

2.17. Wagon UKN143 had standard bogies that were commonly used on freight wagons around the world. The three main pieces of the bogie are one bolster (see Figure 6) and two side frames. The bolster is supported by two sets of two inner and outer coil springs at each end. The coil springs provide the vertical support and are the primary suspension.

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[15] The track evaluation car uses a system with sensors to measure the track geometry, and computer software to continually analyse the measurements. The system produces a real-time exception report that identifies location, type and priority wherever follow-up maintenance is required.

[16] The height of one rail relative to another.

[17] Alignment faults that are repeated at similar spacing.

[18] The distance between the inside faces of the railheads, measured 16 millimetres below the running surface.

[19] The horizontal or lateral position of the track measured on both rails.

[20] The longitudinal level of the running surfaces of the rail measured on both rails.

Bolsters also have small-diameter wedge springs fitted to reduce the oscillation (movement back and forth in a regular rhythm) of the moving wagon (see Figure 6).

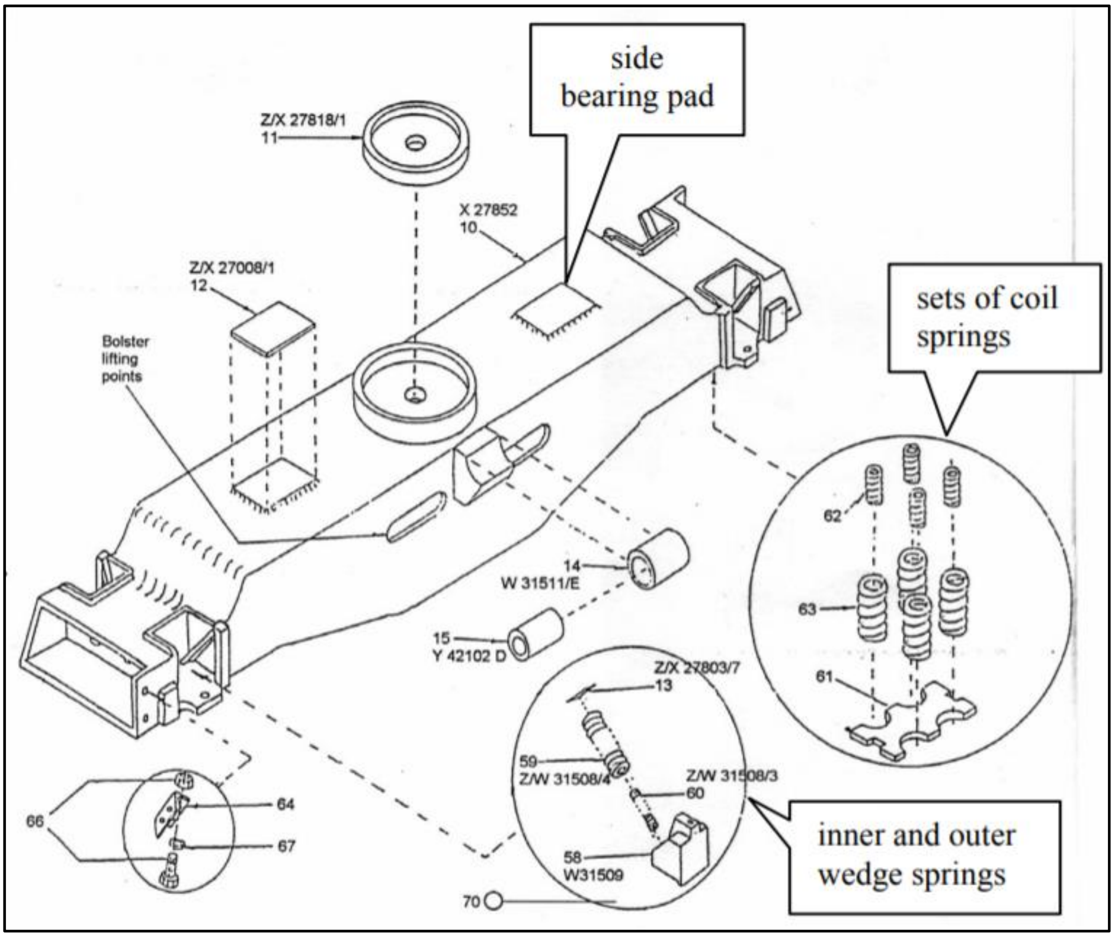


**Figure 6: Diagram of bogie bolster**

2.18. The wagon was carrying three bundles of logs with a declared nett weight of 29.28 tonnes for a gross laden weight of about 49 tonnes. The wagon had not passed over a weighbridge after it was loaded to confirm its actual gross weight. However, KiwiRail records showed the loading company's declared weights had in the past been consistent with weighbridge readings.

2.19. The KiwiRail Mechanical Code M2000 requires all freight wagons to be inspected at the following intervals:

- a pre-departure check
- a B-Check, whenever two or more brake blocks are changed
- a C-Check, every two years
- a detailed inspection of the body-mounted brake cylinders, every 10 years
- a full overhaul bogie check when the ride control element (wedge height) reaches the condemning limit of 39 mm, normally about every 10 years.

2.20. A qualified person carries out the pre-departure check immediately before a train departs from a terminal. It covers a full terminal brake test and a check of the condition of brake hoses, confirms that all handbrakes are released and secure, observes draw-gear connections, wheels, springs, loose/hanging brake equipment, loads, and the end-of-train marker is working. The person carrying out the check then signs a train inspection certificate to confirm that the train is in a proper condition for safe running. The train certificate is attached to the train work orders and remains in the locomotive cab until the train reaches its destination.

2.21. The two-yearly C-Check is to ensure that all maintenance has been carried out to specification so that a wagon can be released in a reliable, fit-for-service condition. The check includes a full structural inspection of the wagon and a detailed examination of the couplers[21], braking system, wheelsets[22] and bogies.

2.22. The most recent C-Check on wagon UKN143 had occurred at Palmerston North during March 2019. The Mechanical Code requires float[23] readings for a wagon (see Figure 7) to be the same on each side of the wagon and when added together to be within the range of 6-10 mm at the handbrake end and 12-16 mm at the non-handbrake end.

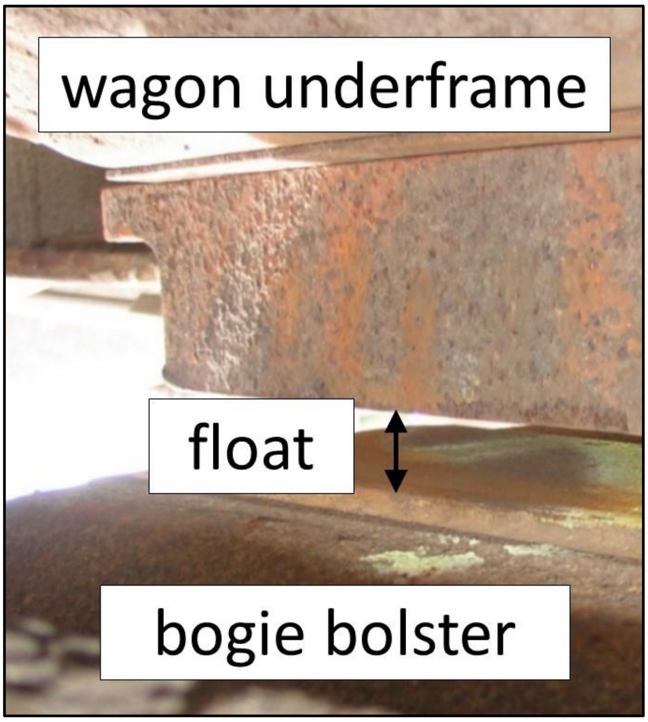


**Figure 7: Measurement of side bearer float**

2.23. Float measurements recorded at the handbrake end were 5 mm on the A-side and 5 mm on the B-side, making a total of 10 mm, which was at the upper limit. The measurements recorded for the non-handbrake end were 5 mm on the A-side and 8 mm on the B-side. While the float of 13 mm at the non-handbrake end of the wagon was within tolerance limits, the respective measurements were not the same.

