Wairarapa SW Carriage Rough Ride and Vibration Review

Planning, Delivery and Tolerances

Prepared for KiwiRail and Greater Wellington Regional Council
Prepared by Beca Limited
Commercial in Confidence

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Contents

Appendices

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Executive Summary

There has been significant investment in both the Auckland and Wellington Metro Networks since July 2020 with increased funding allocated to complete catch up renewals and upgrade tracks, bridges, tunnels, and signalling. Work started on the Wellington Metro Network in 2021, including upgrading the track north of Remutaka Tunnel. The investment in the Wairarapa Line in particular has focused on catch up renewals, after years of deferred renewals caused by historical funding limitations.

Rough rides and vibrations in South Wairarapa (SW) type carriages (SW-type), on certain sections of track, were first reported north of Remutaka Tunnel in November 2022, which following track and train inspections confirmed oscillatory or side to side movements (i.e. "hunting"). Seven speed restrictions are currently in place, as reductions in train speed reduce the severity of the vibrations in carriages. Locomotive Engineers have not reported hunting, nor has the EM80 Track Inspection Vehicle[1] (EM80) correlated track faults to hunting. Data loggers have been installed in some SW-type carriages to confirm hunting locations, and a trial of changing track insulations to amend the gauge has also been completed.

Railways are a system that are made up of multiple variables, hence to identify possible causes and solutions to reduce hunting in SW-type carriages, both above and below track aspects have been reviewed. As hunting propensity in carriages is increased by multiple factors, including:

- carriage design, including loading;
- the rail wheel interface gap (i.e. track gauge, rail head profile, wheel flange width, wheel condition including profile, and wheelset back-to-back measurements);
- carriage suspension characteristics (i.e. more modern bogies have improved capability to dampen out forces); and
- speed (i.e. it is more prevalent as trains accelerate and increase speed on tangent track).

KiwiRail engineering specifications confirm tolerances are 1068mm track gauge, including -4mm/1064mm or +2mm/1070mm on newly installed concrete sleepers. Track gauge is measured dynamically (i.e. underload) at a regularly frequency by the EM80, so faults can be identified and rectified, which confirms track gauge is predominantly 1066mm to 1070mm.

The condition of carriage wheelsets is defined by three profiles; C1 – new, C2 – alternative, and C3 – last turning profile (before wheels are condemned). The wheel flange width reduces by 2mm each time a wheel is reprofiled, which aids to maintain maximum life and ride quality. Currently, 17 of the 18 carriages have wheels at a C1 profile, with one at C2.

The back-to-back distance between wheels varies between the SW-type with 14 of the 18 carriages having 997 (+1 to -0mm) and four having 995mm (+1 to -1mm). An internal KiwiRail engineering change request was issued in September 2016, after Greater Wellington Regional Council (GWRC) took over responsibility of SW-carriages in July 2016, reducing the back-to-back distance between wheels to 995mm. Implications of this change to GWRC, Transdev and Hyundai Rotem needs further review and clarification, as some wheelsets pressed by KiwiRail have been

[1] The EM80 Track Inspection Vehicle is the network calibrated advanced monitoring vehicle designed to check the condition of the rails, detect any irregularities or faults (including gauge), and validate that the tracks remain within defined engineering tolerances.

updated to 995mm, whereas National Rail System Standard/6 – Engineering Interoperability Standards (2013) states 997mm.

Carriages and bogie suspension is inspected at regular intervals by distance and time intervals. Bogie rebuilds are planned in every 400,000kms, and currently 5 of the carriages are planned in for next year. Although specific records were not checked, it was commented that no change in inspections or maintenance has occur, except that wear liners replacement has increased from 2023, and brake blocks are also cracking and needing earlier replacement.

Based on the information provided and reviewed, the track and carriage factors causing increasing hunting propensity in SW-type carriages on the Wairarapa Line are:

- Track geometry, where track is straight and carriage speed exceeds 60km/hour, as hunting is less prevalent on curves and vibrations are reduced at speeds less than 60km/hour (i.e. hunting is likely to be still occurring, but the vibrations reduce).

- Track gauge, which also impacts the gap between the rail head and wheels. A gauge of less than 1068mm reduces the rail wheel interface gap and changes the contact points of the wheels on the rails, which then at higher speeds increases the likelihood for them to hunt for the optimal rail wheel contact point (i.e. increasing the likelihood for vibrations).

- SW-type carriage suspension has no lateral damping, as found in the SE and Martangi carriages, with increased sensitivity to changes in the rail wheel interface (i.e. it cannot dampen out certain vibrations past a certain speed, which are transferred into the carriage). During the interviews held, there were anecdotal reports of vibrations in SE-type and Martangi carriages, but this is yet to be formally verified by data loggers. Additionally, similar works in Auckland Metro has not seen any increased reporting of hunting or vibrations, which suggests SW-type carriages have increased sensitivity to rail wheel interface changes.

- Wheelset condition, the back-to-back distance, and wheel flange width also determine the rail wheel interface gap and the optimal contact point. A wider back-to-back and wider wheel flange narrow the gap and changes the contact points of the wheels on the rails, which then at higher speeds increases the likelihood for them to hunt for the optimal interface (i.e. causing vibrations as the wheels hunt the rail head and strike the rail face).

Based on the interviews held, and information provided and reviewed, the root causes of hunting occurring with SW-type carriages on the Wairarapa Line are:

- The history of deferred renewals on the Wairarapa Line due to historical funding limitations, following major renewals of sleepers in the 1960s and 1980s. Sleeper renewals between the 1960’s and 1980’s replaced the traditional hardwood sleepers to Treated Pinus Radiata (TPR). The 2017 Wellington Metro Upgrade Business Case identifies ~30km of these TPR sleepers were at end of life needing replacement and ~5km of rail close to wear limits. Had progressive renewals been occurring at regular intervals, the quantum of work needing to be completed from 2020 would have been significantly less.

- TPR sleepers have not been widely installed since the mid 1980’s, when pre-stressed concrete sleepers became supplanted. The use of concrete sleepers is now current practice throughout the KiwiRail network due to their structural performance, lifespan, ease of inspection and replacement. However, due to historical deferred renewals, coupled with an update in sleeper type, there has been a significant improvement in track gauge variability around the nominal 1068mm. The renewals work completed to date has now achieved a 32% improvement on nominal gauge variability (1066mm-1070mm), with EM80 track gauge data revealing:

- 2023 track gauge data, 89% between 1066mm and 1070mm, with 96% between 1064mm and 1070mm (expected engineering tolerance for concrete sleepers)

- 2020 track gauge data, 57% between 1066mm and 1070mm, with 96% between 1062mm and 1076mm.

- Due to the improvement in nominal gauge reducing overall variability, previously unknown hunting sensitivity in SW-type carriages has begun to appear on tangent track at speeds greater than 60km/hr. Hunting in SW-type carriages or other trains caused by track renewals was never known or documented prior to the renewals work being planned. As such, no consultation was undertaken between any of the parties when scoping the renewals, as there was no previous risk that the work might cause train interoperability issues. Existing KiwiRail specifications have also subsequently been used to select the materials, so no change management or stakeholder consultation was needed, as nothing had changed or might be deemed different to cause any interoperability issues.

- Hence, hunting in SW-type carriages is now occurring in some sections of renewed tangent track, where track gauge is compliant (within tolerance) but less than 1066mm, travelling in excess of 60km/hr, due to unknown possible limitations within the SW-type lateral dampening capability. In comparison, trains in the Auckland Metro network at greater speeds, on the same type of replaced track have not had any reports of hunting, increased maintenance on carriages, nor track components (i.e. insulators) failing at faster intervals.

Broader recommendations are provided at the back of this report, which identify a range of actions. However, to remove hunting a range of progressive targeted works will be needed. The works will need to be coordinated and continually tested with data loggers to confirm hunting is reducing. Testing with data loggers is important, as they provide independent verified data on the actual forces being transferred into carriages, and therefore provide confidence that changes are reducing hunting as trains start increasing speed. Possible works identified include:

- Rail Head Grinding – Grinding alone will not remove hunting, although it may reduce its severity in the short term. Grinding will however enable an optimum rail wheel interface and reduce the likelihood of other longer-term track and wheelset defects (e.g. rolling contact fatigue, guttering, etc).

- Wheel reprofiling – Changing C1 wheel profiles on SW-type carriages to a C2 wheel profile reduces wheel flange width, improving the rail wheel interface gap by ~4mm.

- Back-to-back distance – Depending on the improvements gained by grinding and wheel reprofiling, adopting the 995mm (+/- 1m) back-to-back should also reduce the likelihood of hunting. As reducing the distance between the wheel flanges also improves the rail wheel interface gap by a further ~2mm.

- If the above works do not reduce hunting in all SW-type carriages, then confirmed isolated track locations where hunting remains will need to be individually investigated. Site specific changes, such as changing insulator configurations (i.e. reclipping), will then need to be further tested. However, widespread changes to increase the gauge beyond 1068mm should only be a last option, as this changes the contact points between the wheels and rail which has potential to create longer-term maintenance issues in both wheels and track.

1 Introduction

1.1 Chronological summary of key documents and events

Relevant information was reviewed before interviews, and requested during interviews, which is summarised in Appendix A, with more detailed relevant information provided in Appendix B. The following section chronologically summarises key time periods relevant to identifying root causes and the identification of hunting in SW-type carriages.

Pre 2017

In 2000 a Technical Report was written by Rail Services Australia on the Rail Wheel Interface Improvement for Tranz Rail. Tranz Rail were exploring what changes they could make above rails to extend the potential life of both wheels and rails, to reduce the longer-term costs of replacing rails and machining of the wheels to restore profiles. As one of the main reasons for the very severe wear in rails and wheels is the high proportion of sharp curves present in the National Rail System. The report focused on the rail wheel interface and provided recommendations to achieve improvements, in particular:

- reduced rail wear;
- reduced wheel wear;
- reduced development of defects;
- reduced cost of rail and wheel maintenance;
- reduced energy associated with wheel-rail interaction;
- improved network capacity; and
- any additional parameters.

The report provides reference to research that identifies the benefits that can be gained by designing suitable wheel and rail profiles, including:

- Improved steering characteristics of wheelsets in curves, and hence reduced flanging forces and wear, together with a reduced risk of wheel climb.
- Improved wheel/rail contact stress and creepage conditions, and hence reduced incidence and severity of contact fatigue defects.
- Improved dynamic characteristics of wheelsets, and hence reduced levels of vehicle hunting particularly in tangent track and shallow curves.
- Improved loading characteristics on the rails, and hence reduced section stresses providing an opportunity for increased rail head wear limits.

