

REPORT INTO CARDAN SHAFT PARK BRAKES

In-service Testing and Evaluation

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Executive Summary

Transmission park brakes, commonly known as a Cardan Shaft park brake (CSB), have been linked to a number of incidents where the vehicle has rolled away causing injury and damage, in three cases over the last decade the injuries have been fatal. A fatal incident in March 2020 has prompted Waka Kotahi to undertake an audit and review of in-service brake testing and performance in an effort to quantify and gain a better understanding of the issue.

In order to quantify these issues, the Waka Kotahi Vehicle Standards Team developed an in-service CSB testing program. The programme involved pulling over vehicles with CSB, gathering data from the driver, conducting a Stall Test as is used during Certificate of Fitness testing and then a Pull Test where the vehicle is held by the park brake and is connected to an anchor vehicle via a strop and load cell then pulled using a force equivalent to 20% of its GVM. The program was conducted over a two-week period in September 2020 at a Commercial Vehicle Safety Centre (CVSC) in Wellington. Ninety vehicles were randomly selected and tested by a team consisting of Police Commercial Vehicle Safety Team (CVST), Waka Kotahi and an independent brake specialist consultant. The aim of the test procedures was to achieve a comprehensive mix of makes, models and usage types, testing was focused on simulating both Certificate of Fitness testing and testing required to meet the full intent of the heavy vehicle braking standards.

Data collected included a range of questions aimed at understanding the general knowledge of drivers and vehicle operators around CSB along with various physical tests of the vehicles CSB performance under a range of loads. The main findings of the testing were:

- Driver/operator knowledge of the park brake type was poor.
- Stall tests performed on Auto & AMT equipped vehicles gave variable results showing that the stall test could not be relied on for granting a Certificate of Fitness (CoF) for these vehicles.
- A 12 tonne GVM is not the cut-off point for vehicles with CSB. Vehicles with up to 23 tonne GVM were observed and tested with a CSB.
- The CSB in 80% of vehicles tested could meet the current CoF inspection “stall test” but they did not provide enough holding power for the “pull test”.
- The CSB in 12% of vehicles tested were not capable of meeting the current CoF inspection “stall test”

A range of initiatives may be required to address the issues born out of this CSB testing program. These include:

- Investigating and implementing an improved in-service and entry testing for vehicles with CSB.
- A comprehensive communications and engagement campaign to ensure vehicle owners, drivers, importers and manufacturers are aware of the limitations of CSB.
- Further evidence gathering and investigation into CSB issues and research into other available levers to Waka Kotahi for managing the risks associated with CSB.

Acknowledgements

This report has been prepared with grateful assistance from Tohora Enterprises, TR Group and Mr Selwyn Rabbits (NZ Cranes). Acknowledgement must also go to our key stakeholder partners Police CVST and the CSB project steering group.

Introduction

Cardan shaft park brakes (CSB), also known as driveshaft park brakes or transmission park brakes, are fitted as original equipment to many commercial vans, four-wheel drive vehicles and small passenger service vehicles (MB, MC & MD class), small to medium light trucks (NA & NB class), plus, a small number of heavy trucks (NC class) and heavy passenger service vehicles (ME class). They can also be fitted to other vehicles, including commercial and industrial vehicles such as telehandlers, forklifts and plant equipment.

CSB have been linked to a number of incidents where the vehicle has rolled away causing injury and damage, in three cases over the last decade the injuries have been fatal. The Coroner's findings into one of these events recommended, "a review of the requirements and testing of park brakes is required" and that "a recommendation in relation to those issues may also raise public awareness of the safety issues". Waka Kotahi NZ Transport Agency (Waka Kotahi) responded by commissioning two independent reviews to investigate any potential shortcomings in both legislation and in-service inspection of HMV park brakes.

The summary of both reports was submitted to Waka Kotahi senior management in September 2019, it indicated that CSB present several challenges in operation and maintenance. There are approximately 55,000 NB vehicles in service in NZ. NB class vehicles typically utilise a CSB. The risks posed due to poor maintenance of these brakes across such a large number of vehicles led to Waka Kotahi taking action. Waka Kotahi initiated a park brake maintenance form (4085D) in December 2019. The form was used by a vehicle inspector where the park brake failed a CoF test. The form would then have to be filled out by the owner confirming the park brake had been maintained and then presented back to the vehicle inspector. The trial period for the forms use was for 6 months ending 30/06/2020.

A fatal incident in March 2020 has prompted Waka Kotahi to undertake an audit and review of in-service brake testing and performance in an effort to quantify and gain a better understanding of the issue.

Cardan Shaft Park Brake Testing Program

Key issues for current in-service CSB testing:

- Vehicles accepted for entry are those that have proven compliance with brake standards in one of the jurisdictions recognised in NZ legislation, this means vehicles with CSB meet at least one of the international standards required.
- The CoF test is the minimum performance requirement for a vehicle to meet the legislation for use on New Zealand roads, the test for CSB does not test the maximum conditions a vehicle is expected to operate in. The stall test is widely used as it is the easiest to perform, however the technique may be inadequate in testing the performance due to differing transmission:
 - in a manual the operator is asked to use an intermediate gear, this could be 2nd, 3rd, or 4th, all of which will produce a different result.
 - in an automatic there is no way to actually stall the engine as the transmission will slip, causing rapid heat to build up that could damage the transmission.
 - new technology has introduced Automated Manual Transmissions (AMT) and Hill Start Assist (HAS) systems that are designed to lock the service brakes to hold the vehicle, this means the clutch will not engage until the park brake is released, therefore stall testing is very difficult.
- Traditional RBM testing of CSB has an inherent danger as these brakes are not designed to stop the vehicle while in motion, damage can occur if not correctly tested.
 - However, some overseas jurisdictions do mandate an RBM test. This is where the vehicle is placed on the roller bed and the brake applied, the rollers are then started, if the brake holds the RBM rollers will reach the slip point and stall, a performance reading can then be obtained.
- The use of a 18% slope is limited as testing sites do not have suitable infrastructure.
- The use of a pull test (a test which is used to simulate testing on a gradient) requires specialised test equipment and infrastructure that is not available at testing sites.

To meet brake standards a vehicle fitted with a Cardan Shaft Brake (CSB) can be tested using either, the 'Stall Test' method, where the vehicle is held by the park brake and an attempt is made to stall the engine, or, the "Hold Test" method, where the vehicle is held by the park brake on a 18% gradient in both directions while fully laden, or, the "Pull Test" method, where the vehicle is held by the park brake and is connected to an anchor vehicle via a strop and load cell then pulled using a force equivalent to 20% of its GVM.

The testing program was conceived by the Vehicle Standards team to simulate the requirements for a CSB to hold the vehicle on a slope in all conditions of loading. Full details of the procedures are covered in Appendix 1 (Operation Orders Transmission Park Brake Testing), all vehicles were subjected to a “stall test” and a “pull test” in both directions

Each vehicle had the park brake applied using a digital scale (Figure 1) to a lever pull force of 15kgf, the number of lever ratchet clicks was recorded, and the vehicle stall tested to simulate a CoF inspection test. Each stall test was done in 3rd gear for manual transmissions and drive for automatic transmissions, although it must be noted the engine cannot be stalled because of torque converter slippage.

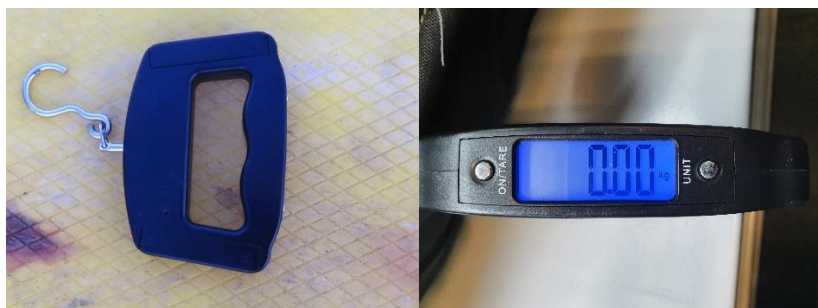


Figure 1: Components of the digital scale used during testing

Once the stall test had been completed the vehicle was attached to an anchor vehicle and the pull force was applied to see if the CSB could withstand the pull applied equivalent to being placed on a 18% slope with the brake applied. The vehicle was connected by 3000kg rated webbing straps through a calibrated digital 5000kg rated load cell (Figure 2) to a 5000kg hand winch so load could be applied (Figure 3) and tabulated.



Figure 2: Load cell used for testing



Figure 3: Hand winch used for testing

Starting at the stall test settings a target pull test force (20% of the vehicles GVM) was applied and the park brake unit observed. If the park brake unit moved before the target pull force had reached the calculated figure the force on the park brake lever was increased and the target pull force re-applied, this continued until the target pull force was achieved and the park brake unit held the vehicle. If the target pull test force was not achieved with the park brake lever at the travel limit of 5 extra ratchet clicks or a lever force of 50kgf or more

was required to move the lever, then the test was concluded. All results were recorded and the park brake performance analysed against the manufacturers specifications and settings (Cardan shaft park brake testing 2809-0810). Each driver was asked a range of questions prior to the conclusion of testing and this was included with the raw data.