2.24. During the C-Check, wedge heights on the leading bogie were recorded as 30 mm on the A-side and 31 mm on the B-side (see Figure 13 in Appendix 2). Wedge heights on the trailing bogie were recorded as 30 mm on the A-side and 29 mm on the B-side.

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[21] A device used to connect wagons for haulage purposes.
[22] A wheelset is two rail wheels mounted on a joining axle.
[23] The clearance between the float block on a bogie bolster and the corresponding block on the wagon underframe.

2.25. A team leader had completed the final sign-off for the wagon's C-Check on 11 March 2019. The sign-off confirmed that all items on the check sheet had been inspected, recorded and signed and that all items complied with Mechanical Code requirements.

2.26. The team leader had identified significant surface defects on wheelset 4 and subsequently arranged a wheelset change-out. All four wheelsets on the wagon had been replaced with new wheels on a mix of new and refurbished axles before the wagon was returned to service on 29 March 2019, a week before the derailment.

2.27. The leading bogie from wagon UKN143 had had its most recent full overhaul check in March 2007, 12 years before the derailment.

## *Key personnel*

2.28. The train driver had operated a hi-rail excavator for two years before starting the formal train driver training programme in November 2012. Full and final certification for train driver duties had been achieved on 3 March 2014. The train driver had worked out of the Palmerston North depot during his on-the-job practical training and since certification. The driver's safety observations and certification were current for the role.

2.29. The driver's mandatory post-accident drug and alcohol test returned a negative result.

## *Previous similar occurrences investigated by the Commission*

### Inquiry RO-2003-114

2.30. On Friday 21 November 2003, express freight Train 220 derailed near Shannon on the North Island Main Trunk line.

2.31. Post-derailment track measurements identified opposing cyclic track twists, within acceptable maintenance tolerance limits, before the POD.

2.32. An examination of the derailed wagon identified worn friction wedges[24] but they were within Mechanical Code limits. The wagon float at the handbrake end was found to be 2 mm outside the code limit, not enough on its own to cause the derailment.

### Inquiry RO-2005-103

2.33. On Thursday 20 January 2005, express freight Train 237 derailed near Hunterville on the North Island Main Trunk line.

2.34. Post-derailment track measurements identified two contributory track conditions, previously identified by the track evaluation car but not repaired. Individually, the track exceedances would not have caused the derailment.

2.35. An examination of the derailed wagon found two inner wedge springs and one outer spring shorter than the minimum length required for reuse.

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[24] Wedges perform a similar function to shock absorbers in a car by controlling the bounce when a wagon passes over undulating track. They also hold the bolster perpendicular to the side frames to provide better steering and a longer wheel life.

2.36. The Commission made recommendations to the Chief Executives of Ontrack and Toll Rail (predecessors of KiwiRail) to critically review current track and Mechanical Code standards and maintenance tolerances to ensure they were compatible and minimised the potential for derailments caused by dynamic interaction[25] (009/05 and 010/05). Codes and standards for the track and wagons have since been changed and the status of the recommendations changed to 'closed acceptable'.

### Inquiry RO-2007-115

2.37. On Wednesday 7 November 2007, express freight Train 533 derailed on the Stratford-Ōkahukura line.

2.38. The Commission was unable to determine conclusively the cause of the derailment. However, both the track condition and the condition of the derailed wagon were at or near the code tolerance limits and were considered to be contributory factors.

2.39. The Commission made a recommendation to the Chief Executive of the NZ Transport Agency to address the issue of the current track and mechanical standards and maintenance tolerances not being compatible, and there remained a high risk of derailments caused by dynamic interaction (029/09). In view of the actions taken in 2.36 above, the status of this recommendation has been changed to 'closed acceptable'.

[25] Dynamic interaction occurs when the track geometry, wagon condition, wagon loading and train speed are individually within tolerance limits, or marginally in excess, but not to an extent that each variation on its own is sufficient to be a prime cause of a derailment. However, when in combination these conditions can result in a derailment.

# 3 Analysis

## Introduction

3.1. While the overall likelihood of a freight train derailment is low, a derailment can potentially cause significant damage and injury. In this accident the derailed wagons ripped up a section of track and points, damaged traction masts and brought down an overhead traction line while passing under an overbridge supporting a major roadway.

3.2. The first wagon to derail was a UKN-class wagon converted from a general-purpose UK-class, container-carrying, flat-deck wagon with standard Type 14 bogies. The UK-class wagons had been assembled in New Zealand from kits supplied from Japan between 1971 and 1981.

3.3. Wagons fitted with Type 14 bogies featured more frequently in the KiwiRail derailment statistics. For the year ending 30 June 2019, wagons fitted with Type 14 bogies ran 40% of the total track kilometres yet featured in eight of the 10 (80%) derailments on the rail network. The Commission found no evidence to suggest that the Type 14 bogies' design contributed to the derailment.

3.4. The following analysis discusses the safety factors that contributed to the derailment and the safety factors that were considered but found to be non-contributory.

## Safety factors contributing to the derailment

3.5. The movement of any type of wagon at speed along a track causes a range of motions and oscillations, of which some are undesirable. The amplitude and effect depend on many factors including the condition of the track, the train speed, the wagon design, the condition of the wagon suspension systems, and the height of the centre of gravity of a loaded wagon.

3.6. Often, oscillations result from track irregularities, which can be accentuated on wagons with excessive float tolerances and/or broken suspension springs.

3.7. In respect of this derailment, the Commission found there was an insufficient vertical load on the leading bogie of log-carrying wagon UKN143 to prevent it climbing the outer (right-hand) curved rail on the 29B set of points (see Figure 8).

3.8. The POD was confirmed by a light, 1 m long wheel flange witness mark across the railhead. The absence of scuff markings on the inside of the rail indicated that the wheel lifted suddenly onto the railhead before dropping on the outside of the rail.

3.9. The Commission found that no single factor led to this derailment. Instead, it is very likely that a combination of factors contributed to the wheel climb that resulted in the derailment:

- the track condition and its alignment
- the train travelling at nearly 36% above the authorised line speed, which was close to its critical rocking speed[26]

[26] The speed at the boundary of stable and unstable bogie running.

- the condition of the wagon's suspension system and its sensitivity to the track conditions
- the multiple cyclic twists that accentuated the wagon oscillation
- the high, but nevertheless within limits, centre of gravity of the loaded log wagon.