The report then confirms that with a 997mm back-to-back on 1068mm gauge:

- Modified wheel and rail profiles will satisfy the main wheel-rail contact requirements, including a definite two-point and relatively broad contact near the centre of the running surface of the tangent rails, which reduce the sensitivity to vehicle hunting and adverse vehicle/track dynamics;

- The marked benefits associated with operating with either worn or modified wheel profiles, which lead to a reduction in the flange energy of about 90%.

The report then makes multiple recommendations, which KiwiRail state are still valid today, and have formed the basis for the current rail grinding profile, current work looking at rolling contact fatigue, and some wheel profile changes. This report also formed the basis of moving to a reduced back-to-back of 995mm in 2016. 995mm was arrived at as a lower limit due design of turnouts and certain track features, not the 5mm reduction (992mm) that was identified in the report.

This report also identifies and recommends that if hunting on tangent track at higher speeds becomes evident then the following three options should be considered;

- Reduce the wheelset back-to-back distance by 4-5 mm (995mm adopted in 2016); and/or
- Reduce the wheel flange thickness by up to 2 mm (i.e. C2 wheel profile); and/or
- Apply the tangent rail profile by rail grinding (currently planned in).

In 2013, National Rail System Standard 6 - Engineering Interoperability Standards - Issue 4 (NRSS /6) was updated. NRSS/6 outlines the minimum requirements for rail vehicle interoperability on the National Rail System. It includes an unchanged back-to-back at 997-988mm and flange widths unchanged, provided in wheel profile drawings provided in Appendix A (i.e. C1. C2, and C3).

Then in July 2016 Transdev Wellington took over the operation of commuter train services in the Greater Wellington region, including the Wairarapa Line from KiwiRail's subsidiary Tranz Metro. The change was part of a wider transition involving the management of the region's rail services. Since then, Transdev Wellington, under the brand name Metlink, has been responsible for running Wairarapa Line services.

In September 2016, an internal KiwiRail Engineering Change Request was issued, instructing the change in back-to-back to 995mm (+/- 1mm). The driver for this change was the analysis and recommendations from the Rail Services Australia Report from 2000, which identified benefits to the National Rail System by moving to a reduced back-to-back.

2017 – 2021

In November 2017 a jointly sponsored Single Stage Business Case by KiwiRail, as the network asset owner, and Greater Wellington Regional Council, as the predominant network asset funder and user, was prepared. It was written to obtain Crown funding for track and civil engineering infrastructure catch-up renewals throughout the Wellington Metro Railway Network.

The primary focus of the Business Case was the Wairarapa Line seeking investment to renew track assets which were approaching the end of their useful lives. A peak of future renewals work exceeding the capacity of the current funding models to address had been identified, which without additional funding, would cause significant impacts on service levels. At that time, the line already had significant speed restrictions in place due to deteriorating asset condition which were forecast to increase in quantity and severity without additional funding. Funding was therefore targeted at removing and preventing any additional speed restrictions, no benefits of increasing Wairarapa line speeds to 100km/hr were assessed.

The Business Case states that overall condition of the Wairarapa line is poor and deteriorating (see Figure 1). It is the worst condition route on the Wellington network. *"There are significant numbers of decayed sleepers, with poor fastenings, and over 5km of rail at or close to wear limits. Need for renewal primarily reflects the track and formation time in service. The line has had little major renewal activity since it was face-renewed with Treated Pinus Radiata (TPR) sleepers over a relatively short period between the 1960's and early 1980's. Deferred maintenance caused by funding limitations has further contributed to build a bow wave of renewals work. This concentration of similar aged assets falling due over a limited period is behind the scale of renewal required"*.

Overall, the Business Case identifies the main deficiencies as:

- Approximately 30km of end-of-life TPR sleepers;
- Poor ballast and formation throughout, in places exacerbated by poor drainage;
- End of life and poor condition track in Tunnel 1 and (major) Tunnel 2;
- Bridges with end-of-life timber elements; and
- 1 high risk slope.

Figure 1. From Single Stage Business Case, "*deteriorated Treated Pinus Radiata (TPR) sleepers. These are endemic on the Wairarapa Line, with the sleepers replaced during significant volumes of renewals nearly 40 years ago now having run through their life cycle"*

The Business Case also provides a summary of the TPR sleeper legacy issues and changes to concrete. TPR sleepers have not been installed on the network since the mid 1980's, when pre-stressed concrete sleepers became supplanted. The use of pre-stressed concrete sleepers is now current practice throughout the KiwiRail network and other railways around the world due to their superior structural performance, lifespan, ease of inspection and replacement.

Risks to train and carriage interoperability was not covered nor mentioned. As the risk of hunting in SW-type carriages or other trains caused by track renewals was not known or had been previously identified prior to the quantum or type of renewal work being specified for the Wairarapa Line. No consultation was therefore undertaken between any of the parties, or engineering change management, as there were no risks in the scope of work that might impact train interoperability.

2022 - 2024

KiwiRail commences catch up renewals of the Wairarapa Line, which will be finished in 2028. GWRC's new hybrid trains are expected in 2029 which allows them to utilise the existing overhead power and then run on the non-electrified sections. Supported by KiwiRail's renewal works, they will allow for more peak and off-peak services.

To date ~38km of the 50km of track has been completed north of Remutaka Tunnel including re-railing and re-sleepering from life expired timber to concrete in many sections.

Completed works to date include:

- Renewed 58.8km of track to Masterton, including the 572m Maoribank Tunnel.
- Replaced the drainage in the Maoribank and Remutaka Tunnels.
- Replaced three aging bridges.

Remaining works:

- Replace the track in the 8.8km Remutaka Tunnel, so trains can go through it faster than 60 km/h. This work is scheduled for the Christmas 2024 network shutdown.

Reports of hunting first began in November 2022, KiwiRail received an emergency call that travelling in SW-type carriages "*the train shakes from side to side*" between 77km – 78.2km (Carterton – Clareville Waingawa) on the Wairarapa Line (WRL). The track was inspected by KiwiRail, and the geometry was found to be within engineering tolerances (i.e. Table 3 of T200 Track Handbook). The last EM80 report was also checked, which had no track geometry tolerance exceedances in the area. Hyundai Rotem (SW-type carriage maintainer) was also notified who inspected the carriages and subsequently found antiroll bars needed replacing.

In February 2023 KiwiRail received information that Hyundai Rotem was still reporting the vibration issue was occurring. Hyundai Rotem had inspected the carriages and found no issues with the antiroll bars, so requested the track north of Carterton be checked. KiwiRail confirmed the track had been re-laid in this area, but had been tamped, inspected, and was ok for linespeed (based on the track measurements and tolerances).

In July 2023 Hyundai Rotem again reported that they were having the vibration issues at 80km/hr, just north of Taita, and just north of Matarawa. They had upped inspections on carriages and maintenance but with very little improvements, so requested the track be checked. KiwiRail completed track inspections via trains, and confirmed the vibration sounds like the "*bogie slapping on the underneath of the carriage*" and referred it back to Hyundai Rotem, as the track geometry had no engineering tolerance exceedances, and the vibration issues were initially thought to be isolated to some SW-type carriages.

In late July 2023, multiple reports were raised increasing locations of rough rides by train crews. KiwiRail suggested Temporary Speed Restrictions (TSRs) in the worst locations as vibrations were significantly less at lower speeds. KiwiRail also sent additional engineers out to inspect via on board monitoring and found SW-type carriages were having increased vibrations at four locations.

As of 24th March 2024, there are 21 TSRs on the Wairarapa Line, seven are vibration, with six north of Featherston, and one Taita, with five at 60km/hour, one at 40km/hour, and one 25km/hour.

Data loggers measuring the vibrations and rough rides were then installed and measurements taken on a SW-type test train, which confirmed that hunting was occurring. Varying locations were identified within the carriages for data loggers to be installed, which also confirmed increased forces measured directly above the bogies versus loggers located in the centre of the carriage.

KiwiRail also completed a track trial to test the SW-type carriage sensitivity to changes in track gauge. They changed insulators (i.e. reclipping) between 68.3km - 68.8km which widened the track gauge to 1071mm (versus 1066mm either side of the trial). This trial confirmed that when the track gauge was widened, increasing the rail wheel interface gap, hunting was reduced at speeds up to 80km/hour.

1.2 Hunting

Hunting is a term used to describe the dynamic instability that can occur when a train is in motion. It describes an oscillatory or side-to-side movement of the wheelsets or bogies that can become increasingly pronounced at higher speeds. This lateral motion can cause the wheel flanges to repeatedly strike the rails, causing vibrations and leading to uneven wear on the wheels and rails, which over time can cause track and carriage defects. There are typically multiple factors that contribute to hunting, which include:

- carriage design and carriage suspension characteristics;
- the rail wheel interface gap (which involves the back-to-back measurements of wheelsets, the flange width of wheels, and track gauge); and
- speed on tangent track.

The repetitive lateral forces exerted by hunting over the longer-term impacts both the track and the carriages, including

- Increased fuel consumption;
- Increased and abnormal wear of the rail head;
- Increased track maintenance due to increased forces exerted on rail components (i.e. pads, insulators, and clips) and the supporting ballast;
- Faster wear on rollingstock wheelsets and bogies, causing increased faults and preventative maintenance; and
- Derailment risk also increases if speeds are not reduced, as a result of increased possibility of wheel climb.

1.3 Scope of the review

Railways are a system that are made up of multiple variables, hence to identify the causes and possible solutions to reduce hunting propensity in carriages, both above and below track aspects were investigated. The KiwiRail, below track scope included:

- Confirm the process that was undertaken to rerail the line, including timeline, planning decisions, approvals, and quality assurance/quality control mechanisms (e.g. design, specifications, pick up, installation, and code of compliance);

- Confirm roles and responsibilities, including which teams decided what, and who inspected/authorised/approved key decisions;
- Identify causal factors, and possible recommendations to prevent reoccurrence; and
- Produce a final report summarising the causal factors and recommendations.

The Greater Wellington Regional Council (GWRC), above track scope included:

- Confirm SW-type wheelset tolerances and current measurements;
- Confirm SW-type bogie maintenance intervals and current condition assessments (maintenance history);
- Identify relevant documents, including their revision history re changes/updates to measurements, tolerances or maintenance interventions;
- Identify likely root causes that are contributing to vibration and rough ride issues;
- Provide a table of possible solutions; and
- Reviews needed or changes to existing tolerances, standards, or maintenance practices.

Specific questions to be answered include:

- Has the rail been constructed within existing KiwiRail tolerances?
- Are the KiwiRail rail tolerances fit for purpose when there is a range of wheel profiles running on the line?
- What can be learnt from this incident about wheel profile tolerances? Reviewing selected incidents, from existing available reports and selected interviews with nominated KiwiRail Staff;
- Review current engineering change processes, including what is defined as an engineering change, current processes, standards, etc. Includes all standards relevant to new rolling stock or changes to track standards and tolerances, including timing of;
    - Comment on possible broader implications, including;
    - Current rolling stock maintenance intervals; and
    - 2029 future rolling stock (Lower North Island Rail Integrated Mobility[2]).