Pre-Testing Initiative

In preparation for the full test program the Vehicle Standards and Safer Commercial Vehicles Teams carried out a pre-testing day in combination with NZ Police CVST on 10 September 2020 at the Plimmerton Commercial Vehicle Safety Centre (CVSC). Team members ran a testing sequence using a new vehicle supplied by Hyundai NZ, the aim was to ensure the procedures set out in the operation order were achievable, repeatable and consistent in delivering the CSB program objective.

The procedures were carried out using the specialised equipment above and an anchor vehicle supplied by TR Group, each test procedure was refined and repeated throughout the day, team members were given specific duties to ensure that test data could be consistently captured, and timings tested.

Full test program

The testing of CSB for the full program was done using a stall test and a pull test, the aim was to simulate the current testing regime for a CoF against the testing regime used by the vehicle manufacturer to comply with the international standards that NZ accepts. Waka Kotahi, vehicle standards team tested the performance, in-service between CoF inspections, of ninety vehicles over an 8-day period, vehicles were selected randomly as they passed through the CVSC.

Each vehicle and its driver completed the testing procedure and questionnaire, the overall process was as follows;

1. Vehicle directed into CVSC by Police, weighed and inspected to level 3 or 5 (compliance with rules and regulations including Licence, RUC, TSL, Mass and Dimension and defects) and a Commercial Vehicle Inspection Report (CVIR) generated.
2. Vehicle handed over to Waka Kotahi team members and the independent brake specialist to conduct testing, details collected, and driver interviewed (see exact questions below).
3. Stall test carried out at pre-determined settings.
4. Testing equipment connected and a pull test carried out using the stall test settings as a baseline followed by a range of force settings up to the pre-determined target kilogram force (kgf) required to hold the vehicle while fully laden 18% gradient, both forwards and backwards.
5. All results collected, collated and verified as correct for the vehicle being tested and a photo taken.
6. Vehicle handed back to driver with a CSB information sheet and a tread depth keyring.

Drivers Questionnaire

1. Are you willing to help NZTA's research?
2. Do you object to our engineer operating your vehicle?
3. Do you drive this vehicle regularly?
4. Are you aware of the type of park brake fitted to the vehicle?
5. Do you have any knowledge or experience with driveshaft mounted park brakes?
6. Are you aware that this type of type of parking brake should not be applied when the vehicle is in motion?
7. Does the load change during the day?
8. How often is the load changed during the day?
9. Do you know when the last maintenance/adjustment of your park brake was?
10. Are you aware of any roll-away incidents or other park brake issues with this vehicle?

Results

A total of 90 vehicles were tested representing seven manufacturers (Figure 4), configured in 13 different body styles (Figure 5) and ranging from 3525kgs through to a GVM of 23,000kgs Gross Vehicle Mass (GVM) (Figure 6). All vehicles were fitted with the drum brake version of CSB. The various body configurations were selected in an effort to cover as many differing uses as possible, as CSB is fitted only to Asian sourced vehicles these were the only manufacturers selected for testing, many of these vehicles are now equipped with driver aids such as air bags, anti-lock braking (ABS), hill-start assistance (HAS) and traction control (TC), however there were none that featured a full electronic braking system (EBS) (Figure 7).

The drivers of each vehicle tested were also asked a range of questions ranging from their knowledge of the vehicle and its park brake system through to any issues they may have had with the CSB. A breakdown of these questions is detailed in the charts below.

Key points from the results include;

- The largest represented manufacturer in the heavy vehicle fleet and also representative in the testing results was Isuzu 43%.
- 30% of vehicles (27/90) tested were fitted with ABS and nearly all of those vehicles had TC or HSA as part of the ABS control system (24/90).
- 80% of vehicles passed the current stall test.
- Almost 8% of vehicles could not be effectively stall tested as they had automatic or automated manual transmissions.
- The park brake eventually held on 72% of vehicles during the pull test in the forward direction (downhill) although one vehicle was so lightly loaded it started to skid.
- The park brake eventually held on 79% of vehicles during the pull test in the rearward direction (uphill).
- 66% of drivers were unaware of the type of park brake fitted to the vehicle they were driving.
- Over 60% of drivers had no knowledge or understanding of CSB.
- 66% of drivers were unaware that CSB should not be applied when the vehicle is moving.
- Almost 80% of drivers were unaware of when the most recent park brake servicing had occurred.
- Over 70% of drivers had encountered park brake issues, including a roll-away event, with the vehicle they were driving.