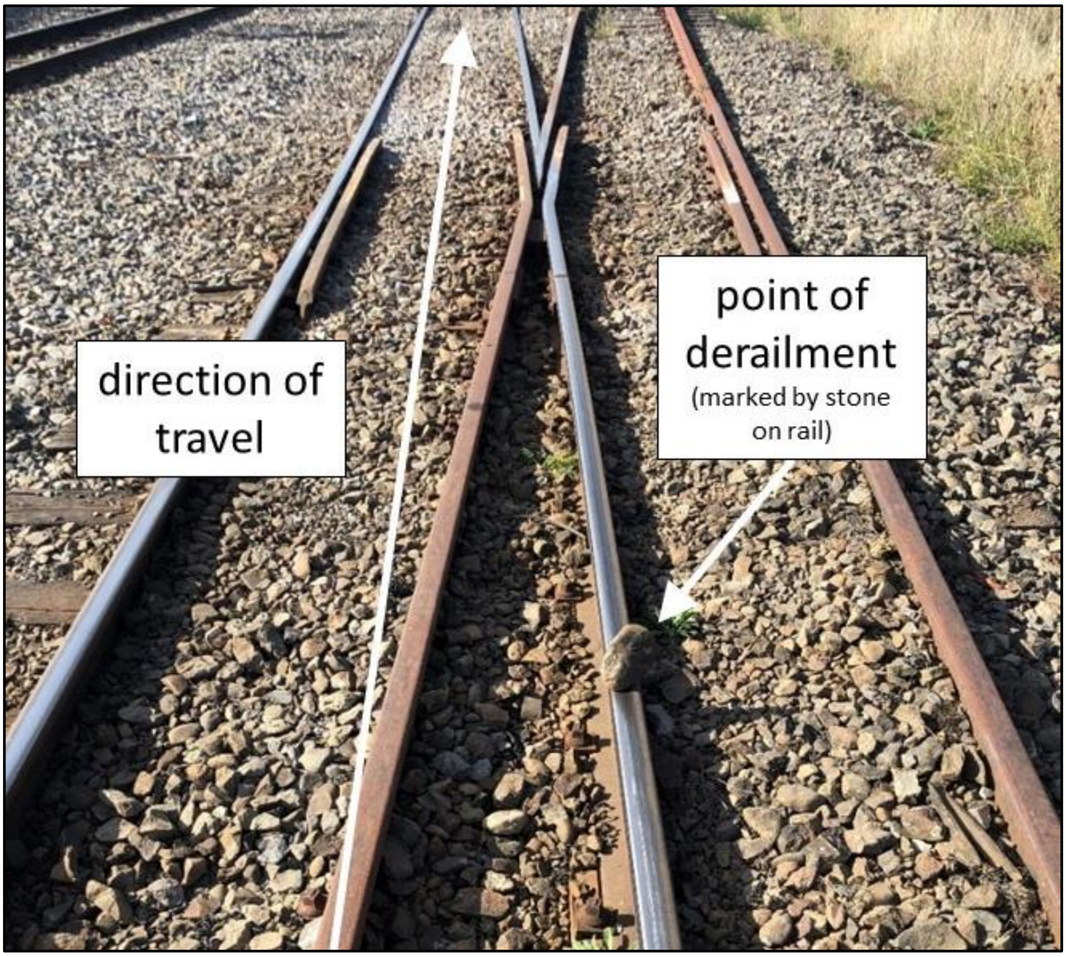


**Figure 8: Point of derailment**

## *The effect of track condition and speed on the derailment*

### Effect of the track condition

***Safety issue: There was no procedure for identifying, evaluating and rectifying track twists of a repetitive cyclic nature.***

3.10. An analysis of the post-derailment manual track measurements showed the following (see Figure 9):

- -20 mm twist, 31 m before the POD
- +8 mm twist, 24 m before the POD
- -18 mm twist, 19 m before the POD
- +7 mm twist, 12 m before the POD
- -18 mm twist, 6 m before the POD
- +14 mm twist, 2 m past the POD
- -17 mm twist, 6 m past the POD

- +21 mm twist, 16 m past the POD.

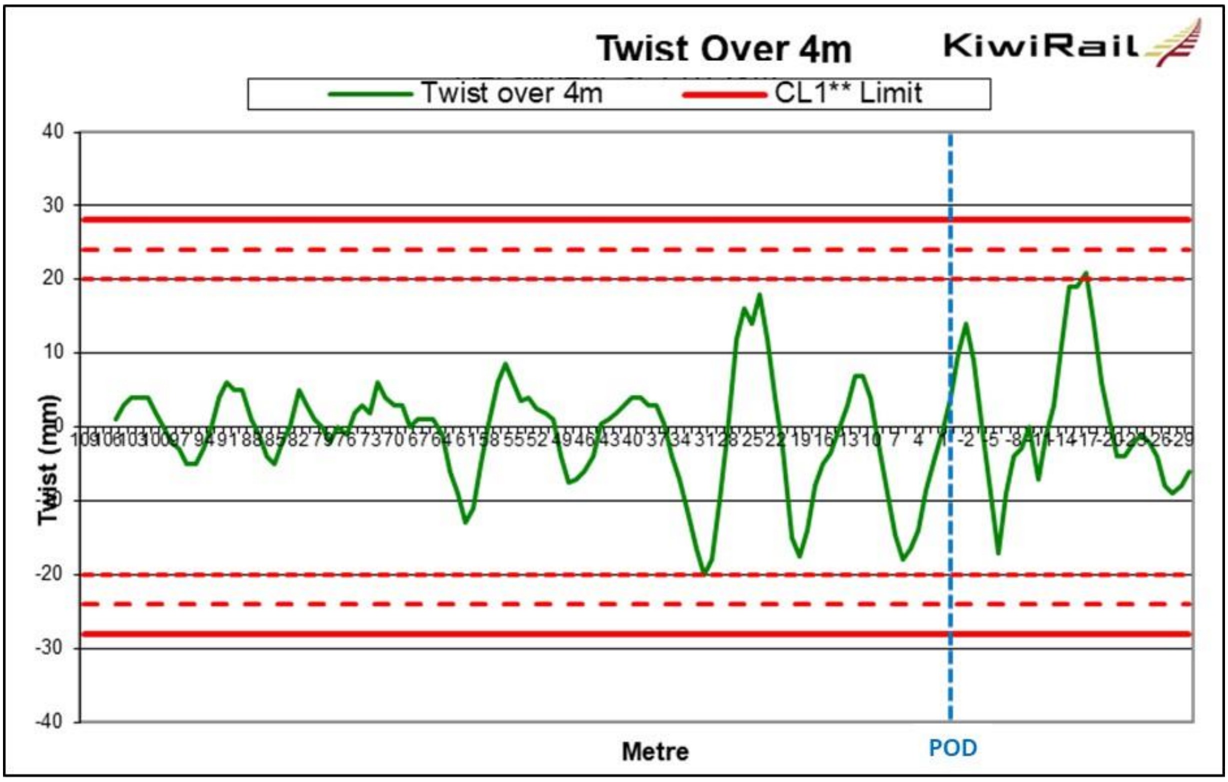


**Figure 9: Output graph of twists over 4 m (provided by KiwiRail)**

3.11. The KiwiRail Standard T-ST-AM-5120, Track Geometry, effective since 3 March 2017, categorises manually found twists within a yard environment of 17-19 mm as Priority 4, requiring the condition to be fixed within 26 weeks. Twists of 20-23 mm are deemed to be Priority 3, requiring the repair to be completed within four weeks. The standard refers to individual track twists but makes no reference to the effects of cyclic twists.

3.12. It was unlikely that each twist would have been identified during a scheduled visual inspection. The post-derailment track measure-up showed that the value of each twist did not meet the threshold for immediate repair action. However, the twists' combined effects and contribution to wagon oscillation were not analysed. Currently there is no procedure for identifying, evaluating and rectifying track twists of a repetitive cyclic nature that promote the unintended oscillation of wagons, potentially resulting in a derailment. A recommendation has been made to the Chief Executive of KiwiRail to address this issue.

### Effect of train speed

3.13. Safe operation through a set of points requires a driver to comply with the authorised line speed in order to reduce the likelihood of wheel climb. Although the set of crossover points was designed for a maximum of 40 km/h running, these points were sited within Palmerston North station limits, where train speeds were permanently restricted to a maximum 25 km/h. The set of crossover points within the yard environment was maintained to standards appropriate for train speeds of 25 km/h.