2 Methodology

2.1 Interviews

Interviews with 17 people were held on throughout March and April via Microsoft Teams and in person at KiwiRail Offices, GWRC Offices, and at the Hyundai Rotem workshop. Relevant documents and information were identified through the course of the interviews, and is listed in Appendix A.

[2] https://www.gw.govt.nz/document/19521/detailed-business-case-lower-north-island-rail-integrated-mobility-2021/

2.2 Document and Information Reviewed

Through the interview process, several documents and a variety of information was requested and provided. Those documents identified as most relevant to the scope of this review are listed in Appendix A. A quick turn-around for findings and recommendations was requested, hence this review summarises all provided information.

2.3 Scope Exclusions

Given the timeframes to complete, interviews were ~1-2 hours long each, and questions were focused predominantly on the scope and what supporting information was available. As such no detailed additional analysis or detailed investigations were possible.

2.4 Inherent Limitations

In carrying out our review, we have undertaken tests of selected controls as appropriate. Occasions may arise where the nature of the controls, the lack of controls or circumstances of the independent review require us to undertake alternative review procedures. The decision to test, or not to test controls, is made by us solely at our discretion. Because of the inherent limitations in any system of internal control, errors, fraud, or irregularities may occur and may not be detected.

Our independent review fieldwork was completed on 10th April 2024. Our findings are expressed as at that date. We have no responsibility to update this report for events or circumstances occurring after that date.

3 Findings

3.1 Planning and Delivery of Capital Works

The scope of work and design for the Wairarapa line is compliant to KiwiRail Track Standards and tolerances according to EM80 data, using standard concrete sleepers, 50kg/m rail, and ballast cleaning to increase asset condition and track quality. The works completed was identified from the existing KiwiRail maintenance work bank, which then went through internal KiwiRail reviews and approvals. No wider consultation occurred as all planned works was within existing KiwiRail standards and tolerances, hence no change or contract requirement to engage.

Works have been delivered predominantly by local KiwiRail teams utilising existing standards and task instructions. Track gauge is inspected, as per T-TI-WO-5926 – Face re-sleepering, with "*Documentation associated with the assessment for speed and clearing for passage of rail traffic must be compiled and cited by the Production Manager before handing back to traffic".*

Rail grinding post rerailing, as defined in the rail management standard, is an activity that is programmed based on track curve radii and route tonnage. Grinding tangent track will improve the rail wheel interface, but typically curved track with high tonnes has increased benefit by moving the contact band away from the stress zone on the rail head.

The Wairarapa Line is predominantly tangent track with low tonnage (e.g. 1.1 Million Gross Tonnes Per Annum MGTPA vs Wellington to Trentham which is 4.3 MGTPA), hence grinding post rerailing would have been proactively prioritised relative to other parts of the network. Passenger services also make up ~70% of Wairarapa Line tonnage, so predominately passenger services with minor freight.

Grinding alone will also not significantly reduce the likelihood of hunting of SW-type carriages. Grinding will however help by creating a smoother wheel-rail interface, improving contact rail wheel, and reducing frictional forces that may contribute to the lateral instability of trains.

Summary Findings

- Roles and responsibilities for review and approval of planned works, and completed works utilised existing internal KiwiRail standards and processes
- Design, the materials used, and installation methods are defined in KiwiRail standards (listed in Appendix A)
- Grinding is prioritised across the network to optimise the cost against longer-term preventative maintenance
- Grinding of tangent track will improve the rail wheel interface in the short-term but will not significantly reduce the likelihood of hunting of SW-type carriages

3.2 Track Tolerances

The track gauge on tangent (straight) track is 1068mm, with a construction installed tolerance on concrete sleepers as completed on the Wairarapa Line, of between +2 and -4mm (T-ST-DE-5200 Track Design). The greater lower tolerance of - 4mm is needed as over time rails will “settle in” and the gauge will widen over time towards a nominal 1068mm (see Note below in Figure 2). A gauge of 1068mm after 6 months is not a set target but indicates depending on multiple factors (e.g. train loading) that gauge will be within acceptable engineering tolerances (i.e. nominal gauge).

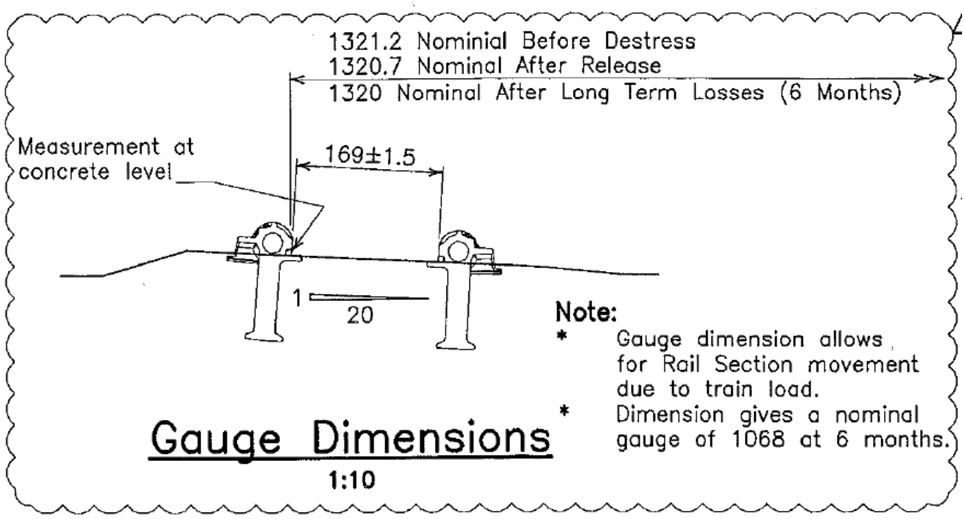

Figure 2. Standard Drawing (September 2011), identifying how a gauge narrower than 1068mm is designed, as it assumes movement will occur over time, depending on the frequency of train tonnage, but a nominal gauge of 1068mm could be expected after 6 months.

The EM80 measured the line on 7th December 2023, between 32.6km and 91.4km and gauge was found to be within engineering tolerance, with only two faults associated with track gauge identified at 32.8km (1052mm on a turnout) and 63.1km (1060mm on a bridge).It can be seen on the EM80 report where the gauge is less than and greater than 1068mm, but additionally it confirms no technical faults (i.e. track geometry including gauge is within allowable measured engineering tolerances) directly correlate to reported hunting.

The EM80 report also identifies where a trial was done by KiwiRail to widen the gauge, which confirms in the December 2023 EM80 data that between 68.3km - 68.8km track gauge was 1071mm (vs 1066mm either side of the trial). This trial also found that when the track gauge was widened by changing the insulator configuration (i.e. reclipping), increasing the gap between the rail head and wheels (rail wheel interface gap), measured hunting was reduced, although not fully tested with all SW-type carriages at speeds greater that 60km/hour.

A Ground Penetrating Radar report, published April 2019, between 19km and 91km was also reviewed, to see if current vibration locations correlated with possible poor track bed condition. This report showed that track bed is more or less consistent and there was no evident correlation of vibration issues to changes in track bed condition.

Rerailing has changed the rails from imperial 91lb/yard to metric 50kg/m rail, so CAD drawings were redrawn to double check the gauge using concrete sleepers. This drawing supported what is being seen on site, with track gauge measuring a minimum of ~1064mm, the EM80 measuring under dynamic testing ~1066mm, with movement over time expected to create a nominal 1068mm gauge (i.e. 1064mm-1070mm is the documented tolerance).

Summary Findings

- Track gauge is 1068mm
- Allowable engineering tolerances for the Wairarapa Line on concrete sleepers with 50kg/m rail is 1064mm to 1070mm (i.e. nominal gauge)
- Measurements and analysis show track geometry, according to KiwiRail track standards, are within defined engineering tolerances
- When track gauge was widened (68.3km - 68.8km) by changing insulators (i.e. reclipping) track gauge was 1071mm (EM80 measure), hunting was measured to be less prevalent between 60km/hr and 80km/hr, confirming the relevance of the rail wheel interface gap

3.3 Carriage Wheelset Tolerances and Bogie Maintenance

The maintenance records and inspections for bogies, together with profile tolerances for wheelsets and back-to-back measurements, are relevant factors that contribute to the rail wheel interface. Relevant documents relating to tolerances and inspections include:

- National Rail System Standard/6 – Engineering Interoperability Standards (NRSS/6) - April 2013, including SW-type wheelset profiles and back-to-back measurements.
- M9311 X28020 Maintenance Guide (September 2019) for SW-type carriages includes guidance on excess lateral movement and bogies reported as oscillating.
- M6000-100 Wheelset Manual – Wheelset Specifications (July 2021) for SW-type carriage wheelsets (X28020), including wheel diameter, rim thickness, tread diameter, and flange profile.

SW-type bogies have distance-based overhauls at “D1” 400,000km and “D2” 800,000km. Depending on carriage utilisation these overhauls typically occur every 4-5 years, with five carriages in the plan for next year. Wheelsets have on average four inspections per year, with:

- “A Inspection” at 12,000km (circa three-monthly) which checks the required dimensions against three types of pre-defined wheelset profiles (as defined in National Rail System Standard/6 – Engineering Interoperability Standards);

- "B Inspection" at 24,000km (circa three-monthly) which has broader checks, but also confirms the wheelset dimensions against the three types of pre-defined wheelset profiles;
- A further "A Inspection" at 36,000km, as above; and then
- An Annual Inspection, every 12 months, where carriages are taken out of service and given a more comprehensive inspection.

Currently, as per the defined wheelset profiles in NRSS/6, 17 carriages wheels are at C1, with one at C2 which was recently been reprofiled. A C1 profile has the same conicity as a C2 profile, however the flange thickness is reduced by 2mm on each wheel, increasing the rail wheel interface gap by 2mm. A C3 wheel profile also has the same conicity but reduces the rail flange by another 2mm.

Since hunting was first reported in SW-type carriages in 2022, there has been an increase, in their wear liners and brake block failures. The lateral movement of the wheelsets is also evident with increased "fretting" between metal-to-metal contact points (see Table 1 and Appendix C - SW-type increased maintenance photos). Table 1 also reveals that in 2024 those carriages with the majority of 995 back-to-back or a C2 profile have all had work done, possibly due to them operating within C1 or 997mm train consists and having increased vibrations transfer between carriage types. Overall, between 2020 and 2024, average work orders for the 995mm back-to-back are lower. There has also been no change in the suppliers or specifications of wear liners or brake blocks during this time.