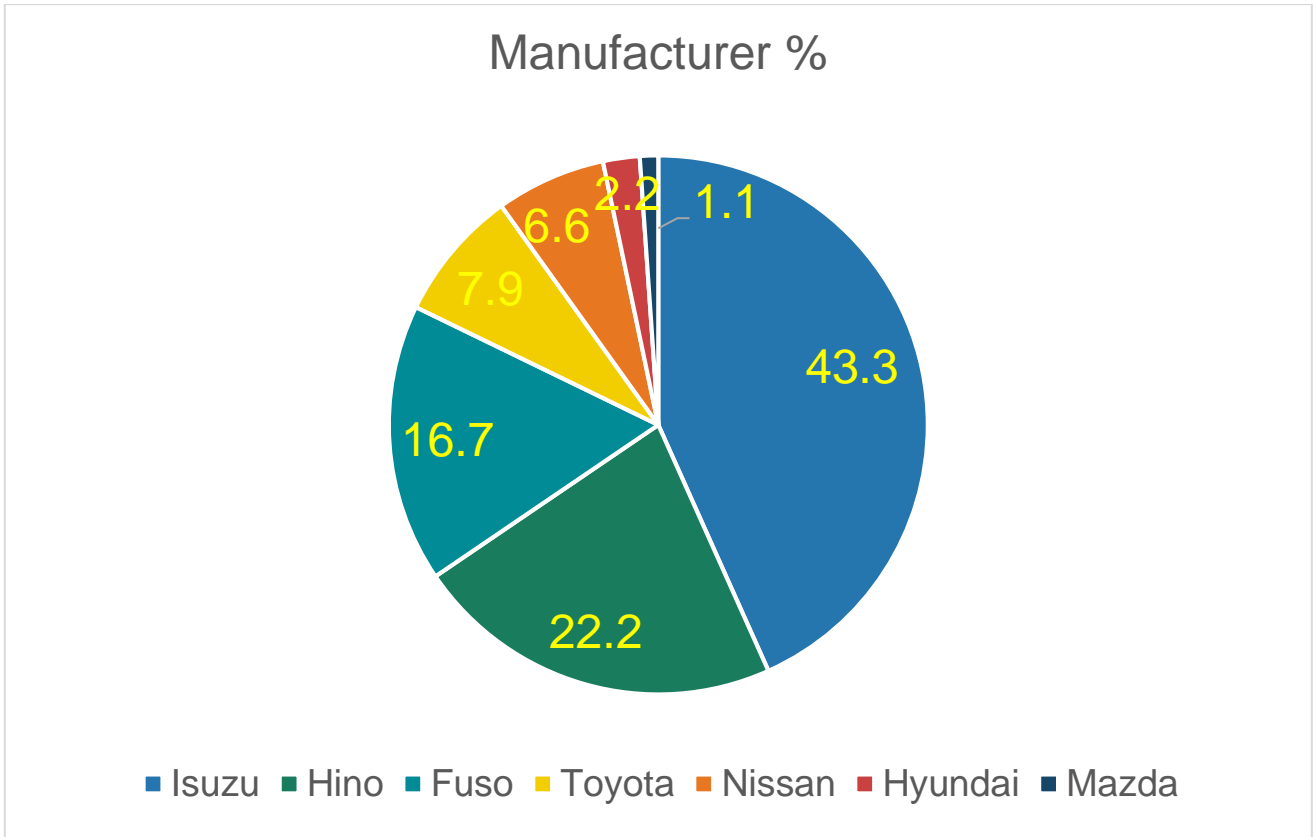


Figure 4: Summary of vehicles tested by manufacturer

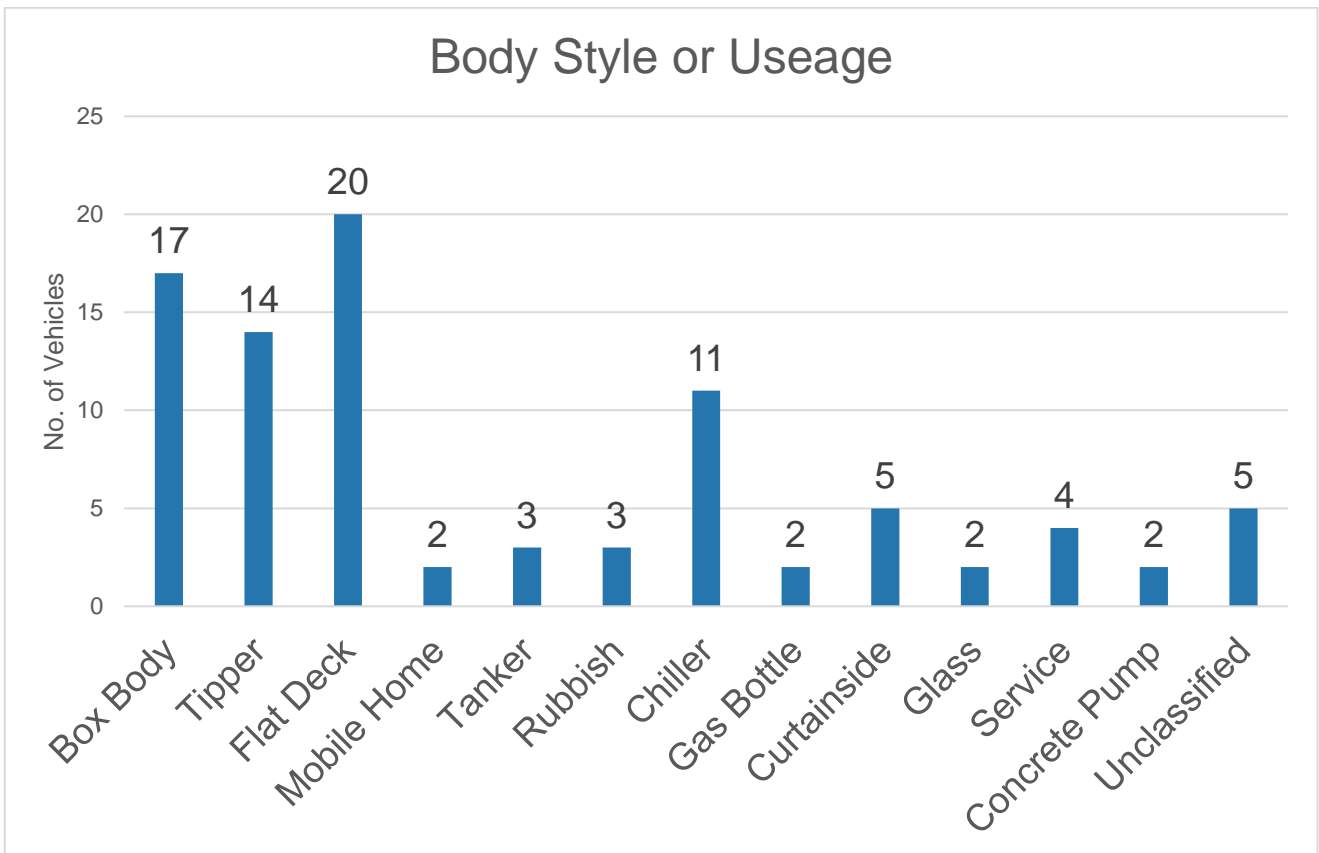


Figure 5: Body type/usage type of vehicles tested

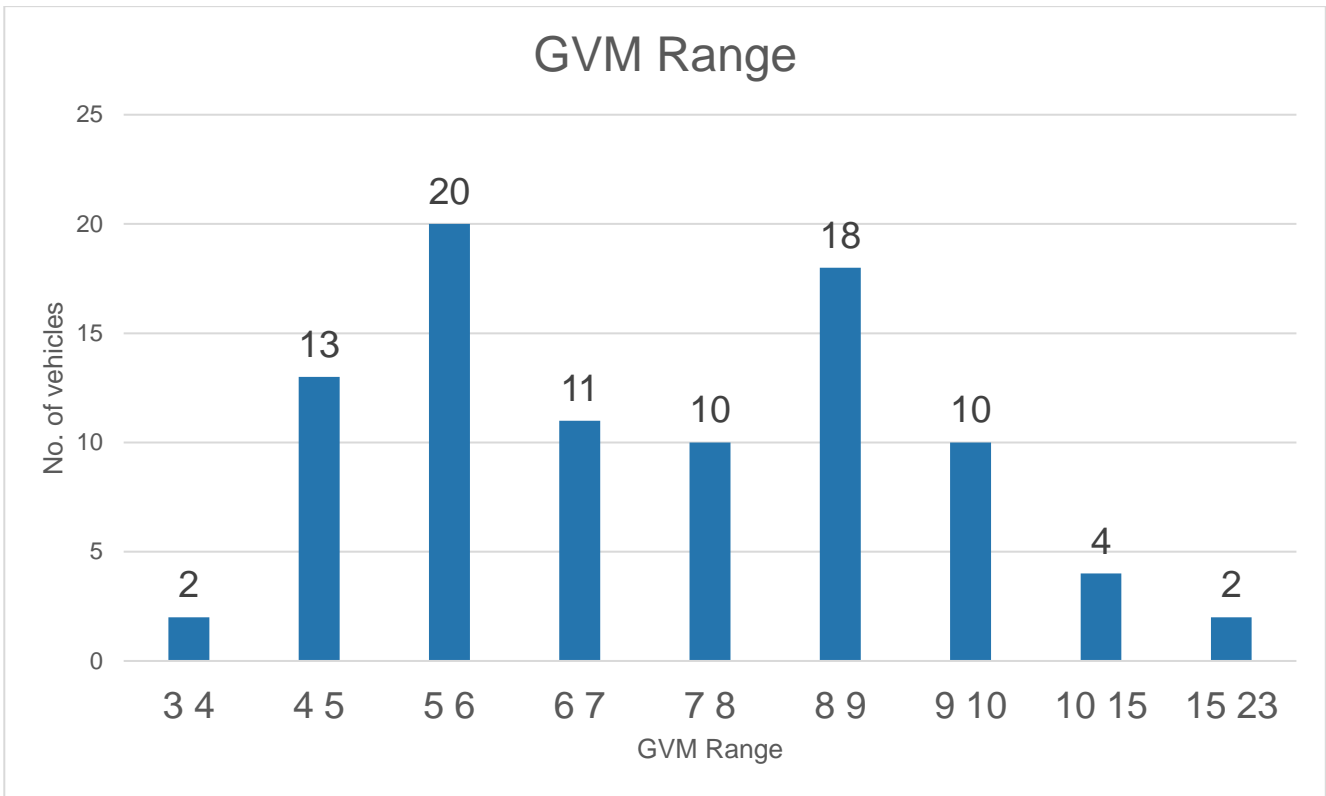


Figure 6: GVM range in Tonnes of vehicles tested

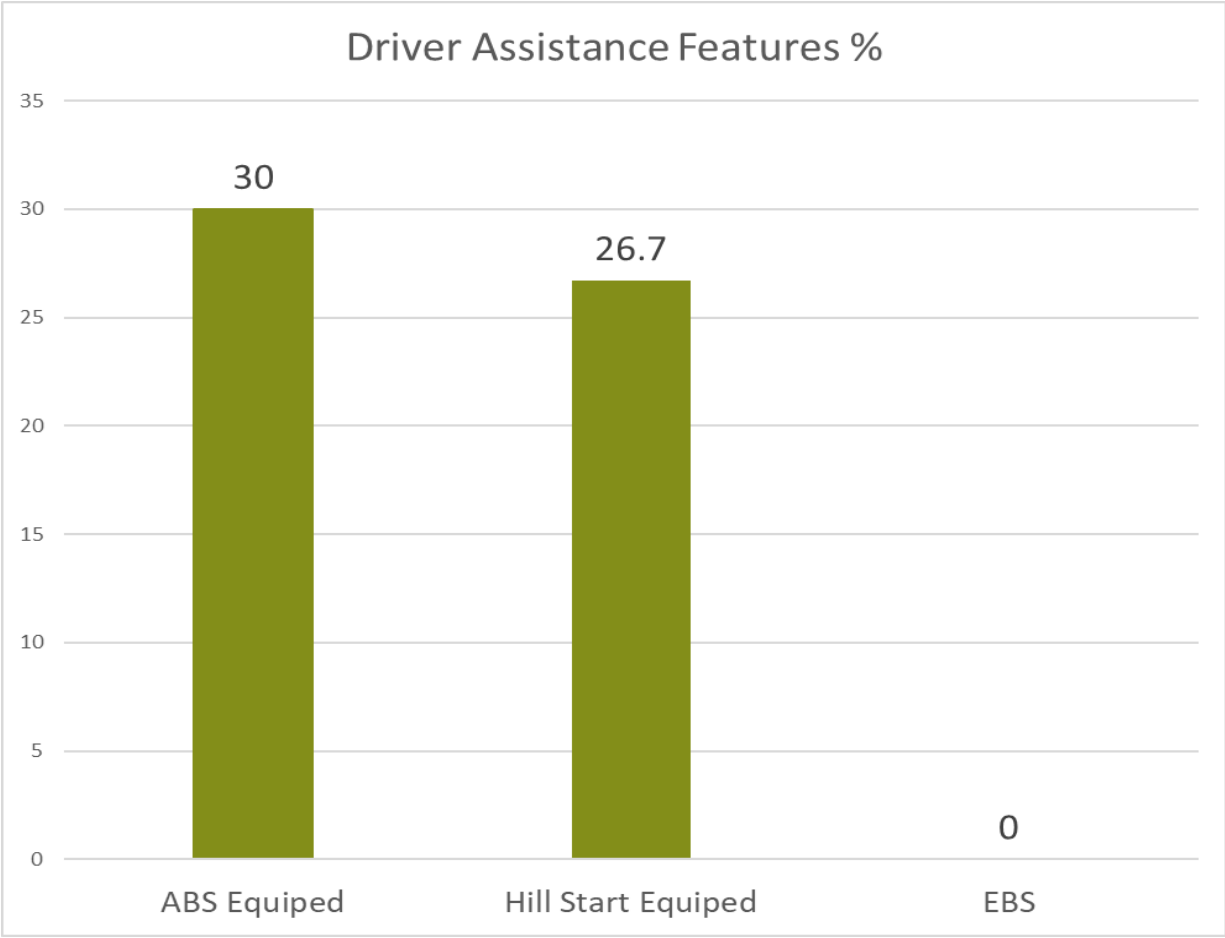
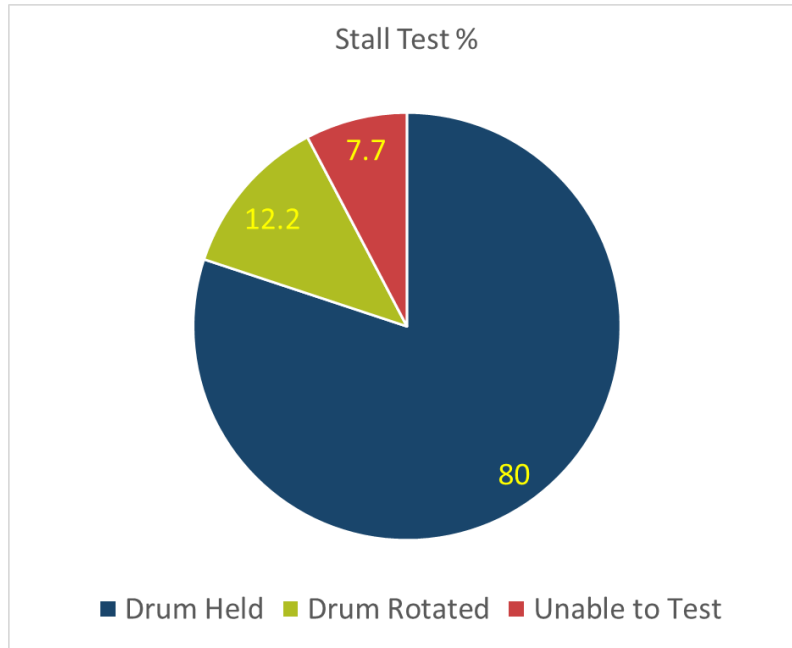