3.14. The driver was starting their third consecutive identical shift departing from Palmerston North Yard with Train 626. Although the maximum authorised line speed was 25 km/h for all three departures, the routes were not the same. For the first two departures the train was routed along the Branch Main line, which did not require it to pass over number 29 crossover points.

3.15. On the third departure, just prior to the derailment, the train had been routed along the arrival and departure road, which required it to pass over number 29 points (see Figure 2). The train was travelling at the maximum authorised line speed when the lead locomotive passed over the crossover points. At about the same time, the driver applied more power. A combination of a gentle down gradient and the additional power allowed the train speed to increase to 34 km/h when the first wagon derailed.

3.16. Train drivers who are trained and certified in the use of 'DAS' are required to use the system on all trains where the routes have been verified and the locomotives are equipped with fully functional units. The system provides a visual output of topographical and network data and provides drivers with information that includes the length of a train, the suggested speed and the operating mode. Speed restrictions are updated automatically into the DAS server.

3.17. The KiwiRail Rail Operating Code required the driver to use the locomotive speedometer at all times to determine train speed, as the DAS global positioning system had not been approved. At the time of the derailment the locomotive's speedometer was displaying a 1% error. The driver had not ensured that the rear of the train was clear of station limits before the train speed could exceed 25 km/h. In this case the train was travelling at 9 km/h or 36% above the maximum authorised line speed when it derailed, still within station limits.

### Combined effect of track and speed

3.18. In most cases wagon oscillation is minimal at speeds below 50 km/h. However, a combination of track irregularities and the natural roll frequency of a loaded wagon can result in unstable running conditions and wagon oscillation.

3.19. Although the cyclic twists referred to in 3.10 were individually at the lower end of the allowed tolerances, they were evenly spaced at 12 m, corresponding to the distance between bogie centres. The combined effect of the train speed and the natural roll frequency of the wagon was at the boundary of instability and likely produced a low speed 'rock and roll' motion.

3.20. On straight track, the oscillating motion is unlikely to result in a derailment, as there is no lateral force applied when the wheel load is reduced. However, on this occasion the applied lateral force increased as the wagon traversed the curved rail on the set of points. At the same time, the oscillating motion reduced the wheel load on the outside rail, which caused the wheel to lift onto and then pass over the railhead.

## *The post-derailment condition of wagon UKN143*

3.21. All rail wagons have some form of damping to minimise the amount of bounce associated with external influences such as track condition. The bogies of the UKN-class wagon use a suspension arrangement whereby the vertical movement is damped by friction. The key components are springs and friction wedges.

3.22. The KiwiRail Mechanical Code requires all wagons that derail, along with the wagons immediately in front of and behind the derailed wagons, to be examined and measurements recorded. The post-derailment recorded measurements for wagon UKN143 can be found in Appendix 2. The post-derailment examination showed that the float on both bogies exceeded the allowable range and that there was a significant difference in values on either side of the wagon. Float above the prescribed values increases the possibility of a derailment.

## *Post-derailment examination of wagon UKN143 bogies*

3.23. Following the derailment, the bogies were transported to KiwiRail's Hutt Workshops for further examination (see Figure 10). On 9 May 2019 the bogies were dismantled, their components were examined, and critical measurements of the components were recorded.

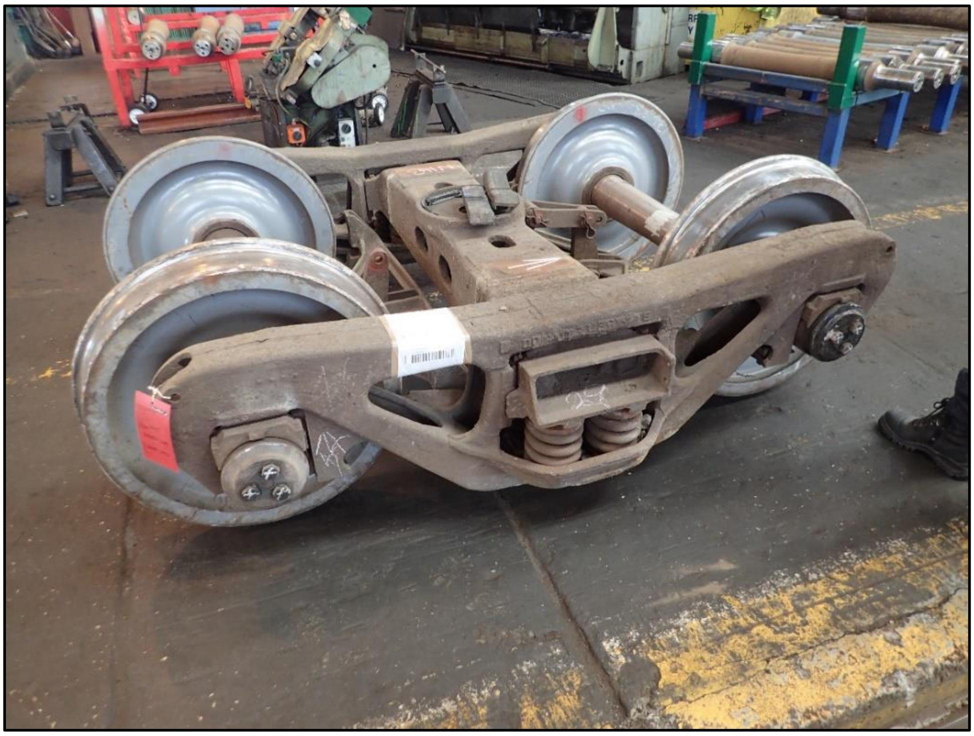

**Figure 10: Leading bogie from UKN143 before examination**

3.24. The centre bowl liner on the leading bogie showed significant wear and distortion (see Figure 11). The trailing bogie was relatively undamaged. It was likely that the damage to the bowl liner on the leading bogie was sustained during the derailment sequence.

3.25. Further examination of the leading bogie revealed two broken inner cylindrical helical springs on the right-hand side in the direction of travel. Both failures had occurred at similar heights, about one turn from the top (see Figure 12). The significant levels of corrosion on the fracture surfaces indicated that the springs had very likely fractured before the derailment.

3.26. A similar fracture of an inner spring had also occurred on the right-hand side of the trailing bogie.

3.27. The two broken inner springs on the leading bogie would have reduced the effectiveness of its suspension stiffness by about 8.5%. The reduced spring performance and its detrimental effects on the suspension would have likely contributed to the wagon's inability to recover from an oscillation and, in doing so, likely contributed to the derailment.