Table 1. Work orders raised to replace brake blocks and wear liners across SW-type carriages.

Count of Work Order / Row Labels	2020	2021	2022	2023	2024	Grand Total	2020-2024 997 Average Work Orders	2020-2025 995 Average Work Orders
SW3282	1	1		3		5	1.67	
SW3294	1	1		1		3	1.00	
SW3339	2	2				4	2.00	
SW3349			3	1	1	5		1.67
SW3355	1	1	2	1		5	1.25	
SW3376	1		2	1		4	1.33	
SW3394	1			2	2	5	1.67	
SW3404	2		3	3		8	2.67	
SW5646	1			1	2	4		1.33
SW5658	2	2	2			6	2.00	
SW5820			1	2		3	1.50	
SW5837	1			2		3	1.50	
SWG3365		1	1	2		4	1.33	
SWG3422				1		1		1.00
SWG5671	1	1	1	1	2	6		1.20
SWS3298	2		1			3	1.50	
SWS5660			1			1	1.00	
SWS5723		2		3		5	2.50	
Grand Total	**16**	**11**	**17**	**24**	**7**	**75**	**1.64**	**1.30**

994-996 Back-to-Back (2021)

997 Back-to-Back with C2 wheel profile

Back-to-back dimensions of wheels is defined in NRSS/6 as "*the dimensions between inside faces of wheels or tyres on a wheelset must be between 997 and 998mm*". However, in September 2016, KiwiRail amended their internal back-to-back wheel press measurement via an Engineering Change Request (ECR1016) to 994 – 996mm. NRSS/6 has not been updated to reflect this change, and Transdev and Hyundai Rotem reportedly only became aware of the change in March 2024.

KiwiRail has supplied wheelsets to Transdev and Hyundai Rotem since mid-2016 and has been progressively changing to KiwiRail's new standard of 994 - 996mm. Potentially, new wheelsets pressed to ECR1016 should have a concession from NRSS/6 provided by KiwiRail. As to date, Transdev states no formal notice has been received from KiwiRail to instruct them on this change.

From information provided during the review (see Appendix A), the reduction in back-to-back measurement is however also advantageous to reducing hunting, as the contact point moves 2mm toward the outside of the tread, and away from the higher conicity flange root area (i.e. improving the rail wheel interface) (Transdev Report 2024).

Data loggers placed in four carriages have been measuring the actual forces generated in the carriages (Figure 3). Varying locations were identified within the carriages for data loggers to be installed, which also confirmed increased forces measured directly above the bogies versus loggers located in the centre of the carriage.

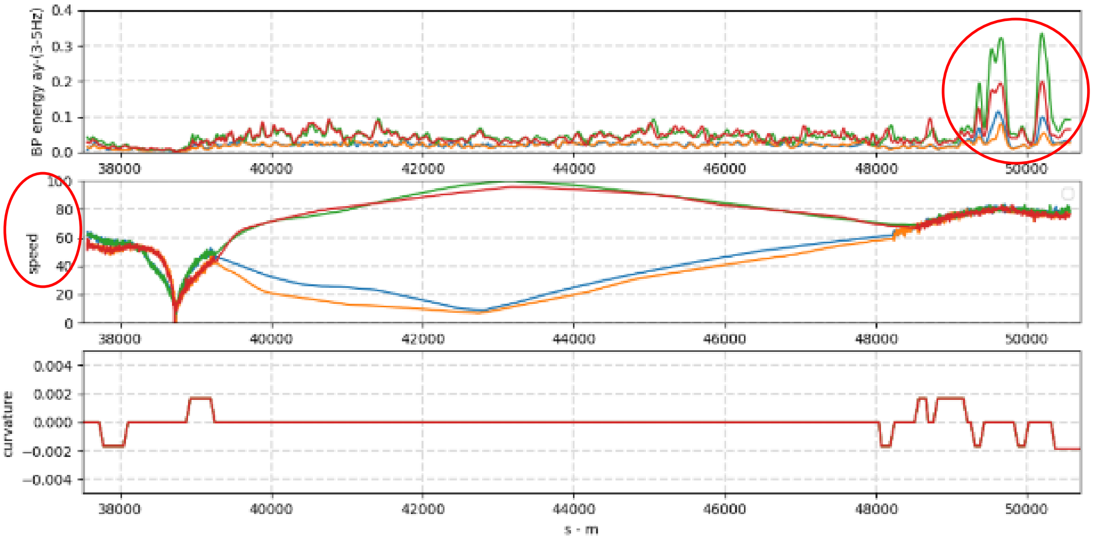

Figure 3. Data logger information recording hunting at ~49km at 80km/hour

Summary Findings

- Bogies and wheelsets are inspected and maintained at regular set time and distance-based intervals.
- Wheelset profiles are all within defined tolerances, with 17 of the 18 at C1, and one at C2
- There is variance between the carriages on back-to-back dimensions, with 14 between 997-998mm and 4 between 994-996mm
- Confirmation on the implications and history of ECR changing the back-to-back dimensions needs further investigating

4 Supporting Analysis – Identified Causal Factors

The following section reviews measurements relevant to the rail wheel interface, as it is likely changes in the rail wheel interface gap is the primary cause of hunting in SW-type carriages.

4.1 Track Gauge Changes

EM80 gauge data for from April 2020 was obtained, as this was effectively the baseline of track gauge before hunting was reported. EM80 gauge data is a standard measure of track gauge across the network in New Zealand, as the EM80 is regularly calibrated to enable consistent measurement. Since then, the only parameters in the track and train systems on the Wairarapa Line that have changed, are rerailing and re-sleepering renewals. So the 2020 EM80 data[3] was compared to the most recent December 2023 EM80 data, see Figures 4 – 7 below.

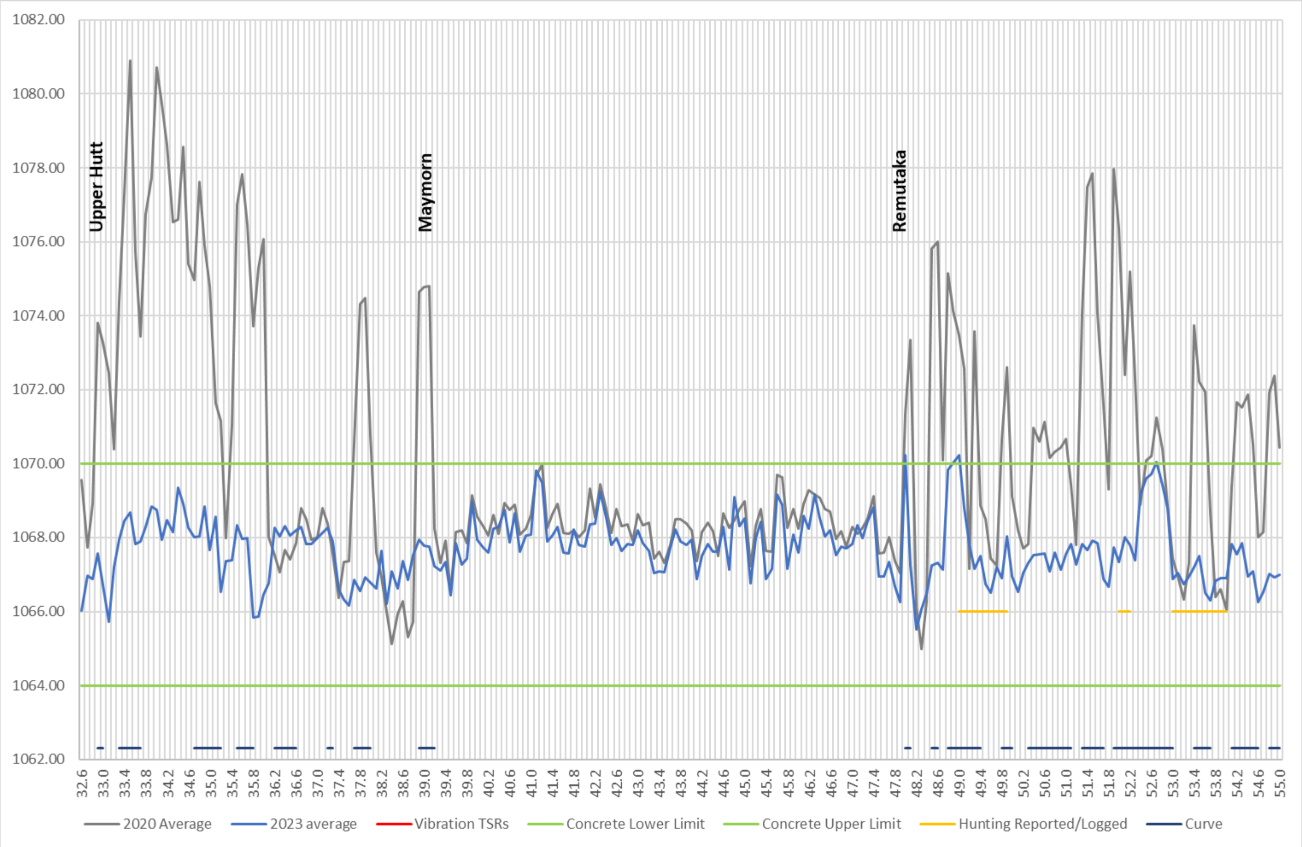

Figure 4. 2020 April EM80 data, 2023 December data, upper and lower tolerances for concrete sleepers (1068mm -4mm to +2mm), data logged/reported hunting between 32.6km to 55km. Current vibration TSRs and approximate curve locations also added at bottom of chart for context