Figure 7: Driver Assistance Features

Stall Test in Detail

The first series of tests was to carry a stall test at a specified figure, based on an average person's application of the lever, a force of 15kgf was placed perpendicular to and at 50mm from the head of the park brake lever and the number of ratchet clicks counted. The chart below plots the percentage of vehicles where the drum held stationary (passed), drum rotated (failed) and those unable to be stalled due to an automatic or automated manual transmission being fitted.



- All vehicles with manual transmissions were tested in 3rd gear
- The average travel of the park brake lever was 7.6 clicks of the ratchet to achieve the 15kgf
- The lowest number of clicks was 3
- The highest number of clicks was 18
- The highest lever force was 48kgf (vehicle did not hold)

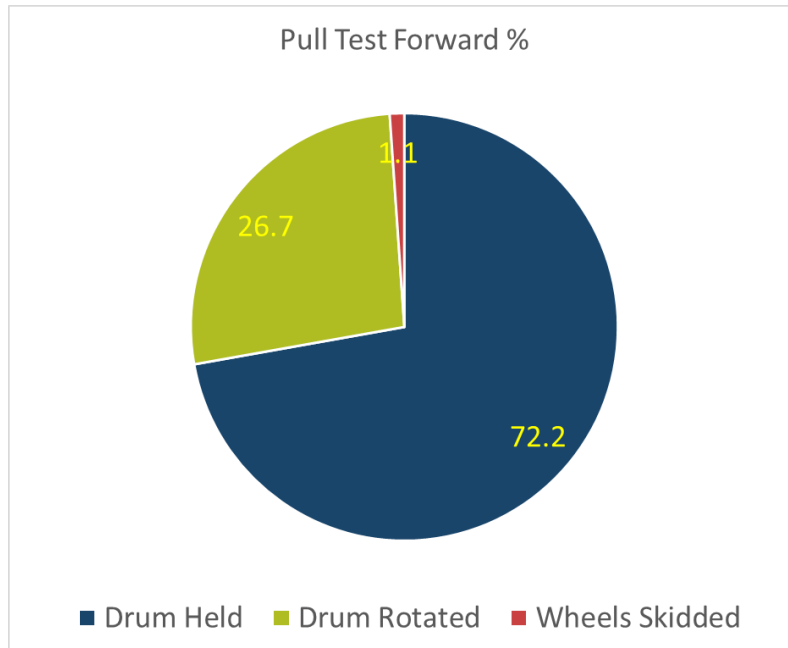
When comparing the stall test against the first pull tests in either direction using the same lever settings the results showed the pull test kgf figure was very low. In 69 (76%) of the 90 vehicles tested the figures show less than half of the pull force required to hold the vehicle on a 1-5 gradient was produced.

To produce the target pull test kgf in either direction the park brake lever had to have;

- the travel increased on average 4 extra clicks
- the force increased to an average 22kgf

Pull Test Forward in Detail

The second series of tests simulated the holding power of the brake with the vehicle being pull tested in a forward direction (downhill if placed on a 18% slope), the target pull force represented 20% of the vehicles GVM. The base starting point was the same as used for the stall test, if the park brake drum rotated the force on the lever was increased and each additional click of the ratchet was recorded until the “drum held”. If the drum did not hold at a total of 5 extra lever clicks or when a maximum of 50kgf was applied to the lever, the test was stopped, and the result recorded as “drum rotated”. The chart below plots the percentage of vehicles where the drum held stationary or the drum rotated.



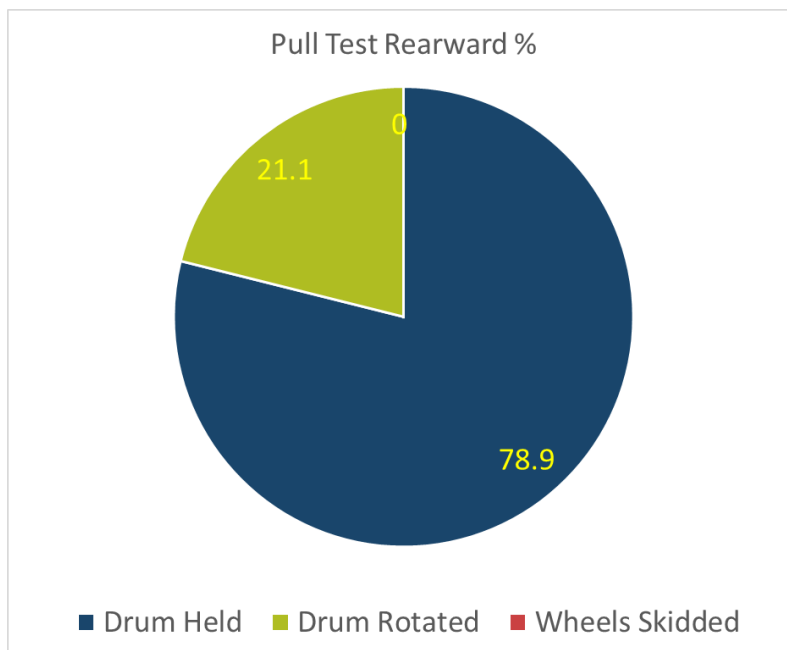
The target pull force was not met by 25 of the 90 vehicles (26.7%) and of the 64 (72.2%) vehicles where the park brake has held 25 (39%) required more than 3 extra clicks of the lever and 15 (23%) required more than the average lever force.

- The highest lever travel was 22 clicks
- The highest lever force was 50+kgf
- 1 (1.1%) vehicle met the target pull force at the same setting as the stall test
- 16 (17.7%) vehicles met the target pull force at 1 extra click
- 22 (24.4%) vehicles met the target pull force at 2 extra clicks
- 23 (25.5%) vehicles met the target pull force at 3 extra clicks
- 1 (1.1%) vehicle failed to develop any pull force at full lever travel

Note 1 vehicle was too light on the rear axle and the tyres skidded resulting in an inconclusive test.

