Report 07-102 (incorporating inquiry 07-111):
freight train mainline derailments, various locations on the national network,
from 6 March 2007 to 1 October 2009

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports be used to assign fault or blame or determine liability, since neither the investigations nor the reporting processes are undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

# Final Report

Rail inquiry number 07-102
(incorporating inquiry 07-111)

freight train mainline derailments, various locations on the national network

from 6 March 2007 to 1 October 2009

Approved for publication: May 2012

# Transport Accident Investigation Commission

## About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is 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. Its purpose is not 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. The Commission carries out its purpose by informing members of the transport sector, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

## Commissioners

| | |
|---|---|
| Chief Commissioner | John Marshall, QC |
| Deputy Chief Commissioner | Helen Cull, QC |
| Commissioner | Captain Bryan Wyness |

## Key Commission personnel

| | |
|---|---|
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| Chief Investigator of Accidents | Captain Tim Burfoot |
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# Important notes

## Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

## Ownership of report

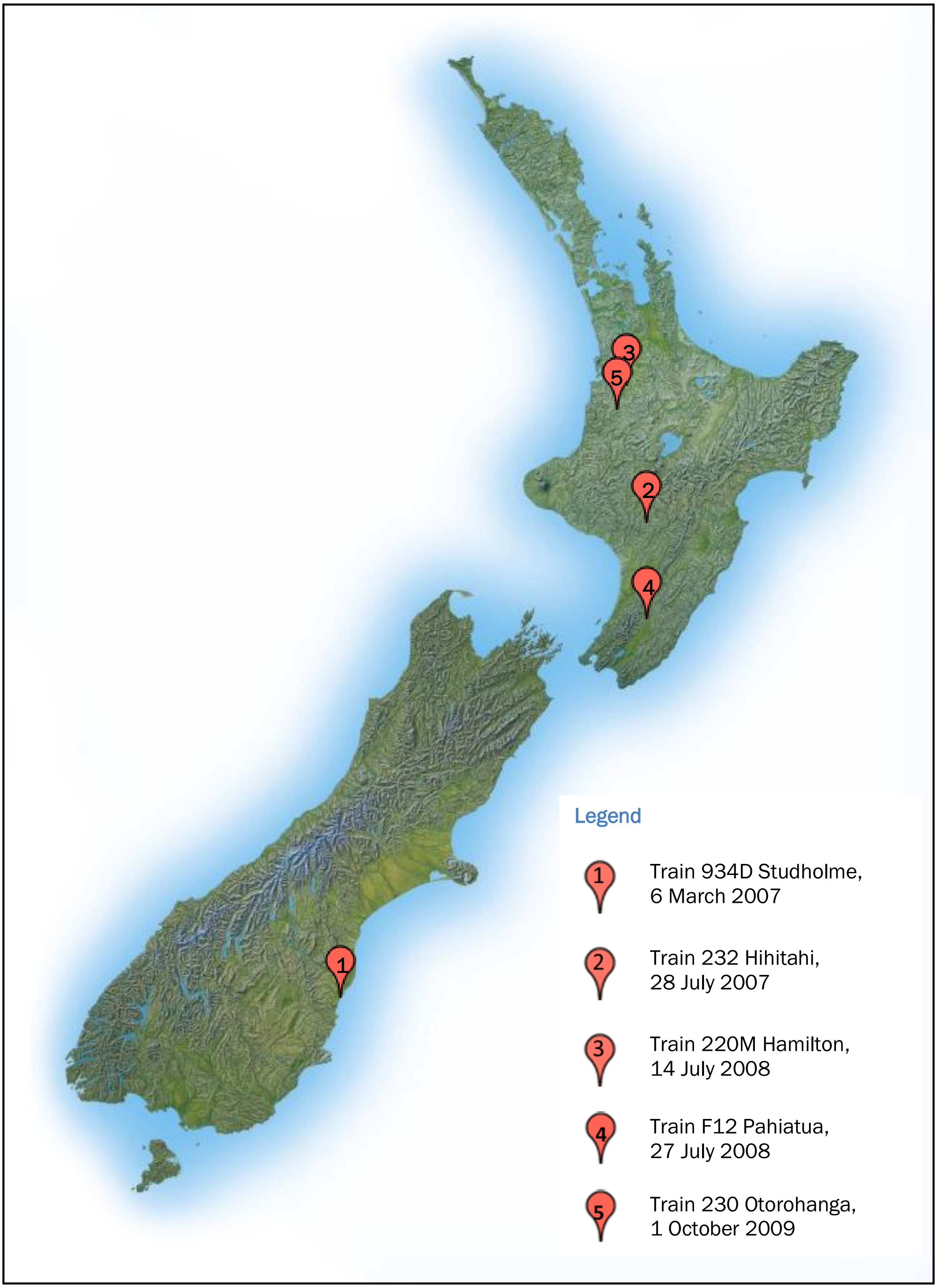


## Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1980 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

## Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.




Locations of accidents

Source: mapsof.net

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## Abbreviations

| | |
|---|---|
| Commission | Transport Accident Investigation Commission |
| EM80 | track evaluation car |
| km | kilometre(s) |
| km/h | kilometre(s) per hour |
| kPa | kilopascal(s) |
| m | metre(s) |
| mm | millimetre(s) |
| NIMT | North Island Main Trunk |
| t | tonne(s) |
| Toll Rail | Toll NZ Consolidated Limited |

## Data summary

### Vehicle particulars

| | |
|---|---|
| **Train type, number and date:** | express freight Train 934, 6 March 2007 |
| | express freight Train 232, 28 July 2007 |
| | express freight Train 220, 14 July 2008 |
| | express freight Train F12, 27 July 2008 |
| | express freight Train 230, 1 October 2009 |
| **Operators:** | Toll NZ Consolidated Limited (Toll Rail) before 1 July 2008 |
| | KiwiRail Limited from 1 July 2008 |
| **Locations** | various locations on the national rail network |
| **Persons involved** | one driver on each train |
| **Injuries** | nil |
| **Damage** | extensive damage to wagons and track |

# 1. Executive summary

1.1. Between March 2007 and October 2009 there were 5 derailments involving container wagons conveying single 6-metre (m) containers loaded with bulk grain, positioned on the leading ends of the wagons. The Transport Accident Investigation Commission (the Commission) combined the events into a single inquiry.

1.2. In 2005 the Commission made a recommendation to review the current track geometry standards and the wagon maintenance standards to ensure those standards are compatible and minimise the potential for derailments caused by dynamic interaction[1], where the condition of the wagon and the speed at which it is travelling interact with one or more rail track faults. This can cause the wagon to oscillate and derail (see Appendix 7 for a description of dynamic interaction).

1.3. For most of the period covered by these accidents the freight train operations and track maintenance and management were with different entities. Today, responsibility for both rests with KiwiRail Limited.

1.4. In 2009 KiwiRail refined the way it measured and managed track faults and prioritised their repair. In 2011 it tightened wagon wheel maintenance requirements. These improvements reduced the risk of dynamic interaction-related derailments. In 2010 KiwiRail installed acoustic bearing monitoring equipment at 3 key points on the rail network to detect failing wheel bearings before they collapsed; another cause of derailments that had resulted in a Commission recommendation. Mainline derailments have about halved during KiwiRail's tenure.

1.5. The Commission believes the actions taken by KiwiRail have significantly reduced the likelihood of future occurrences similar to those that led to this inquiry.