[3] EM80 gauge data was averaged to every 100m to enable sufficient data points

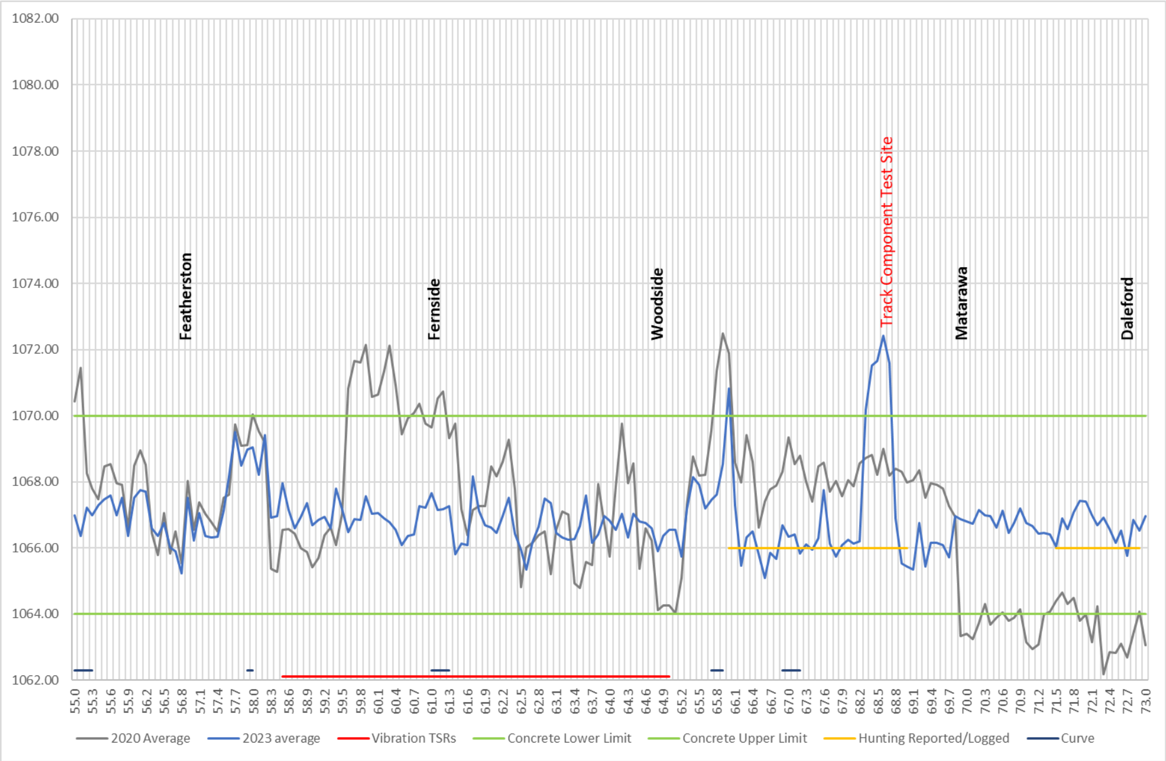

Figure 5. 2020 April EM80 data, 2023 December data, upper and lower tolerances for concrete sleepers (1068mm -4mm to +2mm), data logged/reported hunting between 55km to 73km. Current vibration TSRs and approximate curve locations also added at bottom of chart for context

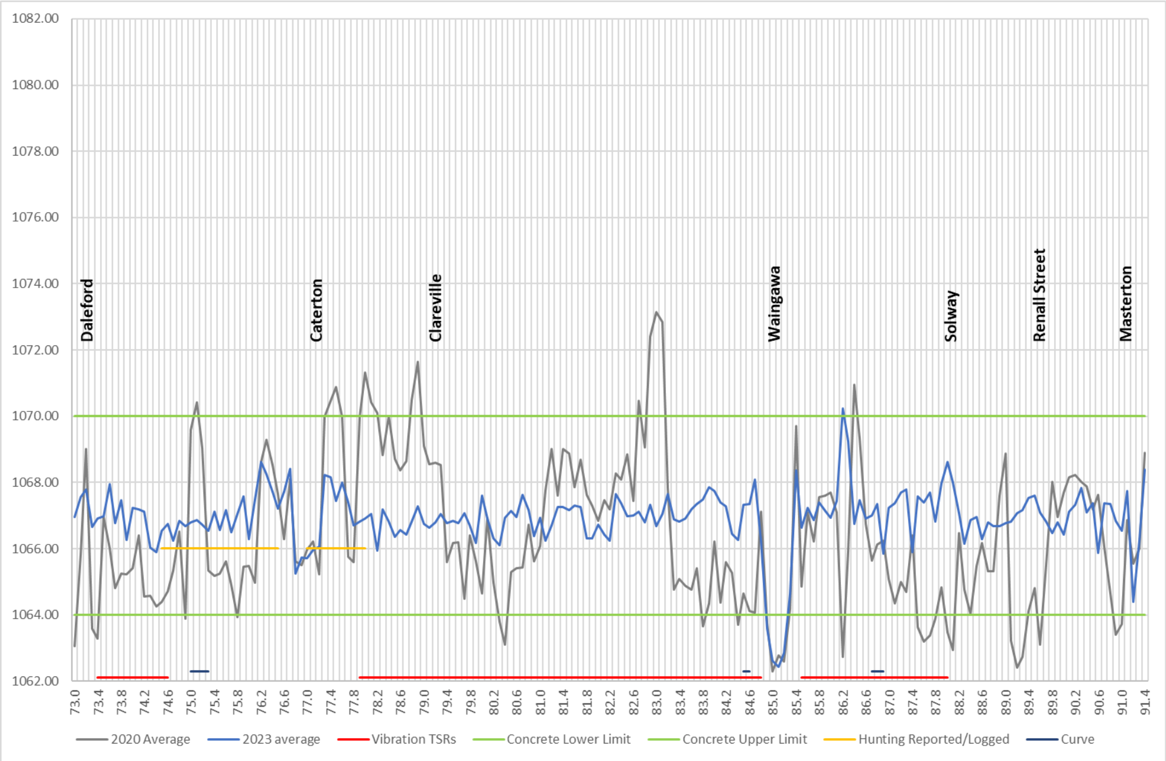

Figure 6. 2020 April EM80 data, 2023 December data, upper and lower tolerances for concrete sleepers (1068mm -4mm to +2mm), data logged/reported hunting between 73km to 91.4km. Current vibration TSRs and approximate curve locations also added at bottom of chart for context

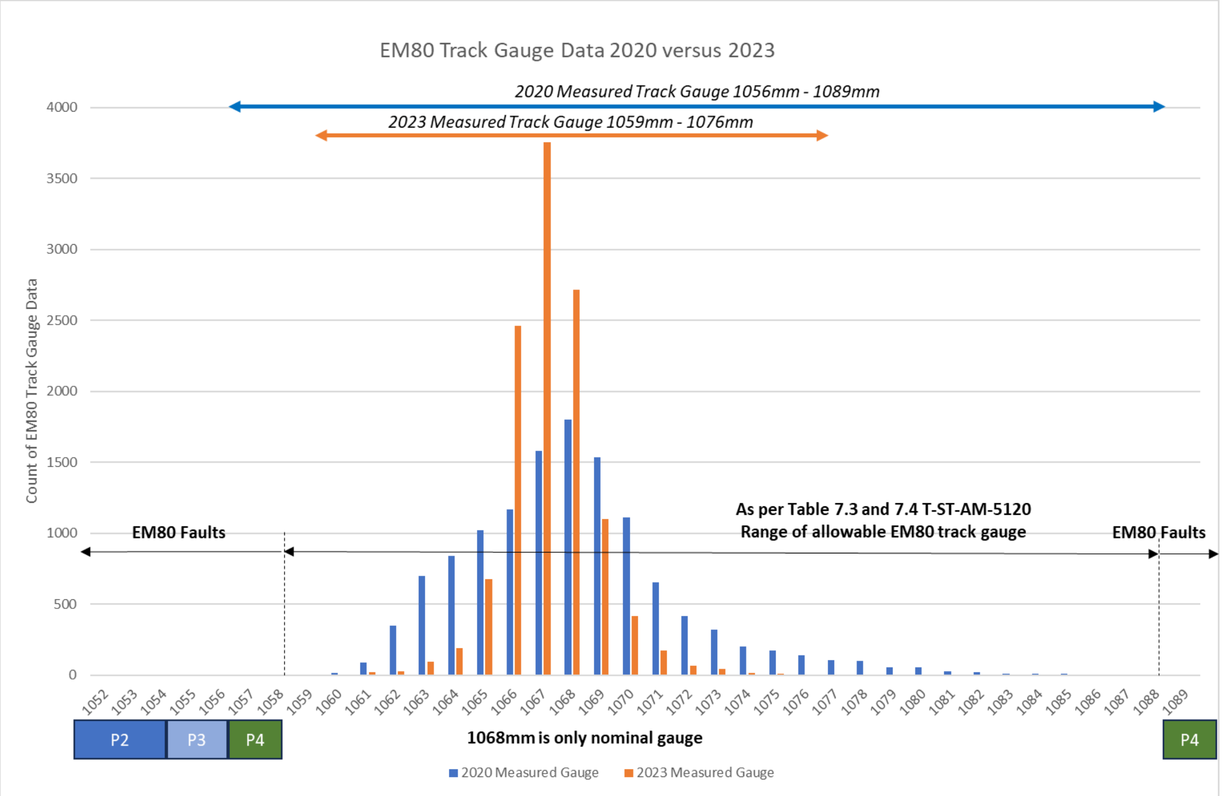

Figure 7. 2020 April EM80 versus 2023 December EM80 track gauge ranges, including EM80 defect notification tolerance and P ratings (as per T-ST-AM-5120 Track Standard: Track Geometry)

The quantum of catch-up renewals, shown in Figure 7, has achieved a 32% improvement on nominal gauge variability (1066mm-1070mm) from 2020 to 2023, with EM80 data revealing:

- 2023 track gauge data, 89% between 1066mm and 1070mm, with 96% between 1064mm and 1070mm
- 2020 track gauge data, 57% between 1066mm and 1070mm, with 96% between 1062mm and 1076mm.

Summary Findings

Reviewing the charts in Figures 4 – 7 reveals that overall:

- Track gauge variability between Upper Hutt (32.6km) and Masterton (91.4km) has improved from 2020 to 2023, because of the renewal works completed. The graphs show a 2023 track gauge is ~90% between 1066mm and 1070mm. So track gauge variability and tolerance has improved towards the nominal 1068mm
- 2020 track gauge had more variability, including more sections that are less than 1066mm, and some that are significantly greater than 1070mm. It was unexpected to find the gauge narrower back in 2020, however the rail head profile may have been more worn in these areas, on more flexible wooden sleepers, hence SW-type carriages were able to be more tolerant of this narrower gauge. The wider gauge would have been most likely due to wooden sleepers with more movement whilst be measured under load by the EM80
- Data loggers have recorded in some carriages hunting in isolated sections where track gauge is closer to 1066mm (e.g. ~66-69km and ~71.5-73km). Other areas reported and recorded for hunting are not as conclusive (e.g. ~49km-49.9, ~52-52.2km, ~53-54km,

~74.5-76.5km, and ~77-78km). Whilst other sections with gauge closer to 1066mm have also had no hunting recorded or reported to date.

4.2 Wheelset Profiles and Back-to-Back dimensions

The 2023 EM80 data identifies that the track gauge post completed works is predominantly between 1066mm and 1070mm. Wheelset dimensions also influence the ride quality of a carriage, so if track gauge now has less variability, wheel flange width and back-to-back measurements need to be examined. See Figure 8 for key measurements, and Table 2, for nominal rail wheel gap assessment.