Pull Test Rearward in Detail

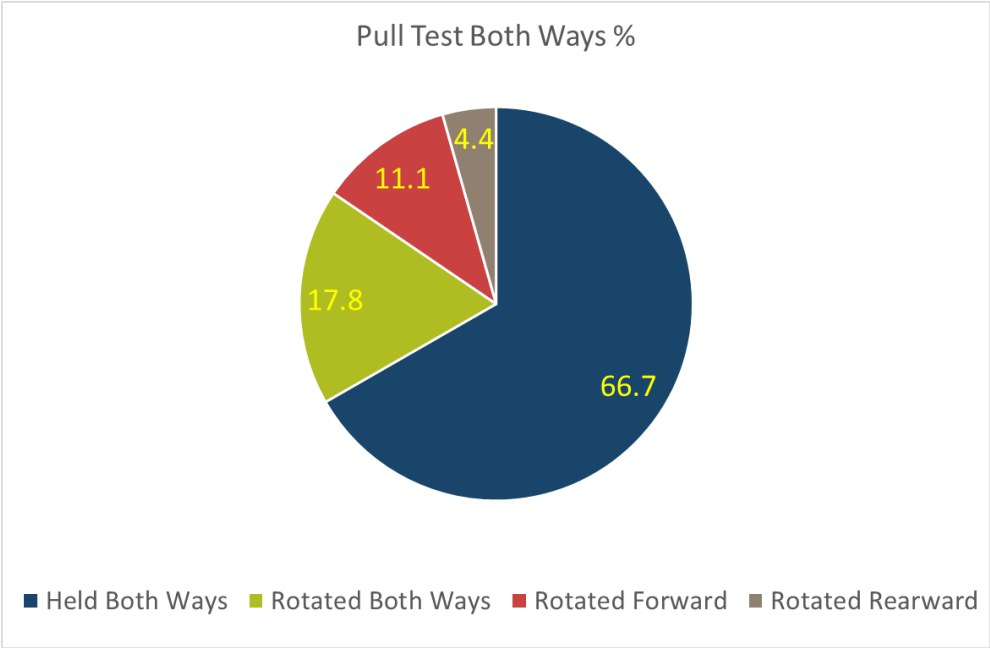
The third series of tests was to simulate the holding power of the brake with the vehicle being pull tested in a rearward direction (downhill if placed on a 18% slope), the target pull force represented 20% of the vehicles GVM. The base starting point was the same as used for the stall test, if the park brake drum rotated the force on the lever was increased and each additional click of the ratchet was recorded until the “drum held”. If the drum did not hold at a total of 5 extra lever clicks or with a maximum of 50kgf applied, the test was stopped, and the result recorded as “drum rotated”. The chart below plots the percentage of vehicles where the drum held stationary or the drum rotated.



The target pull force was not met by 19 of the 90 vehicles (21.1%) and of the 71 (78.9%) vehicles where the park brake has held 29 (40.8%) required more than 3 extra clicks of the lever and 16 (22.5%) required more than the average lever force.

- The highest lever travel was 22 clicks
- The highest lever force was 50+kgf
- 5 (5.5%) vehicles met the target pull force at the same setting as the stall test
- 15 (16.6%) vehicles met the target pull force at 1 extra click
- 15 (16.6%) vehicles met the target pull force at 2 extra clicks
- 24 (26.6%) vehicles met the target pull force at 3 extra clicks
- 1 (1.1%) vehicle failed to develop any pull force at full lever travel

Pull Test - Both Directions in Detail

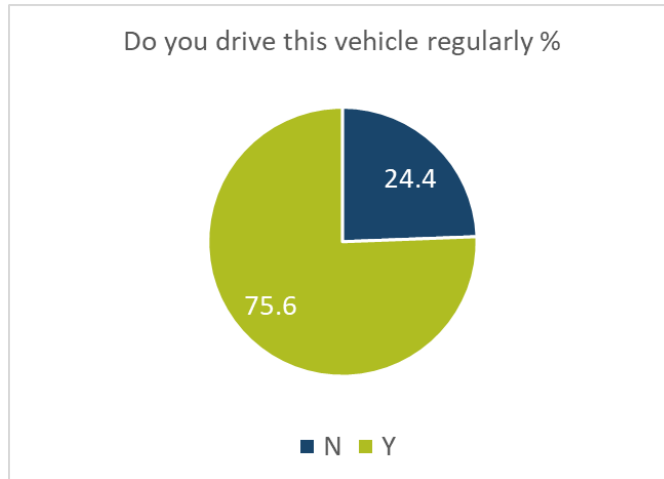


The target pull force in both directions was achieved by 60 (66.7%) vehicles, while 10 (11.1%) did not hold in the forward direction and 4 (4.5%) did not hold in the rearward direction. The target pull force in both directions was not met by 16 of the 90 vehicles (17.8%).

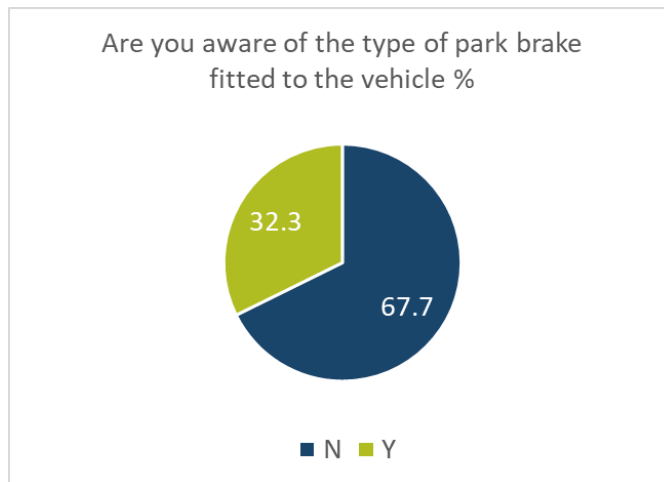
Driver Questionnaire in Detail

Drivers were asked a range of questions about their knowledge and understanding of CSB and the type of use and loading the vehicle was subjected to during the working day. The range of questions and the responses are depicted in the graphs below.

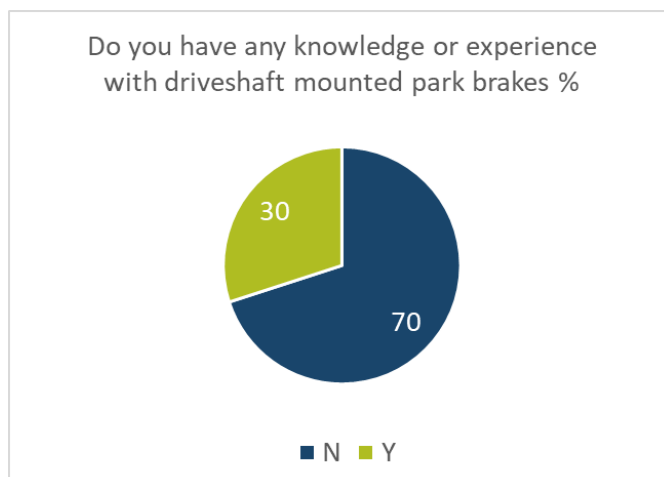
Question 1: 75% of drivers use the test vehicle regularly, while most of the drivers who don't were made up of new or temporary drivers.



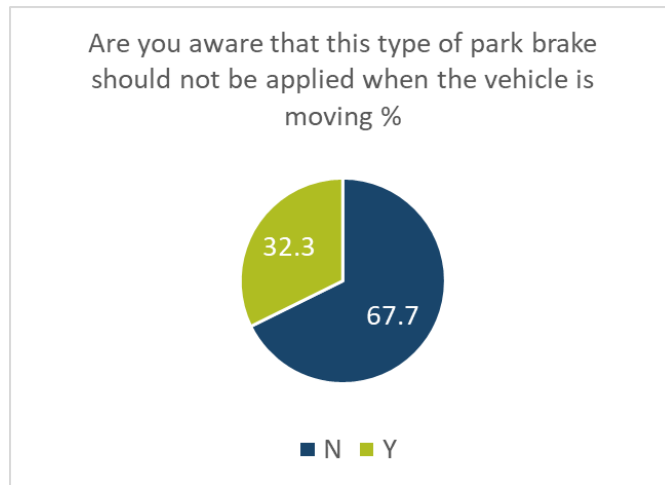
Question 2: 67% of drivers are not aware of the type of park brake fitted to the vehicle they drive regularly, while most of those who were aware had good knowledge.



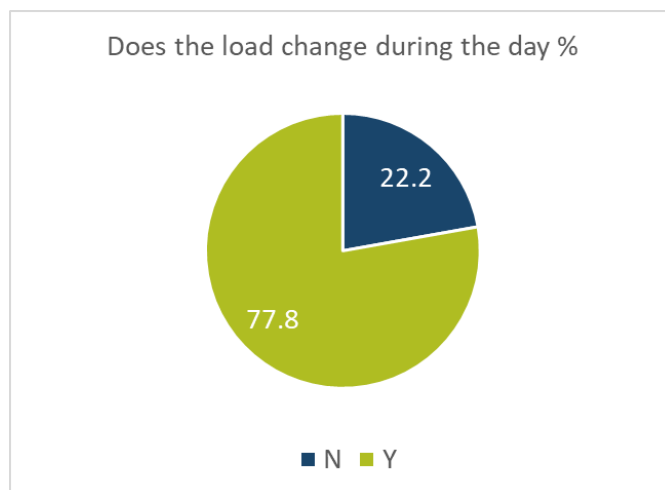
Question 3: 70% of drivers had no knowledge or experience with CSB, while most of those who were aware knew about its operation and any short comings.