1.6. The key lessons learnt from the inquiry into these occurrences were:

- sufficient resources need to be put into maintaining rail track infrastructure and rolling stock if mainline derailments are to be kept as low as reasonably practicable
- if the allowable tolerances for the condition of rail track and rail wagons are not compatible, dynamic interaction between the track and wagons will result in an increase in mainline derailments.

[1] Dynamic interaction is related to the forces present at the wheel-rail interface and is associated with derailments that include wheel climb and wheel lift.

## 2. Conduct of the inquiry

2.1. On Tuesday 6 March 2007 at about 1235, the NZ Transport Agency's predecessor, Land Transport New Zealand, notified the Commission of a derailment under section 13(4) of the Railways Act 2005. The Commission opened inquiry 07-102 under section 13(1) of the Transport Accident Investigation Commission Act 1990, to determine the circumstances and cause(s) of the accident.

2.2. Commission investigators gathered evidence from the accident site, data was downloaded from the on-board event recorder (Tranzlog) and the train driver was interviewed. Track inspection and maintenance records, output from the most recent track geometry recording run (EM80[2]), an analysis of the track geometry leading up to the point of derailment, wagon inspection reports and the operating company's internal derailment report were all used in the inquiry.

2.3. On Saturday 28 July 2007 Land Transport New Zealand notified the Commission of another derailment under section 13(4) of the Railways Act 2005. That derailment had similarities with the first. So the Commission opened inquiry 07-111 under section 13(1) of the Transport Accident Investigation Commission Act 1990, to determine the circumstances and cause(s) of the accident.

2.4. Commission investigators gathered evidence from the accident site, interviewed the driver and collected records from the operator of the freight train (Toll Rail) and the network provider (Ontrack).

2.5. In the following 2 years the Commission was notified of another 3 mainline derailments that appeared to have some similarities with the first 2. These occurred on 14 July 2008, 27 July 2008 and 1 October 2009. All 5 derailments involved container wagons conveying single 6 m containers loaded with bulk grain, positioned at the leading end of the wagons.

2.6. The Commission had already made one recommendation in 2005 to address the safety issue where the track geometry standards and the wagons maintenance standards increased the risk of derailments owing to dynamic interaction. Owing to the slow industry uptake of the recommendation, it was repeated to the rail regulator in 2009.

2.7. After reviewing the circumstances of each of these 5 derailments the Commission combined all 5 events into this single report.

2.8. On 18 April 2012 the Commission approved the draft final report for circulation to interested persons for comment.

2.9. Submissions were received from the operator and regulator, and have been considered and included in the final report where appropriate.

2.10. On 31 May 2012 the Commission approved the publication of the final report.

[2] The EM80 track evaluation car is a specialised, self-propelled rail vehicle that records track geometry continuously, compares the actual value with a predetermined threshold and generates an exception report.

# 3. Factual information

## 3.1. Recent history of the rail industry in New Zealand

3.1.1. From 1996 until 2004 the rail infrastructure and the rail operation were owned by a publicly listed company, Tranz Rail Limited. In March 2002 Tranz Rail outsourced the maintenance of the infrastructure to another entity, Transfield.

3.1.2. During 2003 and 2004, Toll Rail purchased the rail and Interislander ferry operations, including the rail rolling stock and Interislander assets.

3.1.3. At the same time the New Zealand Government bought back the rail infrastructure and managed it under Ontrack, which became the trading name for the New Zealand Railways Corporation. The Government charged Toll Rail an access fee for using the rail infrastructure and it was the Government that began injecting funds into raising the standard of the rail infrastructure.

3.1.4. Soon after its formation, Ontrack brought back in-house the maintenance of the infrastructure upon the expiry of the contract let by Tranz Rail to Transfield.

3.1.5. Until 30 June 2008 Toll Rail operated ferry services and was the exclusive freight operator on the rail network. In compliance with the National Rail System Standard, section 6, Engineering Interoperability Standards, Toll Rail inspected and maintained its rail vehicles to its own standards in accordance with its own safety system.

3.1.6. There had been minimal investment in retaining sufficient expertise and maintaining the rail infrastructure under the various private/public ownership regimes since the Government first sold the network in 1993. This issue was raised by the Commission in its report 05-116, collapse of Bridge 256 over Nuhaka River, Palmerston North Gisborne Line, 6 May 2005. What follows are 2 of the key findings from that report:

> The level of engineering experience in the rail system was not sufficient to support the inspection and maintenance of the rail infrastructure in the years leading up to and at the time of the bridge collapse.
>
> The reduction in the replacement of timber components in rail bridges during successive periods of ownership and structure of the rail system, together with a reduction in the frequency and quality of bridge inspections, increased the risk of a catastrophic failure beyond what would normally be considered safe.

3.1.7. On 1 July 2008 the Government purchased Toll Rail's rail and ferry business, which was renamed KiwiRail. From 1 October 2008 the New Zealand Railways Corporation became the single entity responsible for freight services, long-distance passenger services and the rail infrastructure. The entity is referred to in this report as KiwiRail.

3.1.8. This development meant that once again the responsibilities for setting and maintaining the standards for both the rail rolling stock and the rail infrastructure belonged to one entity.

## 3.2. Derailments

3.2.1. The Commission has published 18 reports into freight train derailments since 1999. It has done so because it is concerned with the high number of mainline derailments and the potential consequences of derailments.

3.2.2. In its rail Inquiry[3] 07-114, the Commission discussed its concern over the consequences of mainline derailments. That discussion included the following comment:

> Derailments represent a high risk to the rail industry, certainly with respect to damage to rolling stock and freight, and damage to the rail infrastructure. The other risk to consider is that to people and the environment…
>
> The Huntly derailment resulted in loaded shipping containers spilling across the adjacent State Highway 1. Fortunately the derailment occurred late at night when highway traffic was negligible.

3.2.3. The above report was focused on derailments due to wheel-bearing failures. At the same time the Commission was considering the issue of derailments due to dynamic interaction.

3.2.4. The owners of the rolling stock and the rail infrastructure were different entities. This created some difficulty within the industry when it came to establishing the true causes of derailments. Often the 2 entities (one publicly listed and one state owned) would or could not agree on the causes.

3.2.5. In each of these occurrences a UK or PK class container flat-deck wagon conveying a single 6 m long container loaded with bulk grain, positioned at the leading end of the wagon, derailed. With all 5 derailments, the leading wheel-sets on the leading bogies[4] (refer to Figure 4) were the first to derail. The derailed wagons were dragged up to 4.5 kilometres (km) before the trains were stopped, resulting in considerable damage to both track and wagons.

3.2.6. Details of these 5 derailments are given in appendices to this report. The Commission was not able to find any new or common cause of these 5 derailments. They were all caused by either wagon or track deficiencies, or a combination of both. It would appear that having a heavy wagon travelling at about 80 km per hour (km/h), loaded on one end of the wagon (which the wagons were designed to do), altered the dynamics of the wagon sufficiently for it to derail when the condition of the track and wagon was close to the limits allowed under the respective codes.

3.2.7. In 2005 the Commission recommended to the Chief Eexecutive of the New Zealand Railways Corporation that he address the safety issue of wagon and track tolerances not being considered collectively (the standards were set separately by 2 different entities). This was contributing to dynamic interaction derailments. The recommendation was worded as follows:

> In conjunction with Toll NZ Consolidated Limited critically review current track and mechanical code standards and maintenance tolerances to ensure they are compatible and minimise the potential for derailments caused by dynamic interaction (009/05).

3.2.8. On 1 April 2005 the Chief Executive of the New Zealand Railways Corporation replied in part:

> New Zealand Railways Corporation (NZRC) intend to implement this recommendation. As this recommendation involves working in conjunction with another party, this may take some time before being fully implemented.