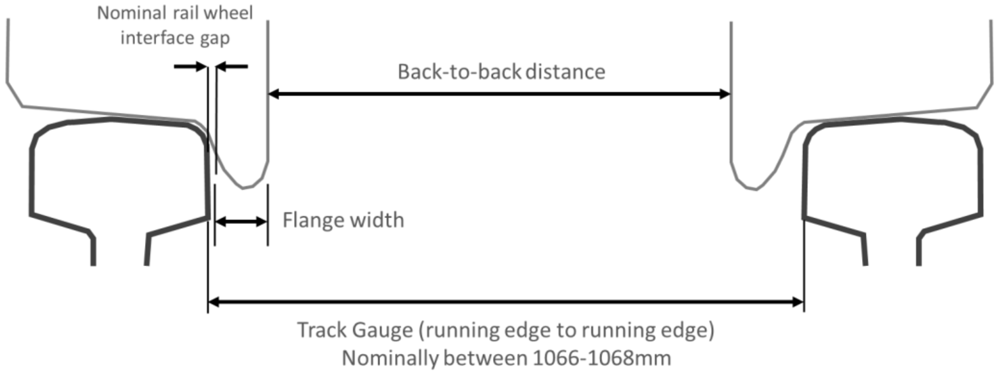

Figure 8. Nominal rail wheel interface gap, key dimensions that influence the gap.

Table 2. Nominal rail wheel interface gap analysis. Down the left side, identifies there are two different back-to-back dimensions in SW-type carriages, interfacing with a range of track gauges (1064mm-1070mm), that are then influenced by the wheel profiles C1 – C3 (with reducing wheel flange thicknesses 28mm-24mm).

		Back to Back	Track Gauge	*Remaining*	Flange Thickness Profiles - Rail Wheel Nominal Gap					
		998-997	1064-1070		C1 - Nominal Gap		C2 - Nominal Gap		C3 - Nominal Gap	
		996-994			28		26		24	
14 SW-type carriages		**998**	1070	72	16	8	20	10	24	12
		998	1068	70	14	7	18	9	22	11
		998	1066	68	12	6	16	8	20	10
		998	1064	66	10	5	14	7	18	9
		997	1070	73	17	8.5	21	10.5	25	12.5
		997	1068	71	15	7.5	19	9.5	23	11.5
		997	1066	69	13	6.5	17	8.5	21	10.5
		997	1064	67	11	5.5	15	7.5	19	9.5
4 SW-type carriages	SW3349, SWG3422,SWG5671, SW3349	**996**	1070	74	18	9	22	11	26	13
		996	1068	72	16	8	20	10	24	12
		996	1066	70	14	7	18	9	22	11
		996	1064	68	12	6	16	8	20	10
		995	1070	75	19	9.5	23	11.5	27	13.5
		995	1068	73	17	8.5	21	10.5	25	12.5
		995	1066	71	15	7.5	19	9.5	23	11.5
		995	1064	69	13	6.5	17	8.5	21	10.5
		994	1070	76	20	10	24	12	28	14
		994	1068	74	18	9	22	11	26	13
		994	1066	72	16	8	20	10	24	12
		994	1064	70	14	7	18	9	22	11

Note: Red indicates that at these rail wheel interface gaps, hunting is likely to be more prevalent. The Technical Report from October 2000 also suggested that the rail wheel interface gap for new wheels on new 50kg/m rails is approximately 9-11mm, which is more likely to be achieved on a C2 wheel profile.

Summary Findings

Reviewing the information in Table 2 it is likely that:

- The 14 SW-type carriages, with a back-to-back of 997 – 998mm, and a C1 wheel profile, will be most at risk of hunting on gauges less than 1068mm on tangent track. This is most likely due to the suspension design having a lower inherent ability to dampen forces out associated with hunting compared to more recent bogie designs (e.g. Martangi carriages)
- The 4 SW-type carriages, with a back-to-back of 994 – 996mm, and a C1 wheel profile, are also at risk of hunting on gauges of 1066 and below. This is most likely due to the suspension design having a lower inherent ability to dampen forces out associated with hunting. Additionally, as C1 wheel profiles become more worn, they will also change the contact point and rail wheel interface gap, increasing the likelihood of hunting
- Hunting in SW type carriages looks less likely to occur when wheel profiles are C2 or C3 (narrower flange widths), as the rail wheel interface gap is improved with no change in conicity (also see Appendix C - Differences between C1 and C2 asset condition).

4.3 Answers to specific questions

Specific questions to be answered were as follows.

Has the rail been constructed within existing KiwiRail tolerances?

Yes, based on KiwiRail standards provided and the current EM80 data, the renewals planned and delivered have been built and are compliant within documented KiwiRail tolerances.

Are the KiwiRail rail tolerances fit for purpose when there is a range of wheel profiles running on the line?

Further information from data loggers in other passenger carriages and trains in the Wellington Metro area is needed to validate if hunting is occurring elsewhere on the network, as:

- If hunting is confirmed as only occurring in SW-type carriages, and not extensively in other carriages and trains, then yes current documented tolerances in KiwiRail standards are fit for purpose. As hunting in SW-type carriages is isolated to an unknown sensitivity within their bogie suspension design, that increases the likelihood of hunting at line speeds greater than 60km/hr, on tangent (straight) track, when track gauge is less than 1066mm on concrete sleepers; **or**
- If hunting is confirmed by data loggers in other carriages and trains across the Wellington Metro network, then documented tolerances in KiwiRail standards may need further review. However, further work will be needed to identify possible changes in KiwiRail standards and/or other interoperability documents. All changes identified will need to be tested and updated in relevant documents in close consultation with all relevant parties.

What can be learnt from this incident about wheel profile tolerances? Reviewing selected incidents, from existing available reports and selected interviews with nominated KiwiRail Staff;

- The rail wheel interface gap is a critical area of the rail system. Wheel profiles together with track gauge and the rail head profile are key factors in train and carriage interoperability and longer-term track and wheelset maintenance implications. National Rail System Standard / 6 – Engineering Interoperability Standards needs to be updated, based on findings from data loggers and other known documented changes in KiwiRail standards since 2013 (e.g. changes in back-to-back dimensions).

Review current engineering change processes, including what is defined as an engineering change, current processes, standards, etc. Includes all standards relevant to new rolling stock or changes to track standards and tolerances, including timing of;

- *Comment on possible broader implications, including;*
- *Current rolling stock maintenance intervals; and*
- *2029 future rolling stock (Lower North Island Rail Integrated Mobility[4]).*

- Currently there is no documented requirement for KiwiRail to consult with Greater Wellington Regional Council on any changes to KiwiRail Standards. Additionally, the changes and updates that have occurred in the Track Standards listed in Appendix A, are mostly improvements and refinements within existing tolerances, not significant changes that would impact the rail system interoperability. However, the implications of 2016 Engineering Change Request updating the back-to-back needs to be further investigated, together with open consultation on the updates needed to NRRS/6 in light of the increased hunting in SW-type carriages and pending confirmation of changes that will reduce it.

[4] https://www.gw.govt.nz/document/19521/detailed-business-case-lower-north-island-rail-integrated-mobility-2021/

5 Possible options to reduce the likelihood of hunting

Options to reduce the likelihood of hunting from SW-type carriages are presented in Table 3. All options consider track and wheelset works, in the short-term and over the longer-term, to reduce the impact to passenger services. A longer-term view is important with new trains in 2029.

Table 3. Range of possible options to reduce the likelihood of hunting.

Options	Risks	Costs between now and 2029	Service Impact
A) SW-type Carriages are restricted on the network to <60km/hr. **No other works completed.**	Increasing risk of damage and defects to rails and carriages. Increasing risk over time that speed restrictions could reduce down further to 40km/hour	**MODERATE** - No cost to implement but likely increased maintenance costs longer term.	Significant impact to the travelling public, with speed restrictions increasing travelling time, and disrupting other services on the network.
B) Change track components (i.e. pads or insulators) to increase the track gauge to 1070mm. **No other works completed.**	Increasing risk of damage and rail defects due to suboptimal contact point and rail wheel interface (e.g. rolling contact fatigue). Not fully tested as a viable option	**MODERATE** – Time needed to change components to widen. Additional track and wheel costs over the longer-term as rail wheel interface remains suboptimal.	Potential increase in track and wheel maintenance over the longer-term, increasing disruptions to train services, due to suboptimal contact point and rail wheel interface.
C) SW-type carriages have wheels gradually reprofiled to C2 and back-to-back gradually changed to 995mm (ECR1016). **No other works completed.**	Time to complete, and potential changes to existing maintenance intervals and interventions. Risk of rail defects due to suboptimal contact point and rail wheel interface (e.g. rolling contact fatigue).	**MODERATE** – Costs associated with reprofiling and changes in back-to-back dimensions. Possible additional track maintenance costs as rail wheel interface remains suboptimal.	Wheelset changes may not be enough to improve rail wheel interface gap on new rails with low tonnage (i.e. rail head profile not optimal) so isolated speed restrictions may still be needed.
D) Rail grinding only, to improve the rail head profile. **No other works completed.**	Fire ban limiting access to complete. Access will need to be coordinated around other works. Time to complete, and possible changes to existing planned work.	**MODERATE** – Costs associated with grinding. Possible additional track and wheel maintenance costs if rail wheel interface remains suboptimal.	Works unlikely to improve rail wheel interface gap over the longer-term, and speed restrictions likely to still be needed.
E) Combination of rail grinding and wheelset reprofiling. Grinding improves rail head profile, and wheelset reprofiling to C2 and with possible gradual back-to-back changes to 995mm, improve the rail wheel interface	Fire ban limiting access to complete. Access will need to be coordinated around other works. Time to complete, and possible changes to existing planned work.	**HIGH** – Targeted works to improve the rail wheel interface gap and rail head profile (contact point)	Staged approach, to validate engineering tolerances and optimum wheel profile tolerances. Speed restrictions could be progressively removed if data loggers confirm reduction in hunting. Improved ride quality and least long term disruption.

6 Key Recommendations

From the information provided and analysis presented, we identify the following recommendations.

6.1 Reducing the likelihood of hunting in SW-type carriages

The completion of rerailing and re-sleepering works, reducing gauge variability from 2020 to 2023, has changed the rail wheel interface gap and increases the likelihood of hunting in SW-type carriages. SW-type carriages due to unforeseen suspension characteristics and possible lighter tonnage (when compared to Martangi and SE) have less ability to dampen the forces from hunting, hence transferring it through into the carriages as vibrations. The SW carriage bogie suspension configuration utilises spring primary and spring secondary suspension with no lateral damping between the bogie and carbody. The SE carriage and Matangi bogies (although different in design) utilise a suspension configuration with spring primary and airbag secondary suspension. In addition, the SE carriage and Matangi have a lateral damper between the bogie and carbody. Transdev believe that both the SW and SE carriage bogies are possibly exhibiting hunting, but the lateral damper found on the SE carriages is reducing the accelerations to the carriage. However, KiwiRail have found no increased damage to track components in Wellington, nor has Auckland Metro had reported increasing track damage from a similar renewal works, suggesting that if hunting is more prevalent it is not impacting the track.