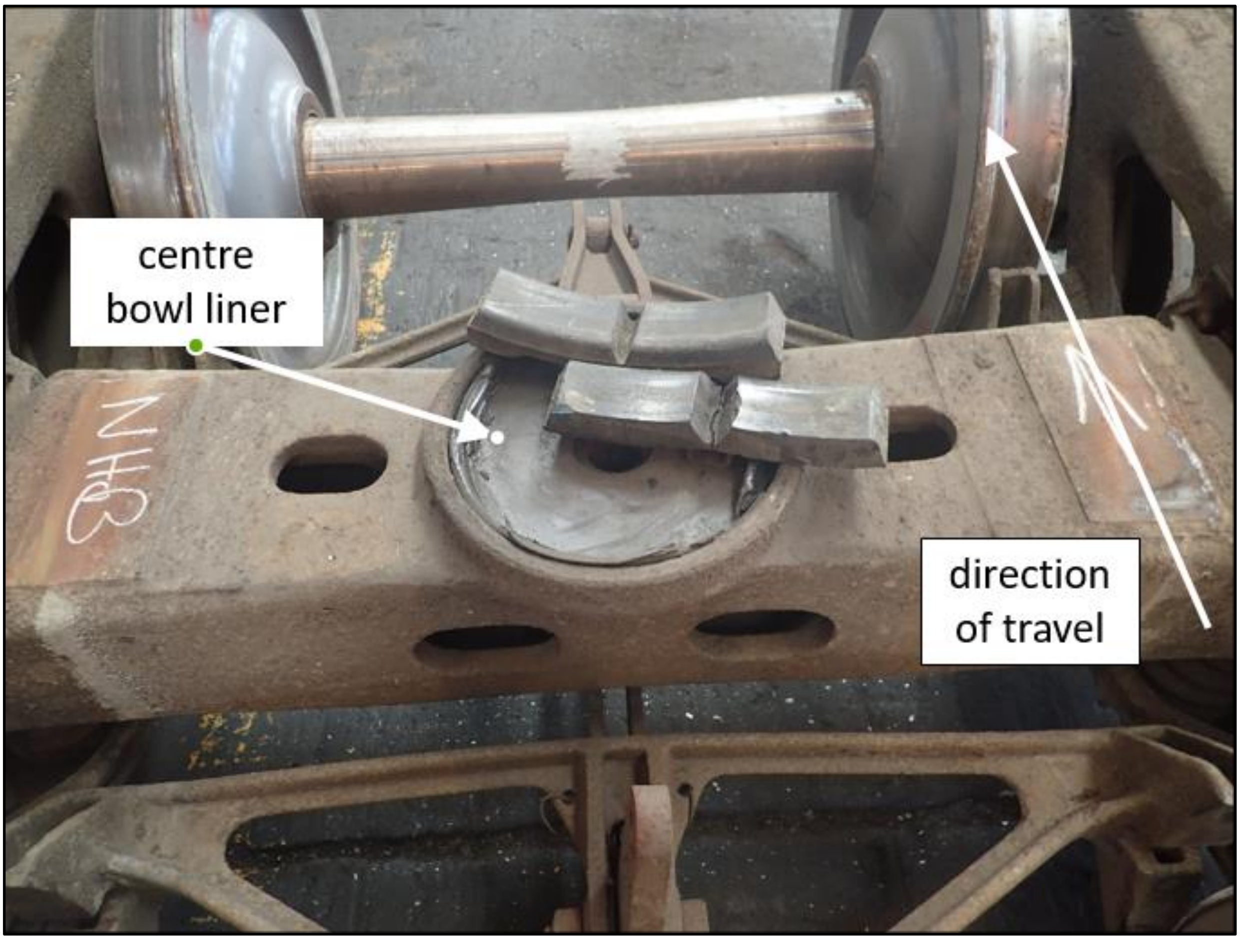


**Figure 11: Centre bowl liner on leading bogie**

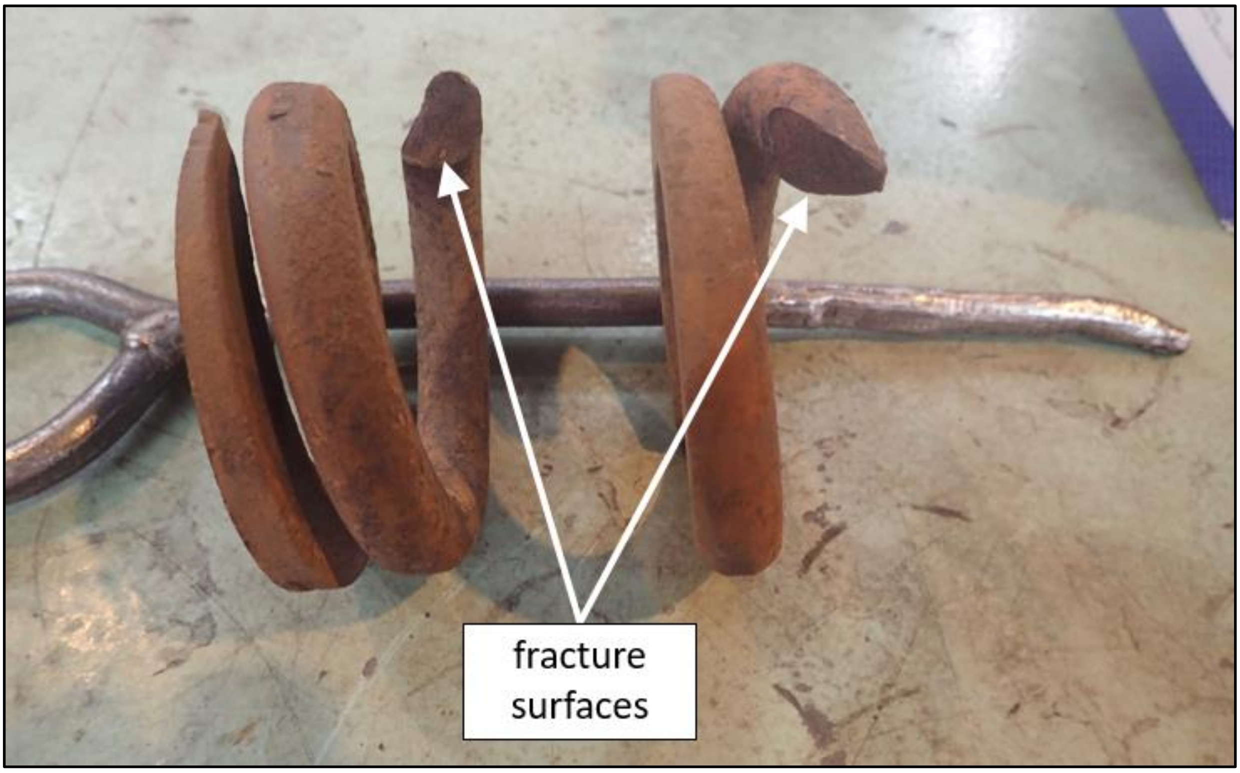


**Figure 12: Fractured inner springs**

## *Wagon inspection requirements*

3.28. The bogies from UKN143 were subject to routine maintenance and inspections, of which one was a C-Check, which was performed every two years. The C-Check inspection was less rigorous than a full overhaul. It included a visual inspection of the springs but did not include a complete breakdown of the bogie or any spring measurements. A full overhaul was only required when the C-Check identified wedge height measurements above 39 mm.

3.29. The full bogie overhaul required a full breakdown of the bogie and an examination and measurement of the column liners, checking that the paired side frames were of the same length, and checking that no parts of the springs were broken or cracked and each spring passed the minimum-length test.

3.30. Records provided by KiwiRail showed that the leading bogie from wagon UKN143 had last undergone a full overhaul in March 2007. The wedge height measurements from the most recent C-Check were between 29 mm and 31 mm. This showed that the ride-control elements were at about mid-life, with an expected five more years of operation before the next full bogie overhaul was required.

## *Centre of gravity of the loaded wagon*

3.31. A key objective when loading wagons is to maximise the load stability by keeping the centre of gravity as close to the wagon deck as possible. The higher the centre of gravity of a loaded log wagon, the greater the destabilising effect from the lateral force created when the wagon follows a curve such as that found at a set of points. The destabilising effect increases the chance of the wagon starting to oscillate and thereby increases the likelihood of a derailment.

3.32. The National Rail System Standard, Section 6, Engineering Interoperability Standards, Clause 7.4 stated in part:

> The centre of gravity should be as low as practicable.
>
> The centre of gravity height for any vehicle loading condition must not exceed 2.0m above rail level for bogie vehicles.