3.2.9. On 4 April 2005 it was recommended to the Chief Executive of Toll Rail that he:

> In conjunction with New Zealand Railways Corporation critically review current track and mechanical code standards and maintenance tolerances to ensure they are compatible and minimise the potential for derailments caused by dynamic interaction (010/05).

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[3] Inquiry 07-114, Derailment caused by a wheel-bearing failure, Huntly, 19 October 2007, and 11 subsequent wheel-bearing failures at various locations during the following 12-month period.

[4] A bogie is a twin-axle wheel-set

3.2.10. On 11 April 2005 the Chief Executive of Toll Rail replied in part:

> We accept this recommendation. A similar recommendation has been raised during the joint internal investigation into a similar incident and has been accepted by Ontrack and Toll Rail management.

3.2.11. On 19 August 2009, because of slow progress in addressing the safety issue, the Commission made another recommendation, this time to the Chief Executive of the NZ Transport Agency. The wording of that recommendation was to address the following safety issue:

> The current track and mechanical code standards and maintenance tolerances are not compatible and there remains a high risk of derailments caused by dynamic interaction (029/09).

3.2.12. On 14 September 2009 the Chief Executive of the NZ Transport Agency responded as follows:

> We intend to work closely with KiwiRail with an aim to implementing and closing these recommendations as soon as practicable. Discussions on them will commence on Wednesday 16 September and will be on going. Any outstanding Transport Accident Investigation Commission (TAIC) recommendations also form an integral part of our annual safety assessments of the rail industry.

3.2.13. On 21 March 2011 KiwiRail issued Code Amendment Notice M2000/003 that amended clause 3.4 (c) of Mechanical Code M2000, Issue 8, of 1 December 2009, which stated in part:

> **Section 3.4** **Bogies** (Replace clause c with the following)
>
> c) Friction wedge height of bogies must be checked using the appropriate gauge as per M9201/15 and must be condemned as per table below: **When checking in the depot** – A 3 mm packing under the gauge is required on items 4, 5, and item 7.
>
> **When checking in the field** – A 3 mm packing under the gauge is required on items 1, 2, 3, 4, 5 and 7.
>
> Table: Wedge Height Condemning Limits

| Item | Bogie Type | Depot Condemning Limit (mm) | Field Condemning Limit (mm) |
|---|---|---|---|
| 1 | T12A | 30 | 33 |
| 2 | T14, T14A, T14S (excl ZH wagons) | 39 | 42 |
| 3 | T14S (ZH wagons only) | 36 | 39 |
| 4 | T14, T14A, (LCS and Infra wagons only) | 42 | 42 |
| 5 | T16A, T16B, T16E | 33 | 33 |
| 6 | T16I (UCA wagons), T16II (C wagons) | 39 | 39 |
| 7 | T18A, T18B, T18S (excl OM wagons) | 33 | 33 |
| 8 | T18C | 39 | 39 |
| 9 | T18S (OM wagons only) | 30 | 30 |
| 10 | T22 | 39 | 39 |

3.2.14. While the condemning limit for the friction wedge heights on bogie flat-top wagons with Type 14 bogies (14.3-tonne axle limits) was formally reduced from 42 millimetres (mm) to 39 mm from 21 March 2011, in practice these revised tolerances had been used by wagon depot maintenance staff since 2009 (see Figure 1). Lowering the maximum allowable limit by 3 mm meant that bogies on both UK and PK wagons were taken out of service one or 2 years earlier depending on the number of kilometres the bogies had travelled during their service lives.

3.2.15. KiwiRail's Significant Information Notice T044, effective from 29 June 2009, changed the **priority system for track inspections from a 3-tier system to a 5-tier system** for track geometry maintenance tolerances for cant[5], twist[6], top and gauge[7]. The actions required were more definitive than the previous instructions and included:

> P1 – apply immediate 25 km/h temporary speed restriction and fix within 2 days
>
> P2 – apply immediate 40 km/h temporary speed restriction and fix within one week
>
> P3 – consider the need for a temporary speed restriction and fix within one month
>
> P4 – consider the need for a temporary speed restriction and fix within 6 months
>
> P5 – fix within 12 months

3.2.16. KiwiRail has progressively installed continuous in-motion weighing equipment at 7 sites throughout the network. At 3 of those sites (Bunnythorpe north of Palmerston North, Tauranga and Rolleston near Christchurch) acoustic bearing monitoring equipment has been installed. These systems monitor wagon axle loadings and the condition of each wheel bearing. An alert is generated when the system detects: an out-of-balance load; an axle load heavier than that permitted for the class of wagon on the line; or a wheel bearing that requires further inspection.

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[5] The cant is the difference in height between the inner rail and the outer rail on curved track to allow higher train speeds than if the 2 rails were at the same level. If the track were canted to the level required for the maximum speed of the fastest train, the level of tilt would be too high for a slower train. A compromise cant value is therefore used, referred to as cant deficiency.
[6] Twist is the cant difference over a 4 m section of track.
[7] Gauge is the distance between the rails on the rail track; currently 1068 mm on straight track.