Track work has improved and decreased the gauge variability across the Wairarapa line, so work to further modify the track gauge should only be considered as a last option. As widening track gauge beyond 1070mm would increase track gauge variability, effectively taking the network back towards a 2020 condition level, which could then increase the level of wheel and track maintenance needed over the longer-term. Hence, improving the rail wheel interface with staged targeted changes that improve the gap and rail head profile should be prioritised first. As improving the rail wheel interface is the best outcome for GWRC and KiwiRail, as it is likely to decrease the longer-term maintenance for both track and SW-type carriages.

Grinding is needed, which although it will not eliminate hunting over the longer-term, is an important factor to improve rail wheel interface. KiwiRail will need to confirm the rail head profile that needs to be achieved by grinding relative to the conicity of SW-type carriage wheelsets. Works will need to be planned in and progressively completed, so testing with data loggers can confirm what improvements have been achieved (i.e. unground baseline vs ground movements).

Progressive testing with data loggers of changes is essential to understand what improvements are being achieved. A complete train consist with all carriages on C2 wheel profiles on a 997mm back-to-back needs to be tested first, as the reduction in flange width is likely to improve the rail wheel gap. Works will need to be planned in and completed, so sufficient testing with data loggers can record a baseline (i.e. hunting) on a C1 wheel profile at 60km/hour, and what improvements have been achieved by changing to C2 wheel profile with a 997mm back-to-back at 60km/hour. If data recorded shows hunting is reduced or eliminated at 60km/hour, then test trains using a C2 wheel profiles on a 997mm back-to-back needs to be progressively tested at increasing speeds, possibly up to 100km/hr.

Depending on data logger results with a C2 wheel profile on 997mm back-to-back, a complete train consist with all carriages on C2 wheel profiles with 995mm back-to-back could then be tested. As the reduction in the back-to-back will also improve the rail wheel gap. Works will need to be progressively completed, so testing with data loggers can show a baseline (i.e. hunting) on a C1 wheel profile at 997mm, then at C2 wheel profile on 997mm, and what improvements have been achieved at 60km/hour, to possibly 100km/hr.

6.2 Wider implications to be investigated

There are anecdotal reports of other trains on other parts of the Wellington Metro having reports of vibrations and rough rides. To confirm or eliminate these reports additional data loggers are needed on other passenger carriages (e.g. Martangi and SE-type carriages). Data loggers will need to be in place for at least two weeks, across multiple carriages, to collect sufficient data at varying speeds to provide conclusive information that can be relied on.

6.3 Updating of documents

National Rail System Standard 6 – Engineering Interoperability Standards was last updated over ten years (April 2013). This document needs to be reviewed, in alignment with all other relevant standards, and updated, specifically around back-to-back dimensions and wheel profile flange widths. Once updated it then needs to go through the standard change control process, including consultation and feedback, before being adopted on an agreed date. The sharing of Auckland and Wellington Metro Interoperability lessons within existing joint forums or meetings, together with communicating planned changes that could impact the rail system, would also be beneficial for both metro rail systems.

6.4 Interoperability of new trains in 2029

With new trains planned for 2029, the rail wheel interface needs to be key component that is verified before their design is approved. Learnings from recent new trains on the Auckland Metro network, together with information from data loggers on the Wellington Metro network, needs to be factored in to confirm design has considered:

- Wheel profile, including conicity;
- Flange width and back-to-back measurements relative to defined and known track gauge tolerances; and
- Bogie suspension characteristics.

Appendix A: Documents Reviewed

Type	Document	Relevancy
Email	FW: MIS 346W Transdev 77km 78.2km Wrapa	First notification
Email	Re WRAPA - Vibration issue	Investigations
Website	https://www.kiwirail.co.nz/our-network/our-regions/wellington/wairarapa-line/	Scope of works
Brochure	Wairarapa Line Upgrade – February 2024	Scope of works
Document	KiwiRail T200 Track Handbook – Revised Issue 7 – Effective 30th September 2022	Engineering Tolerances
Document	Track Standard - T-ST-DE-5200 Track Design – December 2022	Engineering Tolerances
Document	Track Standard – T-ST-AM-5330 Rail Management – December 2022	Wairarapa Line tonnage (MGTPA)
Document	Track Standard – T-ST-AM-5320 Sleeper Fastenings – Sept 2021	Concrete Sleepers
Document	Track Standard – T-SP-MM-60156 Rail Grinding – June 2022	Grinding Frequency
Document	Track Standard – T-TI-WO-5926 Face Re-sleepering – Dec 2022	Gauge check post re-sleepering
Document	Track Standard - T-ST-AM-5120 Track Geometry	EM80 Gauge tolerances
Report	EM80 Upper Hutt ~ Masterton Data – April 2020	Track Gauge Measurements
Report	EM80 Upper Hutt ~ Masterton Data – December 2023	Track Gauge Measurements
Report	GPR Data WRAPA TSR Vibration mark up	Measurements
Drawing	NZR 50kg – 91lb Rail Sleeper Gauge Measurements V2	Measurements
Drawing	60kg 25 Tonne Concrete Sleeper	Measurements
Document	M9311 X28020 Maintenance Guide	Trouble shooting
Document	M6000-100 Wheelset Manual – Wheelset Specifications	Wheel tolerances
Document	M6000-101 Approved tread profiles	Wheel tolerances
Document	National Rail System Standard / 6 – Engineering Interoperability Standards	Wheel tolerances
Document	Wheel and Rail Profile Development – Rail Industry Safety and Standards Board	Wheel tolerances
Report	Technical Report TR.071 – Rail-Wheel Interface Improvement Investigation for Tranz Rail – Version 3.0 October 2000	Track and wheel tolerances
Document	Engineering Change Request (ECR) Wheelset Back-to-Back Dimension Change – September 2016	Back-to-back distance change
Report	Bogue Vibrations – SW Cars asset degradation solutions and remedies – Hyundai Rotem	Increased maintenance
Data	Brake block and wear liners Work Orders	Increased maintenance

Document	ECR no.1016 Wheelset Back-to-Back Dimensions Change	Internal change in back-to-back
Email	FW WMUP WL works – Impact of TSRs and Work	Works completed
Report	Wairarapa Carriage Hunting – Transdev	Increased maintenance
Report	Wairarapa Train Vibration - Notes	Vibration analysis and findings
Report	Wairarapa Line – CEMIT Presentation	Vibration analysis and findings
Business Case	Single-Stage Business Case Wellington Metro Railway Network Track Infrastructure Catch Up Renewals – November 2017	Asset condition and history, and renewals needed

Unless specifically stated otherwise in this report, Beca has relied on the accuracy, completeness, currency and sufficiency of all information provided to it by, or on behalf of, the Client, including the information listed above, and has not sought independently to verify the information provide

Appendix B: Relevant documents history

A large amount of supporting and historical documentation was provided throughout the review (Appendix A), with key documents summarised as follows.

October 2000 – Technical Report for Tranz Rail – Rail Wheel Interface Improvement Investigation

This report identifies:

- How improved wheel and rail profiles create benefits such as reduced level of vehicle hunting, particularly in tangent track.
- A major objective for tangent track is to avoid hunting, as this causes component deterioration and passenger discomfort, which is best obtained by maintaining contact near the centre of the running surface of the rail (i.e. widening the gauge moves the contact band to the inside edge of the rail).
- How a combination of worn wheel with new rail leads can caused a very localised contact in the gauge corner, increasing the risks of rolling contact fatigue.
- Track gauge is 1068 and all wheelsets have a 997mm back-to-back
- Depending on where you measure from, the expectant rail wheel interface gap for new wheels on new 50kg/m rails is approximately 9-11mm. This gap is similar to narrow gauge railways in Australia.
- An increase in the rail wheel clearance would generally be expected to reduce rail and wheel wear. The main reason is that the resultant larger wheelset lateral movements allow an increased rolling radius difference between the wheels to be established and hence higher steering forces, particularly in profiled rails and wheels.
- Grinding delivers significant benefits to prevent defect growth and can extend the rail life by about 50-100%. Grinding on tangent track can also improve the rail head profile and reduce possible vehicle hunting.
- Grinding also reduces rates of wheel deterioration (flange wear, tread hollowing and contact fatigue), due to improved wheel/rail contact and interaction characteristics. And reduce damage to various vehicle components, including wheels, bearings and sometimes bogies.
- Obtaining the optimal rail wheel profile, with a definite two-point and relatively broad contact near the centre of the running surface of tangent rails, reduces the effective conicity between rails and wheels, and hence reduces the sensitivity to vehicle hunting and adverse vehicle/track dynamics.
- Promotes the benefits of modified wheel profiles, including up to 90% reduction in flange energy on modified wheel profiles
- *In the short term, the modified wheel profiles should be introduced on both passenger and freight bogies, at least for trial purposes. During the trials, particular attention should be paid to the vehicle dynamics at the higher speeds in tangent track and shallow curves. This aspect is of importance considering that the modified wheel profile does have a fuller throat region, which could increase the vehicle dynamic response when the wheel throat approaches the rail gauge corner. If this is found to be a cause for concern, the following three options are available:*

- *reduce the wheelset back-to-back distance by 4-5 mm, as discussed in Section 5.9 of the report; and/or*
- *reduce the wheel flange thickness by up to 2 mm; and/or*
- *apply the tangent rail profile by rail grinding, as discussed in Section 6 of the report, in both tangent track and curves with radii above 1000 m, where rail gauge face/wheel flange wear will be negligible.*

September 2011 – Concrete Sleeper Design

This documented was:

- First published in September 2010, and last updated in September 2011
- States the gauge dimensions allows for Rail Section movement due to train load, and dimensions for nominal gauge of 1068mm after 6 months (i.e. close to 1068mm)