3.33. Because the centre of gravity of a loaded log wagon can be relatively high, it can have the effect of lowering the speed at which a wagon can derail.

3.34. The calculated combined centre of gravity for wagon UKN143, the log cradles and its declared load was about 1.75 m above rail level, within the maximum allowable 2.0 m. While within the allowable limits, the relatively high centre of gravity of wagon UKN143 was about as likely as not to have had a destabilising effect, which assisted its ability to climb the rail and lift onto and then pass over the railhead.

## *Non-contributing factors*

### Loading

3.35. The KiwiRail Freight Handling Code set the maximum load capacity for UKN-class wagons at 33.0 tonnes. Although logs are generally of variable low density, it is unlikely that load capacity is exceeded on this class of wagon. In this case, the declared weight of 29.28 tonnes was 88.7% of the maximum permitted load. However, the distribution of the load was unknown because the loaded wagon had not passed over a weighbridge.

3.36. The Commission found that the log-loading process and nett weight of the logs were unlikely to be contributory to the derailment.

### Fatigue

3.37. Fatigue is generally defined as a physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase and/or workload that can impair a person's alertness and ability to perform safety-related operational duties[27].

3.38. It was the train driver's practice to sleep soon after finishing a night shift. In this case, the driver had finished the previous night's six-hour 10-minute shift and was asleep shortly after 0400. The driver was expecting visitors later that morning so woke shortly after 0800. The driver recalled having a two-hour sleep later that day and waking at 1700. The driver had an evening meal at home before making the 30-minute drive to work, arriving at about 2130. Therefore, the driver had been awake for about five hours prior to the derailment.

3.39. The driver self-reported as 'fit for duty' on arrival at work and the derailment occurred within the Palmerston North station limits about 20 minutes after the driver had booked on for work and at a time when the workload was not overly high.

3.40. At interview, the driver confirmed feeling alert but may have been 'a bit lagged' due to not having their usual sleep.

---

[27] ICAO Doc 9966 – Manual for the Oversight of Fatigue Management Approaches.

3.41. The driver's quantity of sleep was less than normal and this was the driver's third consecutive night shift; both increased the potential for them to be experiencing the effects of fatigue. However, the low workload at the time of and prior to the derailment, and the short time on shift, countered this potential. Therefore, the Commission was unable to determine if fatigue contributed to the driver's actions.

# 4 Findings

4.1. There was insufficient vertical load on the leading bogie of wagon UKN143 to prevent it climbing onto and then over the right-hand rail when viewed in the direction of travel.

4.2. No single factor caused the derailment. It was a combination of cyclic twists in the track, ineffective wagon damping, train speed, and the relatively high centre of gravity of the log wagon.

4.3. The combined effect of the train travelling at about 36% above the maximum authorised line speed and the natural roll frequency of the wagon was at the boundary of instability and likely accentuated harmonic oscillations.

4.4. A combination of three broken springs and out-of-code float readings resulted in wagon UKN143 having ineffective damping on its leading bogie.

4.5. More than 12 years had passed since a full overhaul check had taken place on wagon UKN143.

4.6. Currently there is no procedure for identifying, evaluating and rectifying track twists of a repetitive cyclic nature.

# 5 Safety issues and remedial actions

## General

5.1. Safety issues are an output from the Commission's analysis. They typically describe a system problem that has the potential to adversely affect future operations on a wide scale.

5.2. Safety issues may be addressed by safety actions taken by a participant, otherwise the Commission may issue a recommendation to address the issue.

## Measurement of cyclic track conditions

5.3. The Commission found that recent wheel-climb derailments on the network had had a similar combination of contributing factors, including but not limited to:

- track parameters at the low end of the priority action requirement
- cyclic track twists approaching the POD
- degraded wagon damping performance
- train speeds in the range of 25 to 35 km/h.

5.4. The Commission has therefore made a recommendation to KiwiRail to identify the extent of cyclic track conditions on the rail network that could potentially contribute to future derailments, and to develop timescales for inspections and safety actions in order to reduce the likelihood of future derailments.

## Other safety action

5.5. Participants may take safety actions to address issues that would not normally result in the Commission issuing a recommendation.

5.6. The following safety action has been taken:

- in response to the accident, KiwiRail issued a notice, dated 1 August 2019, reinforcing the need for train drivers and remote-control operators to adhere to maximum authorised line speeds until the complete trains had cleared the sections of track to which those speeds applied. The reason was that the end-of-train speed is critical, and that any over speed, particularly at a set of points, will result in wagons becoming unstable and increase the risk of a derailment (see Appendix 1)
- on 4 February 2020, KiwiRail stated that the following work was being undertaken to prevent future derailments:
  - the adoption of AS7509, the rolling stock dynamic performance standard. This specifically includes evaluations of the design against cyclic track defects
  - Type 14 bogie fleet being retired as new wagons are introduced. The bogies on the new wagons have higher, load-proportional damping by design and are laterally stiffer due to cross-bracing and are showing a much lower derailment rate than the Type 14
  - prohibiting the re-use of inner springs on Type 14 bogies at overhaul. However, given that the number of Type 14 bogies is reducing and the lifespan of a bogie means many will be retired before reaching overhaul, this is going to have a very small impact on the risk.

# 6 Recommendations

## General

6.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector.

6.2. In the interests of transport safety, it is important that recommendations are implemented without delay to help prevent similar accidents or incidents occurring in the future.

6.3. In this case, a recommendation has been issued to the Chief Executive of KiwiRail.

## New recommendations

6.4. **On 6 April 2020 the Commission recommended that the Chief Executive of KiwiRail identify cyclic track conditions on the national rail network and develop a standard that prioritises actions to be taken in order to reduce the likelihood of a derailment. (003/20)**

On 20 April 2020, the Chief Executive of KiwiRail replied:

> KiwiRail accepts the recommendation as presented, noting that there is already a cyclic line exceedance that is detected by the Track Evaluation Car for action by site staff as per Track Standard T-ST-AM-5120 Track Geometry.
>
> The same equipment on this vehicle has the potential to detect cyclic top exceedances such as that identified as part of the KiwiRail investigation into the Palmerston North derailment. Further investigation is required to determine if the equipment is suitable, including any modifications that may be required whilst ensuring that any changes to the equipment does not affect its current capability.
>
> Upon determination of the above, a process to develop relevant standards and exceedance levels will be instigated involving third party modelling, site testing, and consultation. It is expected that the conclusion of this work will take approximately 18-24 months.

# 7 Key lessons

7.1. Planned and preventive maintenance is a key safety requirement for any transport-related operation.

7.2. A speed limit is a key risk-control measure that helps to reduce the likelihood and consequences of an incident on the rail network. It is therefore essential that, in order to avoid an unintended consequence, a train driver keeps the train's speed under control at all times.

# 8 Data summary

**Vehicle particulars**

| | |
|---|---|
| Train type and number: | express freight Train 626 consisting of two DL-class locomotives hauling 37 wagons |
| Train length: | 638 metres |
| Train weight: | 1,681 tonnes (including the locomotives) |
| Operator: | KiwiRail Holdings Limited |
| **Date and time** | 4 April 2019 at 2151:37[28] |
| **Location** | 0.912 kilometres[29] Palmerston North-Gisborne line |
| **Operating crew** | one train driver |
| **Injuries** | nil |
| **Damage** | significant damage to the rail infrastructure and rolling stock |

[28] Times in this report are New Zealand Daylight Savings Times (universal co-ordinated time + 13 hours) and are expressed in the 24-hour mode.

[29] The location of the derailment is the distance from a reference point within the Palmerston North Yard.