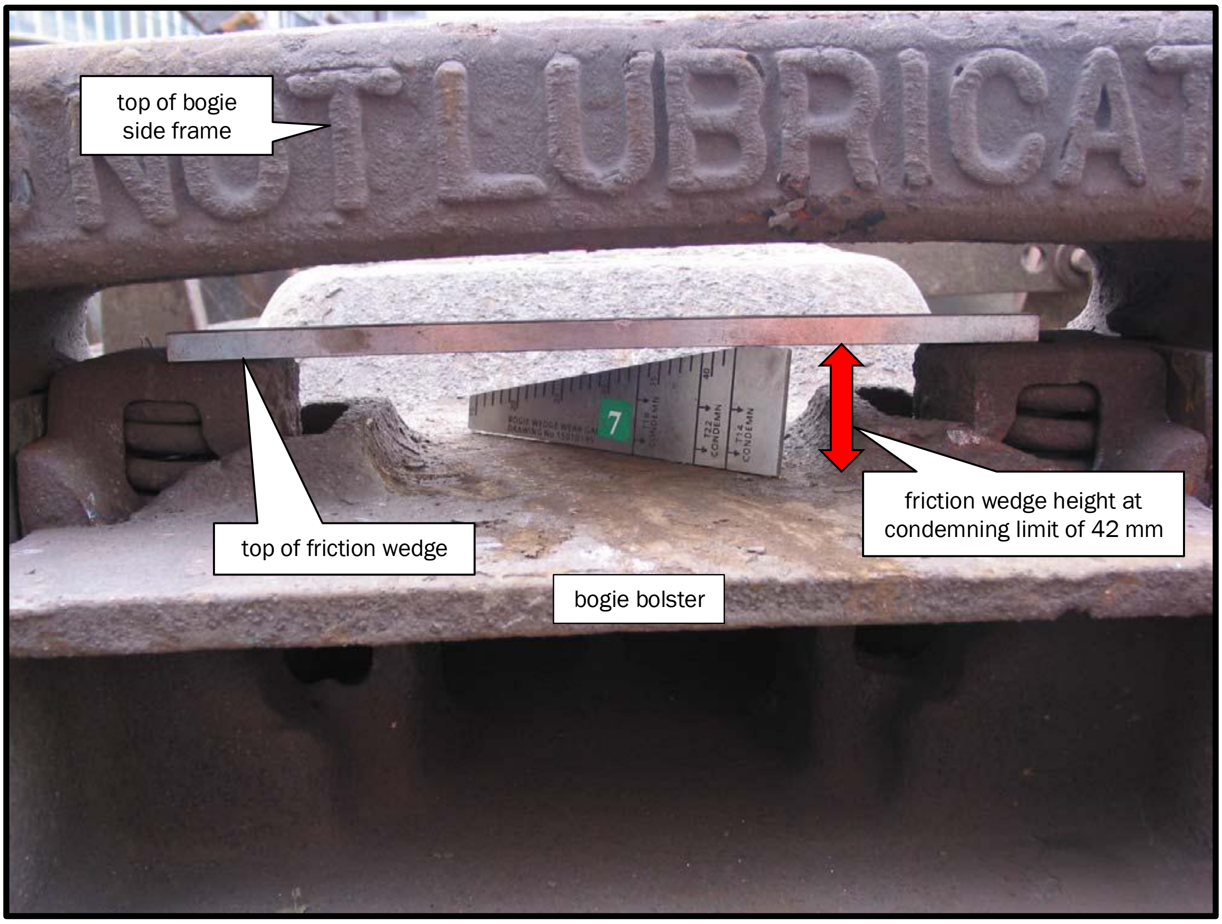


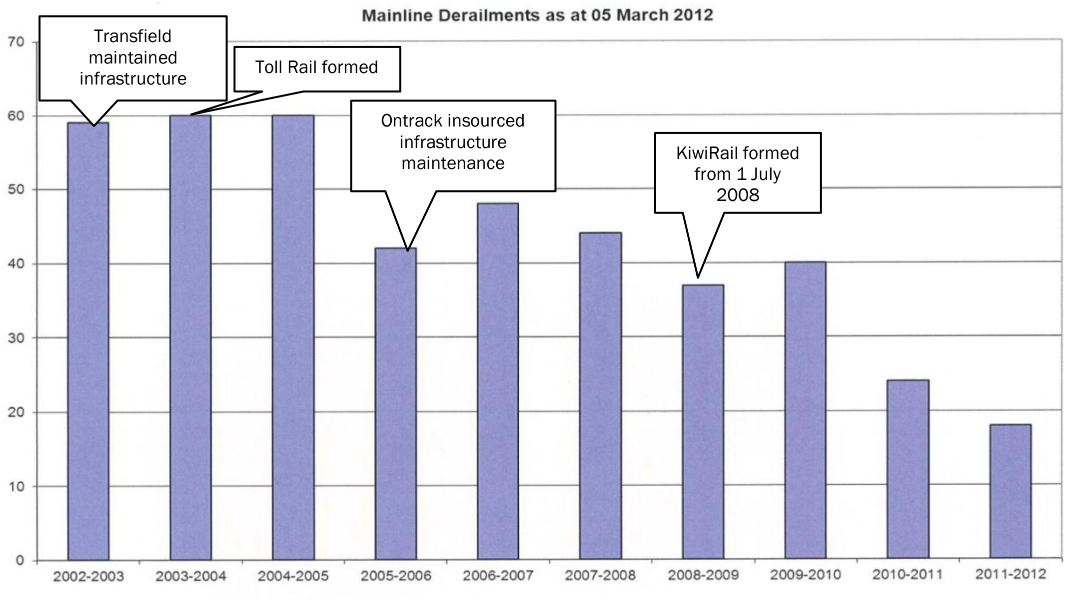

Figure 1
Measuring friction wedge height

3.2.17. In April 2007 Toll Rail and Ontrack jointly engaged an external consultant to establish a cause for the derailment that had occurred at Studholme the previous month (refer Appendix 1), and to investigate the effects of varying certain tolerances to track geometry standards and the mechanical code. However, the modelling was inconclusive in determining a cause for the derailment.

3.2.18. KiwiRail is currently reviewing the guidelines for loading UK and PK class wagons given that end loading has been a contributing factor in a number of dynamic interaction derailments. As new container-carrying wagons have entered service, many of the UK wagons have been reconfigured to carry logs, resulting in a more uniform distribution of the wagon loading.

3.2.19. On the track side, KiwiRail has started a programme to upgrade the EM80 track evaluation car. Included in the programme is the ability to measure track parameters, in particular twist, over longer base lengths of track than the current 4 m base length. The ability to calculate track geometry parameters over lengths of up to 10 m will provide track condition information related to the performance of the rolling stock operating on the network.

3.2.20. Figure 2 shows the number of mainline derailments recorded each financial year.




Data provided by KiwiRail

Figure 2
Mainline derailments

3.2.21. Figure 2 has been annotated with key milestones in the ownership of rail freight operations and rail infrastructure. It shows a noticeable drop in mainline derailments from about 2005, which was when investment in the rail infrastructure increased. This could also be partly attributed to the programmes introduced by Toll Rail to track critical components of freight wagons and carry out more detailed inspections of bogie side frames and roller bearings. A further noticeable drop is post 2009-2010, when the standards for track and rolling stock were reviewed and the wear limits for some rolling stock components were reduced in line with the manufacturers' recommended limits.

3.2.22. The Commission would normally analyse the factual information presented in this report and make findings and recommendations, but in view of the noticeable downward trend in mainline derailments and the actions taken by KiwiRail, it has not done so. This is because the Commission made a number of recommendations in other Commission reports that were published while these inquiries were still in progress. Those recommendations addressed the same safety issues identified in this report.

# 4. Key lessons

4.1. Sufficient resources need to be put into maintaining rail track infrastructure and rolling stock if mainline derailments are to be kept as low as reasonably practicable.

4.2. If the allowable tolerances for the condition of rail track and rail wagons are not compatible, dynamic interaction between the track and wagons will result in an increase in mainline derailments.

## Appendix 1: Information on the UK class wagon

1. The UK class container flat-deck wagons were the mainstay of the general-purpose container-carrying fleet, with about 1400 of these wagons in service. Each wagon had a serviceable deck length of 15.952 m and a tare weight of 14.3 tonnes (t). The wagons were designed to carry a maximum payload of 43 t, giving a maximum gross wagon weight of 57.3 t or 14.3 t per axle. The wagon class typically carried one 12 m or two 6 m or five 3 m containers or combinations of these sizes. KiwiRail's freight handling code restricted the maximum load of a single 6 m long container carried on a UK class wagon to 25 t, and then only when secured by the inner twistlock pins. The maximum load was reduced to 23.9 t when a single 6 m container was secured by the outer twistlock pins (see Figure 3).