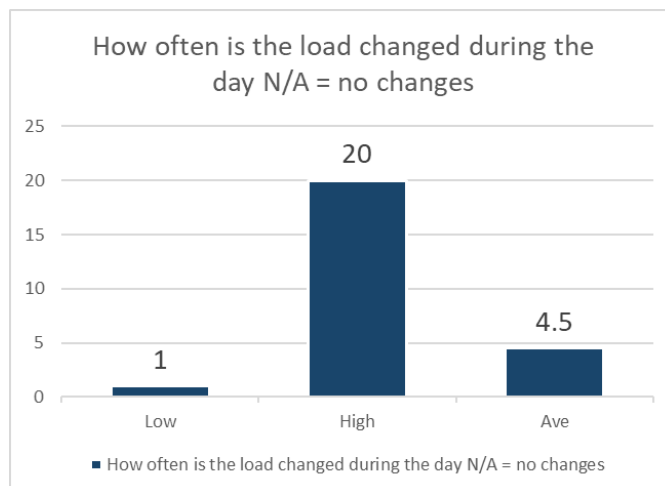
Question 4: 67% of drivers did not know the CSB could not be used as an emergency brake or while in motion, while those who were aware had good knowledge.



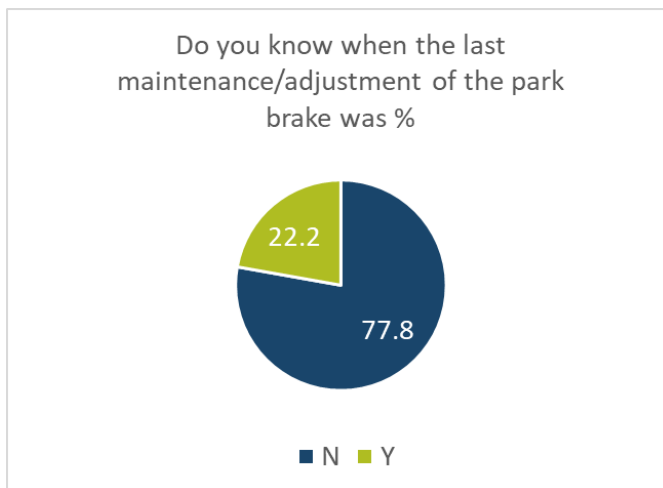
Question 5: 77% of vehicles tested were subjected to load change during the working day, while those that didn't change were mostly dedicated units such as mobile plant, concrete pumps or service vehicles.



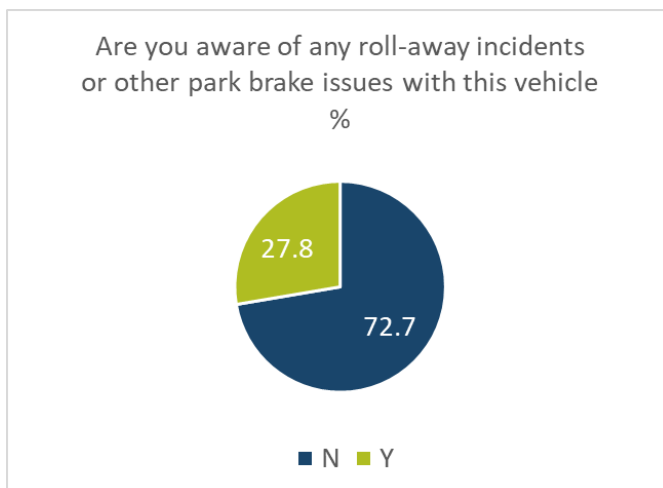
Question 6: Vehicle loads were changed on average 4.5 times a day.



Question 7: 77% of drivers were unaware of when the CSB was last maintained or adjusted while most of those that were aware could not say when it was done.



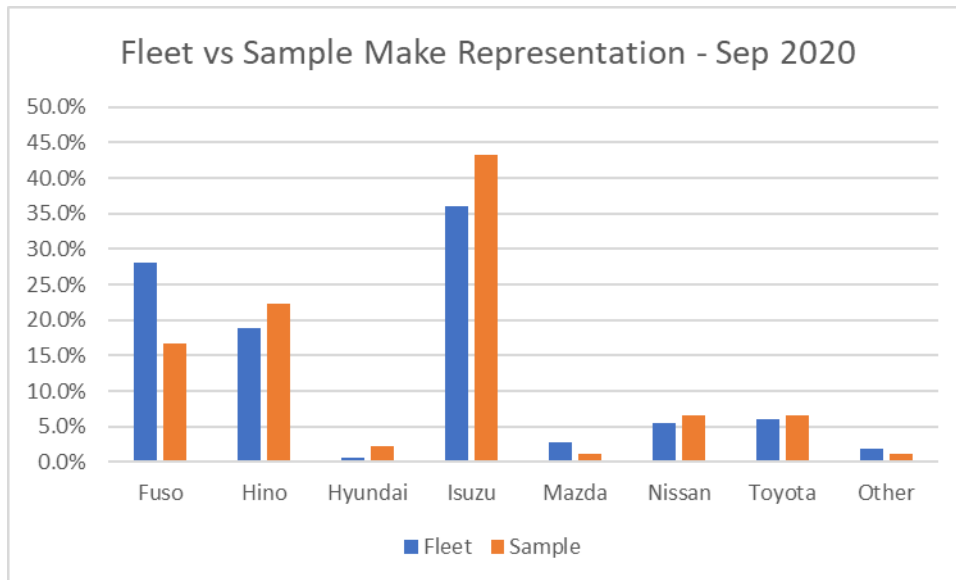
Question 8: 72% of drivers were not aware of any park brake issues in the vehicle they were driving, while those that were knew of issues ranging from the brake not holding the vehicle when parked through to experiencing a full runaway incident.



Statistical Analysis

The data collected from the CSB testing was reviewed by Alistair Gray of Statistics Research Associates Limited (StatsResearch). The full report is included in Appendix 2.

The main reason for engaging independent statistical advice was to get some assurance that the testing method and results were statistically robust and suitably representative of the fleet. The below graph shows a comparison of the overall fleet with the vehicles tested in terms of vehicle make. From this perspective the testing provides a good representation of the fleet. The report from StatsResearch also indicated that the method for selecting vehicles was suitably random, although a greater geographic spread would have been preferable if resourcing had allowed.



Based on the data from the testing, a failure rate of 27% can be estimated for the entire fleet based on the pull forward test (with a 95% confidence interval (18%, 36%)) and a failure rate of 21% (95% confidence interval (14%, 30%)) can be estimated for the pull rearward test.

In terms of the comparison between the pull test and the stall test, the report concluded that on average, the pull test forward required on average 4 more clicks of the handbrake lever than that required for the stall test. This increased to 5 more clicks for the rearward test.

Observations

- Driver/operator knowledge of park brake type was poor
- All vehicles that failed the stall test also failed the pull test
- Stall tests performed on Auto & AMT equipped vehicles gave variable results showing that the stall test could not be relied on for CoF for these vehicles.
- Even among the 'good' results there was often a noticeable difference between the 'uphill' & 'downhill' results indicating a lack of correct adjustment.
- A stall test 'pass' does not effectively reflect the brake performance indicating a new CoF test for CSB is required.
- The general condition or presentation of the test vehicles did not correlate to the park brake performance. Some vehicles appeared to be poorly maintained at first glance but performed well, while some new and tidy vehicles needed adjustment and or maintenance.
- A 12 tonne GVM is not the cut-off point for vehicles with CSB. Vehicles with up to 23 tonne GVM were observed and tested with a CSB.
- There were issues with new vehicles raising the question of whether the manufacturers' pre delivery inspections were being carried out correctly. It should be noted that most new brake systems benefit from being burnished, however, CSB are designed for use only when the vehicle is stationary, so no burnishing takes place in normal service.
- The test programme did not address the issues where a wheel or the vehicle is stopped on different surfaces and the risk of run-away in those circumstances. This is an area that may require further investigation.

Conclusions

The key findings of this report show a distinct difference between a stall test and a pull test to a target force value, this indicates the stall test is an ineffective test of the actual holding power of the CSB. Testing results show the number of CSB systems that are well outside manufacturers specifications is very high with the number of CSB systems not able to hold the vehicle in either direction also being very high.

The conclusions reached are;

- The CSB in 80% of vehicles tested could meet the current CoF inspection "stall test" but they did not provide enough holding power for the "pull test".
- The CSB in 12% of vehicles tested were not capable of meeting the current CoF inspection "stall test".
- The CSB in 8% of vehicles tested could not have a "stall test" due to transmission type being either fully automatic or automated manual transmissions.
- The CSB in 67% of vehicles tested could reach the target "pull test" force but required more lever travel and more lever force than the manufacturers specifications to achieve it.
- Over 20% of vehicles indicated an issue with the cable operation of the CSB, including worn, stretched, and seized cables.
- Over 30% of vehicles indicated poor adjustment of the CSB system, including worn shoes, excess lever travel and incorrect adjustment of the brake shoes.