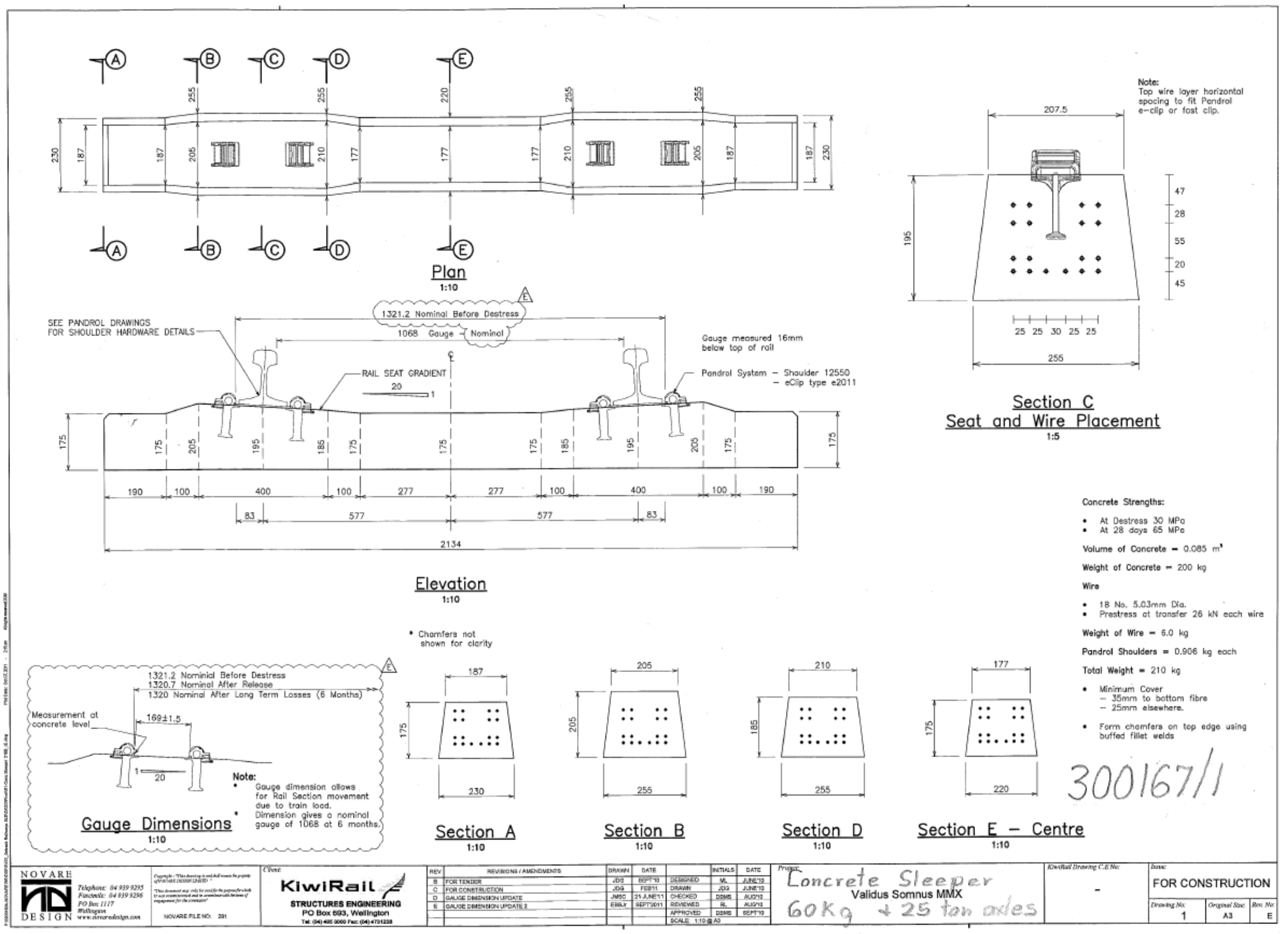

Figure 9. KiwiRail Standard Drawing for 60kg Sleeper – Approved September 2010, last updated September 2011

April 2013 National Rail System Standard / 6 – Engineering Interoperability Standards

This standard includes:

- The 50kg/m unworn rail profile (from 1987)

- *The back-to-back dimensions between inside faces of wheels or tyres on a wheelset must be between 997.0 mm and 998.0 mm, measured at three, equidistant positions around the circumference using gauge Y/X 4603/10.*
- *Wheel profiles must be to a National Rail System standard. Modified Heumann profile wheels with a fundamental tread conicity of 1 in 20 are used on the National Rail System. The current family of acceptable profiles is shown on drawings 7604/11 - 7604/13 in Appendix A* (see Figure 10)*.*

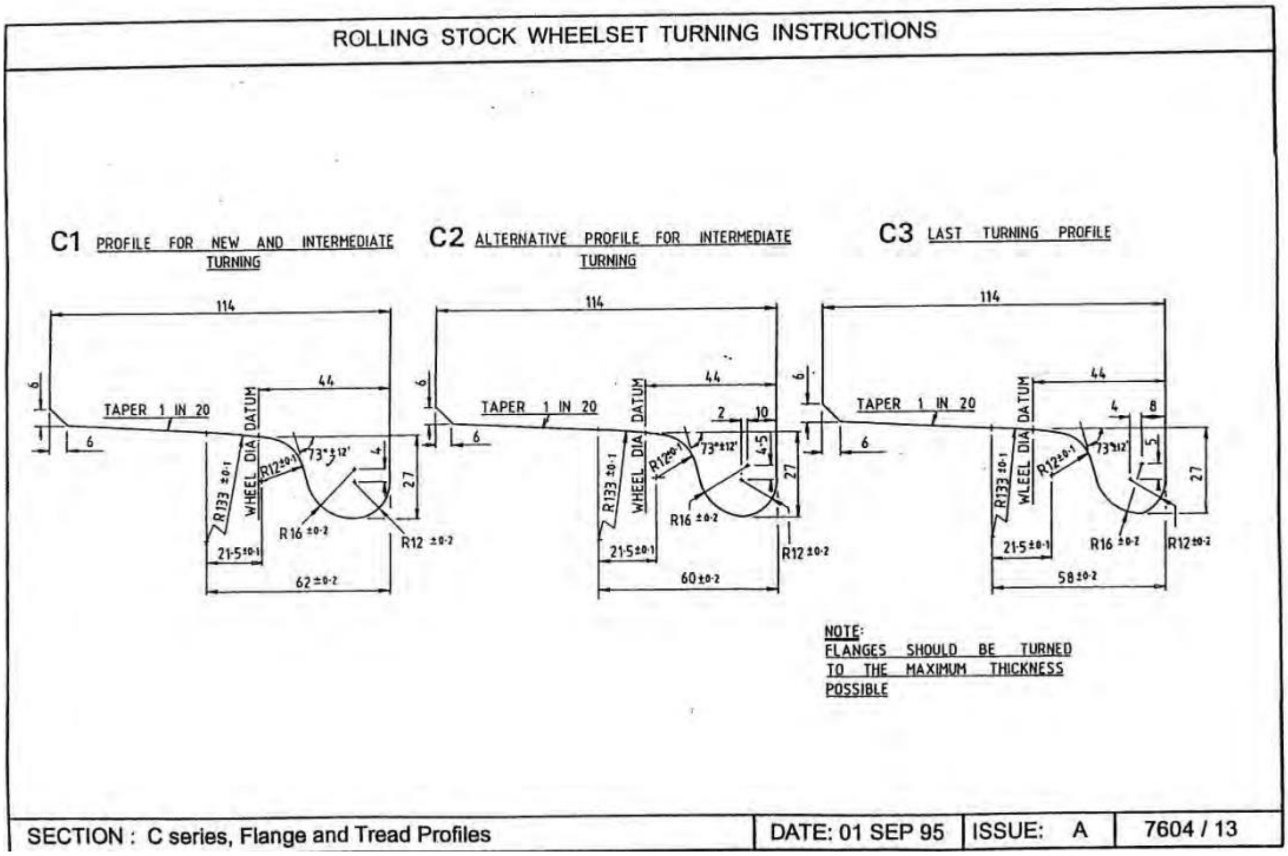

Figure 10. Rolling Stock Wheelset Turning Instructions, dated September 1995.

- *The relevant track standards affecting rail vehicle static and dynamic stability primarily reside in the following of the Access Provider documents (as updated from time to time):*
    - *T200 - Infrastructure Engineering Handbook*
    - *T003 - Track Code*
    - *T100 – Track Supplements*
- *These standards encompass the following:*
    - *Track gauge*
    - *Track construction and maintenance standards*

September 2016 Engineering Change Request – Wheelset Back-to-Back Dimension Change (NCR1016)

This internal KiwiRail change request provides the following:

- *Change Description - Reduce wheelset back-to-back dimension from current 997 (+1,-0) to 995 (+/-1). Agreement email from AME&I attached (note not attached on the version provided)*
- *Scope/ Assets involved - All rail wheelsets (loco's, wagon, carriages). May not affect hi-rail vehicles*
- *Means of Identifying Change - TBC*
- *Reason – It has long been recognised that our current arrangement has the wheel profile sitting too far out relative to the rail head. This change does not go as far as ideal, but at least moves in the right direction.*
- *Risk/ Management - Mixing wheelsets of different back-to-back dimensions on the same bogie is a potential problem, though it is debatable whether the outcome would be worse than having both wheelsets at the current back-to-back dimension. Requires further discussion.*
- *Effect on performance - It should yield wheelsets that track better and have less inclination to hunting. Over time this should see a reduction in sharp flanges, with perhaps an increase in guttering as the driver for wheel turning (skidding aside).*
- *Operational Impact - Theoretically there should be a fuel saving through less flange contact. May be difficult to measure.*
- *How will change be monitored and how often - Needs new back-to-back gauge.*
- *How will change be implemented - Issue change notification and amend codes, design drawings, specs. Can be immediate but does not preclude running existing wheelsets to end of useful life.*
- *Cost Benefit - Cost is minimal – just admin change of amending codes, drawings and specs. Savings accrue for less severe wheel turns and reduction of fuel consumption as new dimension starts to be dominant in fleet.*

Track Standards

Relevant track standards include:

- Track Design, latest version 31/12/2022. Earlier revisions include 30/9/2021, 30/06/2019, 30/04/2017, and 3/03/2017;
- Rail Management, latest version 31/12/2022. Earlier revision includes 31/01/2018
- Rail Grinding, latest version 30/06/2022. Earlier revision includes 30/06/2019
- Sleeper fastenings, latest version 30/09/2021
- Face Re-sleepering, latest version 31/12/2022
- Track Geometry, latest version 3/03/2017

Appendix C: SW-type increased maintenance

Issues affecting carriages: Brake Blocks

Brake blocks from myriad carriages; the failure mode is new

Issues affecting carriages: Wear Liners

Worn wear liners with a very rough finish. Normally they are smooth and evenly worn

Issues affecting carriages: Side bearer

Red-coloured side bearers being found across the fleet.
The red is indicative of iron fretting

Appendix C: Differences between C1 and C2 asset condition

Issues affecting carriages – SWS3394 This car has a #2 profile

The bogies on SW3394 show much less evidence of fretting

Issues affecting carriages – SWS3394 Comparison with another car

SW3394

SW5671

Issues affecting carriages – SWS3394 Comparison with another car

SW3394

SW5671