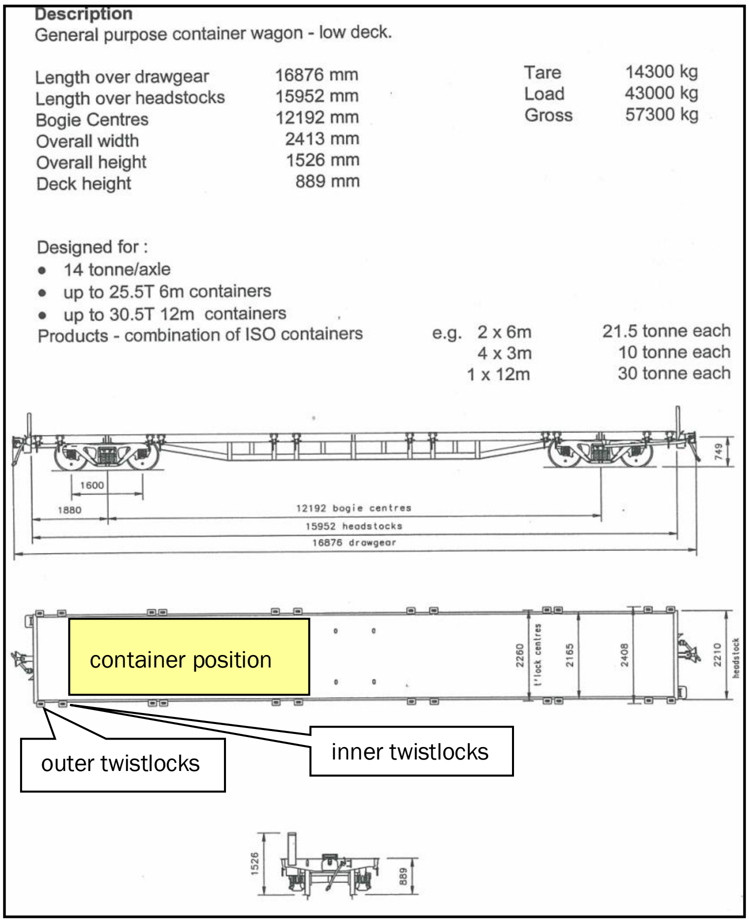



Figure 3
Loading position of container on UK class wagon

2. The UK class wagon was fitted with standard 3-piece bogies commonly used on freight wagons throughout the world. The 3 main "pieces" were one bolster and 2 side frames (see Figure 4). The bolster was supported by 2 sets of coil springs. The larger-diameter coil springs, known as the primary suspension, provided vertical support. The smaller-diameter coil springs, known as wedge springs, applied pressure to a friction wedge to provide damping to reduce the oscillation of the wagon while in transit. The effective functioning of the ride control feature relied on friction between spring-loaded wedges and surfaces on the bolster and side frames. The friction wedge height on a reconditioned Type 14 bogie was about 19 mm. During the wagon's service life, the friction wedge height increased by an average of 2 mm or 3 mm per year.

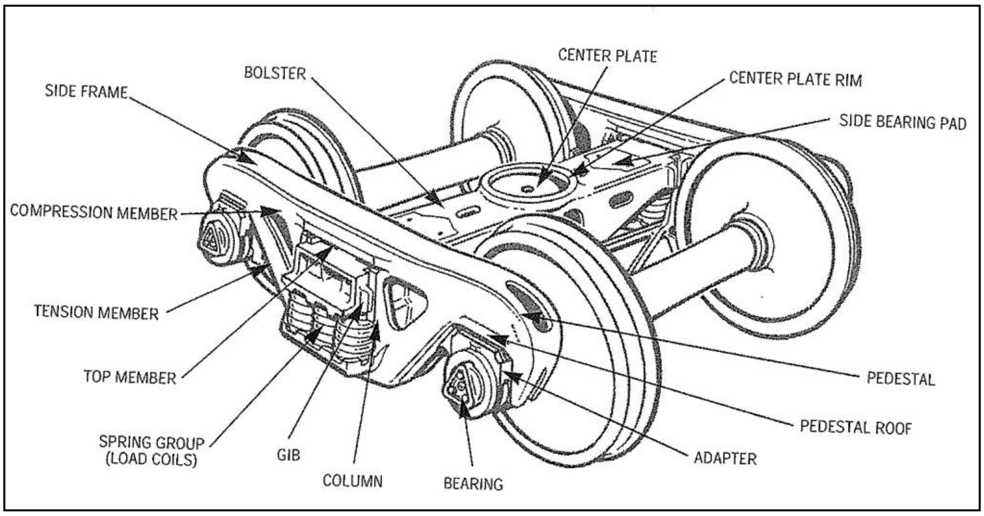



Figure 4
Nomenclature of bogie components

### Information on PK class wagon

3. KiwiRail had a fleet of about 250 PK class wagons. These wagons were also part of the general-purpose container-carrying, flat-deck wagon fleet, but PK wagons were shorter than UK wagons, having a serviceable deck length of 13.1 m. The wagon class, also fitted with the Type 14 bogie, was designed to carry 3 m, 6 m and 12 m containers or a combination of 3 m and 6 m containers up to a total load of 44 t. The freight handling code restricted the maximum load of a single 6 m container on a PK wagon to 25.5 t. The freight handling code stated in part:

> Note: UK, UKA and PK wagons loaded with heavy containers at one end can become unstable and derail under some conditions.

### Wagon inspection policy

4. KiwiRail's Mechanical Code M2000, Issue 7, effective from 1 April 2007, required all freight wagons to have pre-departure terminal brake checks in accordance with the Rail Operating Code. These checks were carried out by yard-operating staff before trains departed terminals to ensure the security of the trains, including the condition of air hoses, the condition of brake blocks and the status of handbrakes.

5. Non-scheduled B-Checks were carried out by trade-qualified personnel when 2 or more brake blocks were replaced. More detailed scheduled C-Checks were carried out every 2 years with an upper limit of 27 months. The C-Check inspection interval was brought forward whenever a wagon was involved in a collision or derailment, or had a fault with the braking system. The C-Check inspection of a bogie required a condition assessment and the measuring and recording critical ride components that included springs, bearing keeps, liners, friction wedge heights, bearing adapters, side bearers, dampers and bearings.

6. The maintenance specification for the UK wagon fleet included:

- Float at handbrake end: minimum 6 mm, maximum 10 mm
- Float at non-handbrake end: minimum 12 mm, maximum 16 mm
- Friction wedge height limit: maximum, 42 mm
- Wheel thickness: the diameters of 2 wheels on the same axle must not differ by more than one mm, the diameters of wheels on the same bogie must not differ by more than 20 mm and the solid wheel rim thickness must be more than the 16 mm.

### Transport of bulk grain

7. KiwiRail and its predecessor owned and operated specialised HUG containers for the distribution of bulk grain throughout the rail network. These containers had 3 roof loading hatches and 2 end-door discharge hatches at one end (see Figure 5). The “fluid” property of grain meant that a load was evenly distributed within the container soon after the wagon began its journey. The HUG container had a tare weight of 2.66 t and was restricted to a maximum payload of 21.34 t, giving a gross weight of 24 t.

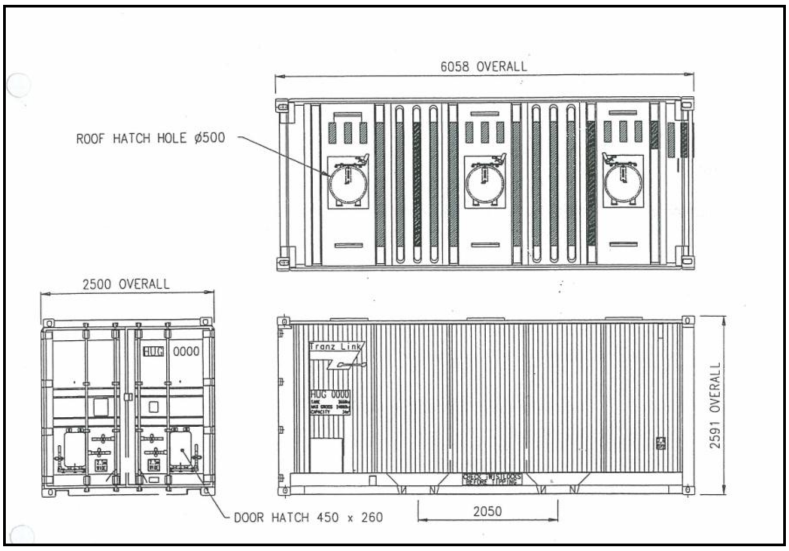



Figure 5
A generic HUG grain container

8. KiwiRail had insufficient HUG containers to meet peak demand, so standard 6 m dry containers were leased and modified to supplement the fleet. An auger was used to load grain through one end of the leased container, progressively adding wooden boards to contain the grain within the open door.