# 9 Conduct of the inquiry

9.1. On 4 April 2019, the NZ Transport Agency notified the Commission of the occurrence. The Commission subsequently opened an inquiry under section 13(1) of the Transport Accident Investigation Commission Act 1990 (the Act) and appointed an investigator in charge.

9.2. Commission investigators arrived on site early the next day to examine the accident site. An order was issued under section 12(1)(c) and (d) of the Act to protect the site and the derailed wagons. A non-tampering order was placed on the four derailed wagons, and on the wagons directly in front of and behind the derailed wagons.

9.3. The train driver was interviewed by Commission investigators on 10 April 2019.

9.4. The Commission obtained the following records and documents for analysis:

- the data downloaded from the train's event recorder
- the train control diagram
- the signal data
- recordings of the communication between the train controller and the train driver
- the train driver's training records and timesheets
- track inspection and maintenance records
- wagon inspection and maintenance records.

9.5. On 9 May 2019 Commission investigators, with assistance from KiwiRail, methodically stripped down the bogies from the first wagon to derail at KiwiRail's Hutt Workshops.

9.6. On 11 December 2019 the Commission approved a draft report for circulation to three interested persons for their comment.

9.7. Submissions were received from the three interested persons. The Commission considered the submissions and any changes as a result of those submissions have been included in this final report.

9.8. On 2 April 2020 the Commission approved the final report for publication.

# 10 Report information

## Abbreviations

| | |
|---|---|
| Commission | Transport Accident Investigation Commission |
| KiwiRail | KiwiRail Holdings Limited |
| km/h | kilometre(s) per hour |
| m | metre(s) |
| mm | millimetre(s) |
| POD | point of derailment |

## Glossary

| | |
|---|---|
| bogie | a metal frame equipped with twin wheelsets and able to rotate freely used in pairs under rail vehicles to improve ride quality and better distribute forces to the track |
| cant | the height of one rail relative to another |
| coupler | a device used to connect wagons for haulage purposes |
| driver advisory system | a computer touch-screen mounted in the locomotive cab that is connected to the locomotive power supply, global positioning system and cellular antennae. It provides a visual output of topographical and network data along with suggested speeds and operating modes. |
| dynamic interaction | occurs when the track geometry, wagon condition, wagon loading and train speed are individually within tolerance limits, or marginally in excess, but not to an extent that each variation on its own is sufficient to be a prime cause of a derailment. However, when in combination these conditions can result in a derailment |
| float | the clearance between the float block on a bogie bolster and the corresponding block on the wagon underframe |
| friction wedges | wedges that perform a similar function to shock absorbers in a car by controlling the bounce when a wagon passes over undulating track. They also hold the bolster perpendicular to the side frames to provide better steering and longer wheel life |
| point of derailment | the exact location where a first wheel flange loses guidance from the rail |
| terminal brake test | a terminal brake test must be carried out when any locomotive hauled train is made up or any wagon added to a train. The test involves |

| | |
|---|---|
| | checking both sides of each wagon on the train to ensure the braking system is connected correctly and functioning in both application and release |
| track twist | the variation in cant over a base length of four metres |
| train control | the national train control centre housed in the Wellington Railway Station, where train movements and track occupations are authorised by train controllers |
| train event recorder | a device that continuously captures and stores train systems' data. The data stored typically includes location, speed, brake pressure, dynamic brake, whistle activation, vigilance activation and cancellation. The data is used to evaluate incidents and accidents |
| train examiner | a person qualified to carry out a full terminal brake test – a pre-departure inspection above and below all the wagon decks while a train is stationary – before issuing a certificate to the driver as confirmation that the train is safe to run to its destination |
| vertical load | the downward force on an individual wheel, which varies as a wagon travels along a track. When the vertical load is low compared to the lateral force, the wheel could climb the rail, potentially leading to a derailment |
| wheelset | two rail wheels mounted on a joining axle |
| witness mark | a physical mark that is made when a wheel flange climbs up and across the railhead |

# 11 Notes about Commission reports

## Commissioners

| | |
|---|---|
| Chief Commissioner | Jane Meares |
| Deputy Chief Commissioner | Stephen Davies Howard |
| Commissioner | Richard Marchant |
| Commissioner | Paula Rose, QSO |

## Key Commission personnel

| | |
|---|---|
| Chief Executive | Lois Hutchinson |
| Chief Investigator of Accidents | Aaron Holman |
| Investigator in Charge | Peter Miskell |
| General Counsel | Cathryn Bridge |

## Citations and referencing

This final report does not cite information derived from interviews during the Commission's inquiry into the occurrence. Documents provided to the Commission in the course of its investigation that are protected under the Transport Accident Investigation Commission Act are referenced as footnotes only. Publicly available documents referred to during the Commission's inquiry are cited.

## Photographs, diagrams, pictures

The Commission has provided, and owns, the photographs, diagrams and pictures in this report unless otherwise specified.

## Verbal probability expressions

This report uses standard terminology to describe the degree of probability (or likelihood) that an event happened or a condition existed in support of a hypothesis. The expressions are defined in the table below.

| Terminology* | Likelihood | Equivalent terms |
|---|---|---|
| Virtually certain | > 99% probability of occurrence | Almost certain |
| Very likely | > 90% probability | Highly likely, very probable |
| Likely | > 66% probability | Probable |
| About as likely as not | 33% to 66% probability | More or less likely |
| Unlikely | < 33% probability | Improbable |
| Very unlikely | < 10% probability | Highly unlikely |
| Exceptionally unlikely | < 1% probability | |

*Adopted from the Intergovernmental Panel on Climate Change

# Appendix 1: Train driver notice

SAFETY, HEALTH AND ENVIRONMENT

KiwiRail

## Notice

### Turn Out Speeds and the Risk of Derailment

| | | | | | |
|---|---|---|---|---|---|
| Issue No. | [Record Ref] | Issue date: | 1/08/2019 | Originator: | Continuous Improvement |
| IRIS No. | 192944 | | | BU reference: | Continuous Improvement |
| Content endorsed by: | | Soren low | | Related docs: | ROC, RORP |
| Content authorised by: | | John Gousmett | | Job title: | Operations Improvement Manager |

**Background**

Train 626 derailed on the Branch Main Palmerston North,and PNGL Line. Five log wagons derailed fouling the Main and bringing down traction poles and over head lines

**Important information or action to be taken**

Train speed was a contributing factor to a serious derailment. It is critical that operators of rail vehicles do not exceed the maximum speeds anywhere in the rail corridor. The posted speed must be adhered to until the whole of the train or rail vehicle is clear of the section to which that speed applies.

- Locomotive Engineers and Remote Control Operators MUST ensure the speed of the whole length of the train does not exceed the maximum speed of the turnout
- The End of Train speed is critical as any speed that exceeds the posted speed of the turn out will make the wagons become unstable and increases the risk of derailment

ROC **1.16 MAXIMUM SPEED**

- Locomotive Engineers must not exceed the maximum speeds shown in the RORP Section 10

**Turnouts** RORP 7.7.3

- The speed of all trains through the curved roads of turnouts must **not** exceed 25 km/h unless a speed board / ETCS authorising a higher speed is exhibited or shown in the schedule of maximum speeds.

*Remember for SHE communication:*

- *Red icon for an Alert = Stop. Assess the Alert and take any required actions before proceeding. (Face to face communication is critical.)*
- *Amber icon for an Advice = Pause. Prepare to stop if necessary. Assess the advice and take any required actions.*
- *Green icon for a Notice = Proceed but pay attention.*

# Appendix 2: Post-derailment wagon examination

Table 1 contains the measurements for wagon UKN143, the first wagon to derail.