Recommendations

A range of initiatives may be required to address the issues born out of this CSB testing program, the recommendations below could be used in isolation or in a combination, and in no particular order they are;

- The current CoF inspection CSB test for entry and in-service operation is ineffective, a new CSB testing procedure should be investigated.
 - A roller brake machine test of CSB should be investigated. The two major RBM suppliers have differing views on using their equipment in this manner and that needs to be discussed directly with both principals.
 - An alternative winch test using the “pull test” method should be investigated.
 - Requiring a 18% slope to be available should be investigated.
 - Any new CoF test must be achieved in both directions with the vehicle in a laden state either through load carried or through load simulation.
- Raise awareness of CSB operation, maintenance and adjustment with service providers, operators and drivers. Options include;
 - Including information in the Road Code
 - Including questions in Driver Licence information and tests.
 - Including CSB information as a requirement for training within the OEM/Dealer/reseller/hirer networks. This class of vehicles typically have frequent weight changes (e.g. tipper trucks, water cartage, building supplies, waste carting) which can increase the risks associated with CSB. This needs to be communicated to vehicle users.
 - An information sheet signed for by the purchaser of a CSB vehicle on delivery.
 - A mandatory specific maintenance requirement statement produced for CoF inspection (e.g.4085D form).
 - Including warning labels in vehicles with CSB. For new vehicles and used imports these could be fitted by the OEM or dealer, for existing vehicles these could be fitted at CoF and service provider outlets.
- Chocks could be useful in a two-person operation where the service brake can be operated while the chocks are removed but potentially dangerous for a lone operator. Waka Kotahi needs to take a firm position on the use of wheel chocks and advise accordingly. This includes aligning messaging with Worksafe.
- Work with Worksafe and the Health and Safety at Work Act 2015 to ensure PCBUs are protecting workers and making sure they are properly trained to operate the equipment and vehicles they use.
- Investigate alternative park brake systems for fitment to vehicles with CSB. USA and European manufactured vehicles in this GVM class do not use a CSB, they instead opt for a wheel operated park brake, typically this is a spring brake chamber acting directly on the service brake. **Note:** It needs to be noted that these jurisdictions do not ban CSB use as they import many thousands of Asian sourced vehicles in the same manner as both Australia and NZ.
- Investigate a change to the import of vehicles fitted with CSB including testing requirements, it should be noted this will not address the 55,000 (approx.) vehicles currently in use throughout the NZ fleet.

APPENDIX 1: OPERATION ORDER TRANSMISSION PARK BRAKE TESTING

OPERATION ORDER TRANSMISSION PARK BRAKE TESTING

WAKA KOTAHI NZ TRANSPORT AGENCY – VEHICLE STANDARDS

16 SEPTEMBER 2020

FINAL

Background

1. Transmission park brakes, commonly known as a Cardan Shaft park brake (CSB), have been linked to a number of incidents where the vehicle has rolled away causing injury and damage, in three recent cases the injuries have been fatal.
2. The Coroner's findings into one of the events recommended, "a review of the requirements and testing of park brakes is required" and that "a recommendation in relation to those issues may also raise public awareness of the safety issues".
3. Waka Kotahi NZ Transport Agency (Waka Kotahi) responded by commissioning two independent reviews to investigate any potential shortcomings in both legislation and in-service inspection of HMV park brakes.
4. The summary of both reports was submitted to Waka Kotahi senior management in September 2019, it indicated that CSB present several challenges in operation and maintenance. There are approximately 50,000 NB vehicles in service in NZ. NB class vehicles typically utilise a CSB. The risks posed due to poor maintenance of these brakes across such a large number of vehicles led to Waka Kotahi taking action.
5. Waka Kotahi initiated a park brake maintenance form (4085D) in December 2019. The form was used by a vehicle inspector where the park brake failed a CoF test. The form would then have to be filled out by the owner confirming the park brake had been maintained and then presented back to the vehicle inspector. The trial period for the forms use was for 6 months ending 30/06/2020.
6. A further incidence has prompted Waka Kotahi to undertake an audit and review of in-service brake testing in an effort to investigate other options for testing of CSB systems.

Operation Scope

7. This operation is a combined Waka Kotahi/NZ Police Commercial Vehicle Safety Team (CVST) effort.
8. The operation involves parties from both Waka Kotahi, CVST and independent brake specialists (where required).
9. The aim of this operation is to inspect and test up to 100 NB class (3500 – 12,000Kg GVM) heavy motor vehicles fitted with a CSB.
10. The operation is set to take place during mid to late September 2020.
11. The operation will be run at the Waka Kotahi/CVST Commercial Vehicle Safety Centre located in Plimmerton, Wellington.
12. The operation, dependent on CVST operational requirements, will be conducted at either site, Northbound may produce more loaded vehicles while Southbound will interfere less with daily operations but may have more unladen vehicles.
13. A surface friction test has been carried out prior to the commencement of testing at all testing sites by a member of the Police serious crash unit using a surface friction measuring device mounted to a patrol vehicle. Both sites were measured at 0.79u Dry, 0.65u Wet.

14. A site safety induction will be conducted prior to the operation by a member of CVST, the site safety officer will also be a member of CVST. All participants must have the minimum PPE of a Hi-Vis jacket and Safety boots.
15. A safe testing area will be set up and separated from normal traffic flow using 900mm road cones (see appendix 1).
16. Vehicles will be stopped using the “ALL TRUCKS STOP” signs located prior to the entry of each site.
17. Vehicles will be directed over the weighbridge and inspected by a member of CVST.
18. Vehicles will be screened by a member of Waka Kotahi, if identified as a CSB vehicle, then directed to the testing area and tested according to the testing procedure (see appendix 1).
19. If resource allows, it may also be useful to collect data on the number of NB class vehicles which pass the testing station and are not tested. This will provide data on the ratio of total vehicles assessed.

Distribution List

NZTA	Police CVST	Independent Specialists
Neil Cook Deputy General Manager – Regulatory Services Mark O’Conner Project Manager Michael Aitkin Senior Manager Policy and Planning Davey Uprichard Manager Vehicles Team Robbie Stephens Senior Engineer Neil McAlpine Vehicle Specialist Alex Currie Senior Engineer	Inspector Mike Brooklands Senior Sgt Mike Moloney Senior Sgt Aaron Bunker Sgt Tim Walker Const. Rob Keen VSO Calvin Haycock	Steve Bullot Tohora Enterprises Doug Latto Brake Specialist John Long Brake Consultant Selwyn Rabbits NZ Crane Hire MTA HV advisor Mark Ngatuere RTF Alan Raynor VTNZ Alistair Gray – StatsResearch

Legislation

Current legislation pertaining to heavy vehicle brake testing is contained in the Land Transport Act 1998 (LTA), the Land Transport Rule Vehicle Standards Compliance 2002 (VSCR) and the Land Transport Rule Heavy Vehicle Brakes 2006 (HVBR). As New Zealand does not have a heavy vehicle manufacturing industry it is a technology taker, drawing on other similar jurisdictions for motor vehicles standards. Both the VSCR and HVBR use aspects of UN/ECE regulation 13, ADR 35, FMVSS 105 & 121 and Japan Technical standards for heavy vehicle brakes.

Each of these standards set out rigorous and sustained testing parameters for brake systems including park brake systems that a vehicle must meet. The standards do not stipulate the in-service inspection requirements for the park brake testing. The HVBR recognises and accepts those standards and also sets out standards for vehicles built prior to the rule introduction in 2006 as well as those for a combination of vehicles, and those for modification and repairs carried out in NZ at any time after the vehicle was first registered in NZ.

In all jurisdictions that NZ recognises, the in-service testing is set by the regulator as it would be impractical to repeat the same degree of testing that is required to meet the standard, thus NZ uses the Vehicle Inspection Requirements Manual (VIRM), supplemented by the Heavy Vehicle Brake Testing Protocol. Key Service Delivery Partners (KSPDs) are appointed to carry out brake testing as required by the VIRM and protocol.

The in-service (CoF) test for a park brake is dependent on design and is either;

- A roller brake machine (RBM) test in which the brake must obtain 20% efficiency at 60% or more of the axle GVM, or
- A slope test of 18% in which the brake must hold the vehicle in forward and reverse direction at up to its GVM, or
- A stall test in which the vehicle must not move using an intermediate gear.

The use of an RBM for CSB testing is considered impractical as CSB systems are not designed or constructed to bring the vehicle to a stop while in motion, damage may occur to the vehicle or the RBM. The slope test is impractical in most locations as there are no 18% slopes close to the KSDP site, to have a slope on site would require major investment. The use of the stall test is the most common method used by KSDP’s for CSB CoF inspections.