## Appendix 2: Occurrence 07-102, derailment between Glenavy and Studholme on the Main South line, 6 March 2007

1. On Tuesday 6 March 2007, Train 934D was a scheduled express service travelling from Dunedin to Christchurch. The train consisted of locomotive DFT7132 hauling 29 wagons, with a gross weight of 956 t and an overall length of 488 m. At about 0605, the leading wheel-set on the 22nd wagon, UK3296, derailed at about 221.52 km[8] on the Main South Line between Glenavy and Studholme.

2. About 1.5 km farther on, the driver became aware that the train speed had slowed by about 20 km/h even though the train was travelling down a gentle grade. After another 2 km the train speed had slowed a further 20 km/h to about 40 km/h, so the driver looked back along the train to see whether there were signs of dragging equipment, but he saw nothing unusual. He then stopped the train about 4.57 km past the point of derailment[9] and radioed train control to advise that the train had been losing speed and he would walk back to check the train. The driver later confirmed with train control that wagon UK3296 had derailed to the right-hand side and the 7 trailing wagons had derailed to the left. The weather was reported as being fine at the time.

### Track and operating information

3. The maximum authorised speed for express freight trains travelling between Glenavy and Studholme was 80 km/h.

4. The locomotive event recorder confirmed that at the time of the derailment the locomotive speedometer had been displaying a speed 10 km/h less than the true speed. The locomotive speedometer was indicating 79 km/h when the true speed was 89 km/h.

5. The point of derailment was determined as 221.520 km Main South Line. At this location the track alignment was straight and on a down grade of 1 in 220. A single witness mark across the head of the right-hand rail confirmed a distance of 4 m from the point of derailment to the drop-off point[10].

6. The track materials at the point of derailment consisted of 91-pounds-per-yard rail manufactured in 1969 and subsequently welded into 76 m lengths fastened to a 50:50 mix of hardwood and treated Pinus radiata sleepers. The hardwood sleepers laid in 1960 were in poor condition and spotted with alternate Pinus radiata sleepers of medium condition up to 20 years old.

7. Ontrack's Bulletin No. 12 of 8 February 2007 identified the track section from 221.30 km to 222.06 km as a heat-restricted area. Heat-restricted areas identified in the Bulletin included sections of continuous welded track where there was no record of track destressing[11] and track sections that had shown signs of rail stress during hot weather or had been identified through track stability analysis as having a high risk of misalignment. As mitigation, when the rail temperature recorded on the heat sensor at Studholme reached a predetermined level, an alert was sent automatically to train control and a 40 km/h temporary speed restriction was placed over the identified track section. At the time of the derailment, there was no temporary speed restriction in place.

[8] Distance in kilometres from a track reference point at Lyttelton.
[9] The point of derailment is where the wheel flange climbs on to the head of the rail.
[10] The drop-off point is where the derailed wheel flange loses contact with the head of the rail.
[11] Track destressing is when continuous welded rail is lifted and refastened at the equivalent neutral temperature of 32° centigrade.

8. The track section leading up to the point of derailment had been disturbed the previous week. Maintenance work carried out included docking[12] and drifting the rail and re-profiling the ballast section with an excavator. The crushed metal ballast was clean and the formation was well drained. The track had been last tamped[13] and regulated[14] during July 2003.

9. The track had been inspected from a Hi-Rail vehicle the previous week in accordance with the track code. Although poor line and a 12 mm low joint leading up to the point of derailment had been identified and recorded, their severity was minor and had not required immediate treatment.

10. The most recent EM80 track evaluation run over the derailment site had been undertaken in September 2006. At the time, there was no track geometry condition identified that required follow-up action.

11. After the derailment, critical track geometry measurements were taken on the undisturbed track at 1 m intervals for 110 m leading up to the point of derailment and 20 m past it. The parameters included the gauge, the cant and the offset to the rail from a 20 m long chord. An analysis of those measurements confirmed that the only parameter to exceed maintenance tolerance limits was the rate of change of cant deficiency[15] at 8 m before the point of derailment. This deviation from code was such that a 40 km/h temporary restriction would have been required had the condition been identified.

### Wagon UK3296

12. Wagon UK3296, travelling with the handbrake leading, was conveying a 6 m long container loaded with grain destined for the Port of Lyttelton. The container was secured on the wagon by the outer twistlock pins at the leading end of the wagon. The declared weight of the product was 23.2 t. The container was weighed at Christchurch after the derailment and the gross weight recorded was 25.7 t some 1.8 t heavier than the maximum weight permitted by the operator's freight handling code for a container secured by the outer pins on a UK wagon.

13. The wagon was examined after the derailment. Measurements of critical components were recorded, including the wheel profiles, the friction wedge heights and the float clearances[16]. In addition, an overall condition assessment was made on draw-gear components, springs and bogie/horn liners. The condition of the bogie/horn liners and draw-gear were described as well worn. The height and thickness of the wheel flanges on the leading wheel-set of the leading bogie were at the maintenance limits. The wheel diameter difference on this wheel-set was outside maintenance limits at 7 mm.

14. The float clearance on the trailing bogie was recorded as 17 mm, 1 mm greater than the code limit maximum of 16 mm at the non-handbrake end. The float clearance on the leading bogie was 6 mm, the minimum specified in the code for the handbrake end of the wagon class.

15. The friction wedge height on the leading bogie was 27 mm for both the A and B sides of the wagon. On the trailing bogie the friction wedge height was 37 mm on the A side and 41 mm on the B side. The A4 and B3 spring inners were broken on the trailing bogie.

16. The scheduled maintenance checks were current. The previous C-Check had been completed on 7 May 2005 and the most recent B-Check had been carried out 9 January 2007, when 2 brake blocks were replaced.

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[12] Docking is the removal of the end batter at a rail joint.
[13] A tamper is a mechanised rail vehicle used to lift and line the track.
[14] A regulator is a mechanised rail vehicle used to ensure an even distribution of ballast to the required profile.
[15] The rate of change of cant deficiency is the rate at which cant deficiency is increased or decreased relative to the maximum speed of a vehicle travelling around a curve.
[16] The float clearance is the distance between the side bearing pad on the bolster and the float block on the underside of the wagon body.

## Appendix 3: Occurrence 07-111, derailment between Ngaurukehu and Hihitahi on the NIMT, 28 July 2007

1. On Saturday 28 July 2007, Train 232 was an express freight service travelling from Wellington to Auckland. The train make-up from Palmerston North was electric locomotives EF30203 and EF300132 hauling 26 wagons with a gross weight of 891 t and an overall train length of 466 m.

2. At about 1055, the leading wheel-set on the leading bogie on wagon UK20868, the ninth wagon, derailed at 272.972 km[17] on the North Island Main Trunk (NIMT), between Ngaurukehu and Hihitahi.

3. The wagon was dragged with the leading bogie derailed until it struck the facing points[18] at the south end of Hihitahi crossing station. There was a rapid loss of brake pipe pressure and the brakes applied automatically. The train stopped with derailed wagon UK20868 at 277.134 km, some 4.172 km past the point of derailment. The driver thought that the train had burst a brake hose, so he base-called train control and said that he would walk back along the track to see what had initiated the brake application.

4. After checking the train, the driver informed train control that UK20868 had derailed, as had the wagon in front and 7 trailing wagons, of which 4 had tipped over. The traction overhead system remained secure and intact.