'Z' is the thickness of the solid wheel rim. The condemning limit is 16. A low value is a thin rim.

'X' is the wheel flange thickness. A high 'X' value means a thin flange. The condemning limit is 40.

Float is measured on both sides of the bolster and the two figures are added together (see Figure 8). The acceptable float limit for the bogie at the handbrake end is 6-10 mm, and it is 12-16 mm for the bogie at the non-handbrake end.

The wedge height depot condemning limit is 39 mm and above.

Figure 13 is a schematic showing the wagon and bogie layout.

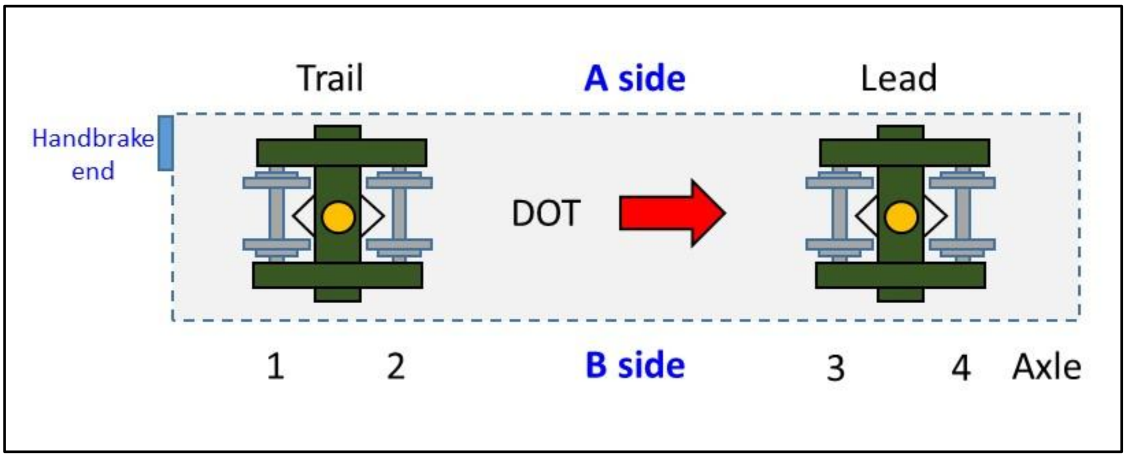


**Figure 13: Wagon and bogie layout**

| Wheel From (HB) | Wheel 'Z' [mm] | Wheel 'X' [mm] | Wedge [mm] | Float [mm] | Wedge [mm] | Wheel 'X' [mm] | Wheel 'Z' [mm] | Wheel |
|---|---|---|---|---|---|---|---|---|
| **A1** | 54 | 2 | | | | 2 | 54 | **B1** |
| | | | 28 | 4 +12 | 30 | | | |
| **A2** | 54 | 2 | | | | 2 | 54 | **B2** |
| | | | | | | | | |
| **A3** | 54 | 2 | | | | 2 | 54 | **B3** |
| | | | 28 | 4 + 16 | 29 | | | |
| **A4** | 54 | 2 | | | | 2 | 54 | **B4** |

**Table 1: Measurements for wagon UKN143**

Transport Accident Investigation Commission

**Recent railway occurrence reports published by the Transport Accident Investigation Commission (most recent at top of list)**

| | |
|---|---|
| RO-2019-101 | Safe-working occurrence, Westfield yard, Ōtāhuhu, Auckland, 24 March 2019 |
| RO-2019-102 | Clinton derailment, 29 March 2019 |
| RO-2018-102 | Freight train SPAD and wrong-routing, Taimate, 1 October 2018 |
| RO-2018-101 | Metropolitan passenger train, derailment, Britomart Transport Centre, Auckland, 9 May 2018 |
| RO-2017-106 | Mainline locomotives, Wrong-routing and collision with work vehicle, Invercargill, 16 November 2017 |
| RO-2017-105 | Collision between freight Train 353 and heavy motor vehicle, Lambert Road, level crossing, near Kawerau, 6 October 2017 |
| RO-2017-104 | Unauthorised immobilisation of passenger train, at Baldwin Avenue Station, Avondale, 17 September 2017 |
| RO-2017-101 | Signal Passed at Danger 'A' at compulsory stop boards protected worksite, Pongakawa, Bay of Plenty, 7 February 2017 |
| RO-2017-103 | Potential collision between passenger trains, Wellington Railway Station, 15 May 2017 |
| RO-2017-102 | Signalling irregularity, Wellington Railway Station, 3 April 2017 |
| RO-2016-101 | Signal passed at danger leading to near collision, Wellington Railway Station, 28 May 2016 |
| RO-2016-102 | Train 140 passed Signal 10R at 'Stop', Mission Bush Branch line, Paerata, 25 October 2016 |
| RO-2015-103 | Track occupation irregularity, leading to near collision, between Manunui and Taumarunui, 15 December 2015 |
| RO-2014-105 | Near collision between train and hi-rail excavator, Wairarapa Line near Featherston, 11 August 2014 |
| RO-2013-101 | Derailment of freight Train 345, Mission Bush Branch line, 9 January 2013 |

# TAIC Kōwhaiwhai - Māori scroll designs

TAIC commissioned its kōwhaiwhai, Māori scroll designs, from artist Sandy Rodgers (Ngati Raukawa, Tuwharetoa, MacDougal). Sandy began from thinking of the Commission as a vehicle or vessel for seeking knowledge to understand transport accident tragedies and how to prevent them. A 'waka whai mārama (i te ara haumaru) is 'a vessel/vehicle in pursuit of understanding'. Waka is metaphor for the Commission. Mārama (from 'te ao mārama' – the world of light) is for the separation of Rangitāne (Sky Father) and Papatūānuku (Earth Mother) by their son Tāne Māhuta (god of man, forests and everything dwelling within), which brought light and thus awareness to the world. 'Te ara' is 'the path' and 'haumaru' is 'safe or risk free'.

## Corporate: Te Ara Haumaru - The safe and risk free path

The eye motif looks to the future, watching the path for obstructions. The encased double koru is the mother and child, symbolising protection, safety and guidance. The triple koru represents the three kete of knowledge that Tāne Māhuta collected from the highest of the heavens to pass their wisdom to humanity. The continual wave is the perpetual line of influence. The succession of humps represent the individual inquiries.

Sandy acknowledges Tāne Māhuta in the creation of this Kōwhaiwhai.

## Aviation: ngā hau e whā - the four winds

To Sandy, 'Ngā hau e whā' (the four winds), commonly used in Te Reo Māori to refer to people coming together from across Aotearoa, was also redolent of the aviation environment. The design represents the sky, cloud, and wind. There is a manu (bird) form representing the aircraft that move through Aotearoa's 'long white cloud'. The letter 'A' is present, standing for aviation.

Sandy acknowledges Ranginui (Sky father) and Tāwhirimātea (God of wind) in the creation of this Kōwhaiwhai.

## Marine: ara wai - waterways

The sections of waves flowing across the design represent the many different 'ara wai' (waterways) that ships sail across. The 'V' shape is a ship's prow and its wake. The letter 'M' is present, standing for 'Marine'.

Sandy acknowledges Tangaroa (God of the sea) in the creation of this Kōwhaiwhai.

## Rail: rerewhenua - flowing across the land

The design represents the fluid movement of trains across Aotearoa. 'Rere' is to flow or fly. 'Whenua' is the land. The koru forms represent the earth, land and flora that trains pass over and through. The letter 'R' is present, standing for 'Rail'.

Sandy acknowledges Papatūānuku (Earth Mother) and Tāne Mahuta (God of man and forests and everything that dwells within) in the creation of this Kōwhaiwhai.

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