### Track and operating information

5. The maximum authorised speed for express freight trains travelling between Ngaurukehu and Hihitahi was 80 km/h. However, because of the track alignment, the maximum line speed on the derailment curve was restricted to 45 km/h.

6. Locomotive EF30203 was fitted with its original, 25-year-old Locolog event recorder. A review of the event recorder short log (final 6 minutes before the train stopped) confirmed:

   - from 360 seconds to 25 seconds before logging stopped, the train speed ranged between 43 km/h and 47 km/h
   - at 19 seconds before logging stopped, the brake pipe pressure began to drop. The train speed was 39 km/h and the throttle was in power
   - at 17 seconds before logging stopped, the throttle was returned to idle
   - at 15 seconds before logging stopped, the locomotive brake cylinder pressure began to register in response to the falling brake pipe pressure
   - at 8 seconds before logging stopped, the locomotive stopped. Brake pipe pressure was 330 kilopascals (kPa) and the locomotive brake cylinder pressure was 430 kPa, indicating that the brake pipe had been opened along the train or the automatic brake valve was in the emergency position.

7. The point of derailment at 272.972 km was within the transition length[19] leading to a 195 m radius left-hand curve on a rising grade of 1 in 65. A single witness mark across the right-hand rail (high-leg rail) was 5.5 m from the point of derailment to the drop-off point.

[17] The distance in kilometres from a track reference point located at Wellington.
[18] Facing points are the tapered rails in a mechanical installation that allow trains to be guided from one track to another. The points can be moved laterally into one of 2 positions to direct a train from the narrow end straight ahead or to the diverging path.
[19] The transition is the section of track of increasing cant between the straight track and the circular curve. The standard transition length is 70 m, with the cant increasing by 1 mm per lineal metre from zero to 70 mm.

8. The track materials at the point of derailment consisted of transposed, continuously welded 50-kilogram-per-metre rail manufactured in 1979 fastened to 14-year-old concrete sleepers with "Pandrol" elastic fastenings. Track materials were all described as being in excellent condition, the ballast was clean, the shoulders were full, the formation was well drained and there was nil voiding. The derailment curve had last been mechanically lifted and lined in May 2004 and destressed the following year.

9. A full measure-up of the track geometry leading up to the point of derailment was completed and no condition outside code maintenance standards was identified. Track inspections were current.

### Wagon UK20868

10. Derailed wagon UK20868, travelling with handbrake leading, was conveying a single 6 m long container loaded with grain. The container was loaded at Ashburton on the handbrake end of the wagon. A gross wagon weight of 39.40 t was recorded when the wagon travelled at 25 km/h over the in-motion weighbridge at Christchurch. The leading bogie was carrying 14.5 t on each axle while the trailing bogie weight had about 5.2 t distributed to each axle. The loaded wagon had travelled 715 km before it derailed.

11. Wagon UK20868 was examined after the derailment. A friction wedge height of 40 mm was recorded on both sides of the leading bogie, which was approaching the maximum allowable 42 mm for the wagon class. The wagon float of 8 mm at the handbrake end and 15 mm at the non-handbrake end was within maintenance limits.

12. The wagon inspections were current. The most recent C-Check had been completed on 21 September 2006 and a B-Check had been carried out on 20 February 2007.

## Appendix 4: Occurrence 07-111, derailment between Rukuhia and Hamilton, on the NIMT, 4 July 2008

1. On Monday 14 July 2008, Train 220M was an express freight train travelling from Wellington to Auckland. The train consisted of electric locomotive EF30134 hauling 31 wagons, with a gross weight of 1143 t and an overall train length of 532 m.

2. At about 2320, the leading wheel-set of the leading bogie on wagon UK17971, the 21st wagon, derailed at 536.915 km NIMT, between Rukuhia and Hamilton. The signal box operator at Te Rapa called the driver to inform him that a member of the public had reported sparks coming from towards the rear of the train. The derailed wagon was dragged for about 4.5 km and was on its side when the driver stopped the train. The lead axle on the leading bogie of the wagon UK1880, 2 wagons behind UK17971, also derailed.

### Track and operating information

3. The maximum authorised speed for express freight trains travelling between Rukuhia and Hamilton was 80 km/h.

4. The locomotive event recorder download data confirmed that the train had been travelling at 80 km/h when wagon UK17971 derailed.

5. The track alignment at the point of derailment was straight and on a down grade of 1 in 182. The track materials consisted of continuously welded 91-pounds-per-yard rail manufactured in 1969 fastened to 2-year-old concrete sleepers with "Pandrol" elastic fastenings. The rail had been destressed during 2006 and the track had last been mechanically lined and lifted during April 2008.

6. The track between Rukuhia and Hamilton had been inspected on the morning of the derailment and no out-of-code condition identified.

7. The most recent EM80 track evaluation run had occurred on 10 June 2008. There had been no track geometry condition identified near the point of derailment that required follow-up action.

8. A post-derailment measure-up of the track geometry on the undisturbed track was carried out. An analysis of the track geometry identified a positive 20 mm twist[20] 11 m before the point of derailment and a negative 18 mm twist 2 m before the point of derailment. At the time, the Infrastructure Engineering Handbook (T200) classified twists from 18 mm to 21 mm as Priority 2 and to be programmed for maintenance with no time limit to remedy.

9. From the track geometry measure-up, the maximum calculated value for the rate of change of cant deficiency was 552 millimetres per second per second ($mm/s^2$) and occurred 14 m before the point of derailment. The acceptable limit was 200 $mm/s^2$. The EM80 classified a rate of change of cant deficiency exceeding 340 $mm/s^2$ as a Class 1** condition that required a temporary speed restriction of 40 km/h until the defective track condition was fixed. However, during the 10 June EM80 run no out-of-code condition had been recorded near the point of derailment.

[20] A track twist is the change in cross level over a 4 m length of track.

### Wagon UK17971

10. Wagon UK17971 was conveying a 6 m long container loaded with grain that was secured on the leading end of the wagon by the inner twistlock pins. The container had a declared weight of 21.22 t and the wagon travelled 979 km from Ashburton before derailing a few kilometres from its destination of Hamilton.

11. The wagon was examined after the derailment. By assessing wheel damage, it was confirmed that the leading wheel-set on the leading bogie had been the first to derail. The post-derailment float measurement of 15 mm at the handbrake end and 10 mm at the non-handbrake end would have been unlikely to represent the float condition pre-derailment because of the significant wagon damage that prevented the bolster seating correctly, which in turn prevented the wagon deck seating evenly in the centre casting. All other critical ride quality components were code compliant. The bogie wedge height readings were consistent with a recent overhaul.

12. The wagon maintenance inspections were current. The wagon had had a 10-yearly brake check and C-Check during May 2008. The wheel bearing survey on the wagon had been conducted during March 2008 and the previous B-Check had been completed on 27 November 2007.

### Correctional site works carried out near the point of derailment.

13. The derailment of Train 220 on 14 July 2008 at 536.915 km NIMT was the fourth recorded derailment at the same location within the previous 2 years. A fifth derailment was reported as being within 21 m. Common factors with these derailments included:

- all involved north-bound freight trains travelling at about 80 km/h
- the first wagon to derail was a container flat-top wagon with Type 14 bogies conveying a single, loaded 6 m long container secured on the leading end
- the product load ranged from 17 t to 25.1 t
- the first wheel-set to derail was the leading wheel-set on the leading bogie
- with 4 of the derailments, the bogie wedge heights on the first wagon to derail were within 1 mm or 2 mm of the wagon having to be withdrawn from service
- the EM80 run immediately before each derailment had not identified corrective action near the point of derailment.

14. A KiwiRail investigation team was set up in July 2008 to investigate the multiple derailments occurring at the same location. A static track geometry survey was carried out and it was determined that the track geometry was code compliant and the material components were in good order.

15. Despite the track geometry survey findings, a 30 m length of track covering the 5 derailment sites was lifted and the formation below was excavated to a depth of about 500 mm (see Figure 6). During the excavation it became apparent that the sub-grade supporting formation included soft material predominantly made up of organic fills. The soft material was excavated and taken to a dump site. A filter material was laid and the formation was replaced with a graded structural fill.

Figure 6
Excavated track formation

16. There have been no recorded derailments at this location since the formation improvements were completed.

## Appendix 5: Occurrence 07-111, derailment between Mauriceville and Pahiatua on the Wairarapa Line, 27 July 2008

1. On Sunday 27 July 2008, Train F12 was an express freight service travelling from Wellington to Palmerston North via the Wairarapa Line. The train consisted of locomotives DFT7226 leading, DX5108 in trail and DC4692 dead hauling 24 wagons, with a gross weight of 888 t and an overall train length of 430 m. At about 1438 the leading wheel-set on the leading bogie of the rear wagon, UKA1002, derailed towards the left-hand side of the track at 148.020 km[21] on the Wairarapa Line, between Mauriceville and Pahiatua.

2. The driver felt a slight surge in the train and when he looked back along the train he saw a cloud of dust. He applied the train brake immediately and stopped the train 698 m past the point of derailment. After inspecting the derailed wagon, he secured the derailed wagon and the wagon ahead, advised train control and made arrangements for the head of the train to clear the section.

### Track and operating information

3. The maximum authorised speed for express freight trains travelling between 144.29 km and 158.50 km with vehicles with an axle load exceeding 16.3 t and DX class locomotives was 55 km/h.

4. Download data from the event recorder on the lead locomotive confirmed that Train F12 had been travelling at 58 km/h when wagon UKA1002 derailed.

5. From witness marks on the head of the rail, the point of derailment was confirmed as 148.020 km Wairarapa Line. The track alignment at this location was straight and on a down grade of 1 in 100.

6. The track materials at the point of derailment consisted of medium-weight, jointed, 70-pounds-per-yard rail manufactured in 1926, fastened to 1964 treated Pinus radiata sleepers with N-type fastenings. KiwiRail considered one in 4 sleepers to be in poor condition, with the fastenings having "punched through" the support area. During 2008, every fourth sleeper had been replaced with a second-hand sleeper of mixed age. The ballast profile was also in poor condition and the track had last been mechanically tamped and lined during April 2000.

7. The track between Masterton (90 km) and Woodville (171 km) was inspected on a weekly basis and had been inspected the previous week. From that inspection there was no maintenance work identified near the point of derailment.

8. The most recent EM80 track evaluation run between Masterton and Woodville had been completed on 4 June 2008. No track condition outside maintenance tolerance limits had been identified near the point of derailment.

9. A full track geometry measure-up was carried out on the undisturbed track leading up to and immediately past the point of derailment. The analysis of the data suggested that although there were some issues with the line and top, there were no significant track geometry issues.

### Wagon UKA1002

10. Wagon UKA1002, travelling with handbrake leading, was conveying a 6 m long HUG container loaded with grain from Ashburton to Palmerston North. The container, loaded to within 320 mm of the top, had a declared product weight of 21.1 t and was secured on the leading end inner twistlocks in accordance with KiwiRail's Freight Handling Code. The loaded wagon had travelled 590 km from Ashburton to the point of derailment.

[21] The distance in kilometres from a track reference point located at Wellington.

11. The wagon was examined after the derailment. The float, recorded as 8 mm at the handbrake end and 12 mm at the non-handbrake end, was within code. The friction wedges exhibited significant wearing and the wedge heights at 39 mm and 40 mm on the leading bogie and 38 mm and 42 mm on the trailing bogie were at or near the condemning limit of 42 mm.

12. The wagon had last had a B-Check on 14 November 2007 when a draw-bar assembly was replaced and all 8 brake blocks were replaced. Eight bearing adapters had been replaced when the previous C-Check was completed on 13 October 2006. The 10-yearly brake check had been completed on 7 May 2003.

## Appendix 6: Occurrence 07-111, derailment between Hangatiki and Otorohanga, on the NIMT, 1 October 2009

1. On Thursday 1 October 2009, Train 230 was an express freight train travelling from Wellington to Auckland. The train consisted of electric locomotives EF30134 and EF30013 hauling 41 wagons, with a gross weight of 1442 t and an overall train length of 718 m.

2. At about 1207, the leading wheel-set of the leading bogie on wagon PK3328, the thirty-third wagon, derailed at 490.030 km NIMT, between Hangatiki and Otorohanga. The derailed wagon, conveying a 6 m long container loaded with grain secured at the leading end, was dragged almost 2.5 km until there was a sudden loss of brake pipe air pressure when the train parted immediately behind the derailed wagon and the train brakes applied automatically. When the train stopped, the leading bogie on wagon PK3328 had derailed all wheels towards the right-hand side. There was a separation of 139 m between the derailed wagon and the rear portion of the train.

### Track and operating information

3. The track at the point of derailment was in the body of a 670 m left-hand curve on a down grade of 1 in 600.

4. Although the ballast was considered to be in good condition, there was a soft spot with some water ponding under the left rail (low-leg of the curve) at the point of derailment.

5. The locomotive event recorder download confirmed that the train had been travelling at the maximum authorised line speed of 80 km/h when wagon PK3328 derailed.

### Wagon PK3328

6. The container, with a declared weight of 21.05 t of grain, had been secured with the inner twistlock pins to wagon PK3328 at Ashburton. The loaded wagon had travelled 932 km before derailing.

7. The wagon was examined after the derailment. The wheel profiles, friction wedge heights, float clearances and draw-gear heights were all within code. There was no fault found on the wagon that was considered contributory to the derailment.

8. The wagon inspections were current. The last B-Check had been completed on 7 July 2009 when 2 fused brake blocks were replaced, 2 months after all 8 brake blocks had been replaced on 5 May 2009. The most recent C-Check had been completed on 21 October 2008.

## Appendix 7: Derailments attributed to dynamic interaction

1. A train derailment attributed to 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 the derailment. However, when in combination these conditions can result in a derailment.

2. With dynamic interaction derailments, the speed of the train does not necessarily mean the train was travelling too fast. A 1990 publication by an International Government Research Program on Track Train Dynamics on Train Derailment Cause Finding identified the usual speed for "bogie hunting" derailments as being above 75 km/h. Hunting increases the lateral forces that lead to wheel climb and in extreme cases cause wheel lift, often on straight track. This means that while speed can be a factor in derailments attributed to dynamic interaction, this is not necessarily a reflection of driver technique but more an unfortunate combination of the condition of the track, the state of the wagon and the speed at which the wagon was travelling.

3. A wagon has a complex suspension system through which it resonates at a natural harmonic frequency when subjected to some external force. If a force is applied that causes the wagon to roll, the springs on one side of the bogie compress. The energy stored in the springs then feeds back into the wagon body to compress the springs on the opposite side of the bogie. This behaviour continues at a constant frequency and amplitude unless an additional force is applied. Should an additional force be applied in phase, such as when passing over track with irregularities, the amplitude of oscillations can increase rapidly and lead to wheel unloading and eventually wheel climb. A wagon's ability to resist such a condition is reduced when the friction wedge heights are at or near the condemning limit.

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Price $28.00

ISSN 1178-4164 (Print)
ISSN 1179-9102 (Online)