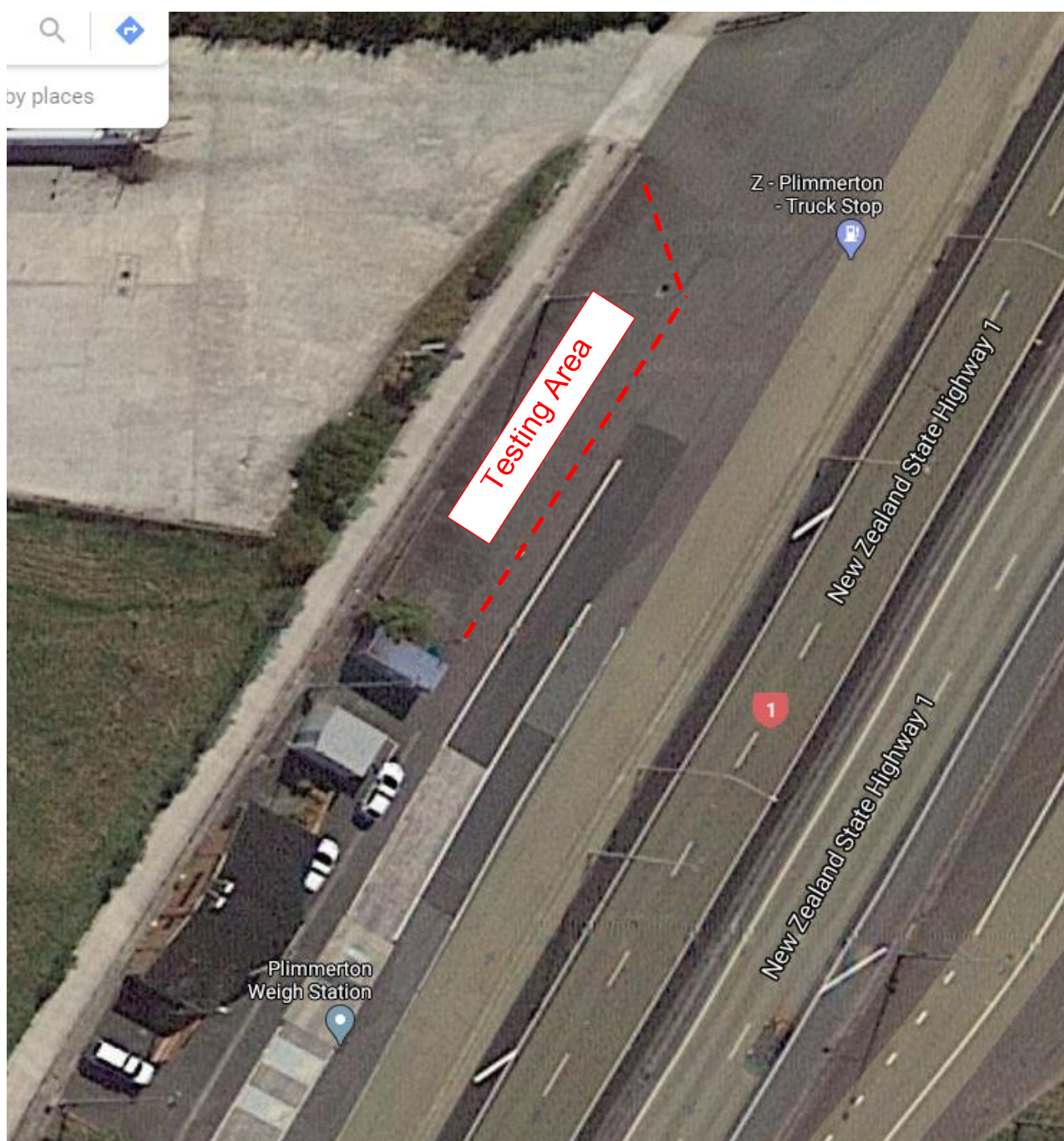
Appendix 1 – Site Layout and Testing Procedure

Site safety requirements and layout

1. A site induction will be carried out for all personal who have not been inducted previously.
2. The testing site is to be set up according to the site safety plan below. All persons within the testing area must always have minimum Personal Protection Equipment (PPE) of a High Visibility Vest and Safety Boots.
3. The site safety officer will be responsible for all persons within the testing area and will have the power to cancel testing if it is deemed unsafe to carry on. Note that the intention is to test in as dry conditions as possible (in accordance with the HVBR).
4. Site safety plans.

1. Northbound

900mm road cones are to be placed at 2mtr intervals, extending northward from the concrete plant box to the south side of the Z refuelling site driveway, entrance and exit will be controlled by removing and replacing cones as required.



2. Southbound

900mm road cones are to be placed at 2mtr intervals, extending southward from the Commercial Vehicle Safety Centre building, to a point approx. 5mtrs past the light pole, entrance and exit to be controlled by removing and replacing cones as required.



Risks:

- The outer lane of each site is a live lane, highway traffic is not restricted in these areas, care must be taken when moving around the sites especially when large vehicles are present.
- The north bound site has a refuelling station at its northern end, the site is accessed from the live lane, care must be taken in this area as vehicles move in and out of the site, Waka Kotahi members must stay within the coned area.
- Each weighbridge lane has a speed restriction of 5km/h, this lane is an operational area for CVST, Waka Kotahi personal must be accompanied by a Police member in this area.
- Beware of loose material, pot holes, slippery surfaces, heavy equipment, drains and lighting equipment. Refer to the Plimmerton Health and Safety at Work Act (HSWA) folder for further detail.

Testing equipment

1. An NC class 6X4 heavy motor vehicle with a Tare weight of approx. 8t equipped with a certified draw-beam or a suitable alternative to act as an anchor point.
2. A hand powered recovery type winch rated to a minimum of 5000kg capacity.
3. A digital load cell capable of reading a pull force up to 3000kg/f or equivalent suitable for mounting in-line with the winch and pull test equipment, the display of which must be in 10kgf increments and be visible to the operator.
4. A digital load cell capable of reading a pull force up to 100kg/f or equivalent suitable for mounting at 50mm from the forward end of the park brake lever, the display of which must be in 1kgf increments and be visible to the operator.
5. Recovery type strops, cables or rope that are in good condition and rated to a minimum of 3000kg breaking strain.
6. Other equipment as may be required to make safe connections between the test vehicle and anchor vehicle. This equipment must also be in good condition and rated to 3000kg breaking strain.

Testing procedure

1. Vehicles will be directed into the safety centre with the use of the "ALL TRUCKS STOP" signs (section 125(4) of the Land Transport Act 1998).
2. A CVST officer will be the only person to engage with the driver in the first instance and direct the driver over the weighbridge.
3. The vehicle will be screened by a Waka Kotahi member to determine if it is an NB class vehicle fitted with a CSB park brake.
4. The CVST officer will direct the vehicle to the test area (only one vehicle is to be positioned in the testing area until the site is cleared).
5. The CVST member will carry out a Level 3 inspection, the details are to be noted on a Commercial Vehicle Inspection Report (CVIR see appendix 5).
6. While the CVST officer is conducting the inspection, if it is safe to do so, the Waka Kotahi Vehicle Specialist (VS) will carry out a visual inspection of the park brake system noting any issues, photos may be taken where necessary.
7. Once the CVIR is completed the vehicle will be handed over to the Waka Kotahi member collecting the brake test data;
 - o The driver will be asked if they have any objection to a designated Waka Kotahi member operating the vehicle for testing procedures.
 - o If there is a legitimate reason for refusing, the test may be abandoned, or an alternative arrangement made.
 - o The vehicle details will be collected on the data sheet, and
 - o The driver will be asked to answer the questionnaire (appendix 2a).
8. The vehicle is to be positioned in line with the test rig and facing forward, noting any service brake issues.
9. The brake test specialist will connect the testing equipment and select the target test pull force from the table in Appendix 3.
 - o The park brake lever digital load cell will be connected to the hand brake lever at approx. 50mm from the forward end of the lever. The display must be visible to the driver or observer while operating the park brake.
 - o The pull test load cell and equipment will be connected to the most suitable connection point on the chassis, preferably a factory tow connection. The display must be visible to the winch operator or an observer using a remote display.
 - o If no suitable chassis connection can be found an alternative may be used, the connection must be verified as suitable by a Waka Kotahi VS or a CVST Vehicle Safety Officer (VSO).
10. The park brake lever will be applied with a 15kg lever force, noting the number of clicks of the ratchet. The vehicle will be stall tested in a forward direction using 3rd gear, or drive (if automatic).
 - o If the vehicle moves after any driveline lash is taken up, another click on the lever will be applied and the vehicle stall tested again.
 - o Continue above until the vehicle stops or the maximum number of clicks set by the manufacturer is achieved.
 - o Note the lever force readings at each click and results on data sheet.
11. The park brake lever is to be released, the park brake unit is to be marked with a chalk line to indicate movement relative to the mounting and then the lever reapplied with a 15kg lever force, noting the number of clicks of the ratchet.

12. The VS or VSO must observe the park brake unit for movement while the target pull test force is applied using the hand winch, care must be taken to ensure the force is maintained as the vehicle may move slightly on its suspension or through driveline lash.
 - The pull force must be applied evenly and smoothly to avoid excessive movement or bouncing of the vehicle and test equipment.
 - The pull test equipment should be reasonably horizontal to the pavement so that no excessive lift-up or pull-down forces are present.
 - If, during any testing, deformation of the vehicle connection points becomes visible the test will be stopped and an alternative connection used.
13. If the park brake unit is stationary;
 - a) Hold the pull test force for 1 minute ensuring the force does not decrease.
 - b) If the park brake unit remains stationary, apply an additional 10% of the test pull figure and note the figure on the data sheet.
 - c) If the park brake unit remains stationary, repeat steps 11, 12, 13 a) and b) in the reverse direction.
 - d) If the park brake unit is stationary for all tests record the results on the data sheet, disconnect the test equipment, hand the vehicle back to the driver with an information pack, place a sticker on the windscreen and clear the vehicle from the test area.
14. If the target pull test force is not reached and the park brake unit moves during steps 11 and 12;
 - a) Note the pull test force achieved, then increase the force to the park brake lever to move it one click of the ratchet and note the lever force reading. Re-apply the pull test force.
 - b) If the park brake unit moves, repeat a), one click at a time up to a MAX of 5 additional clicks on the ratchet or MAX 50kg/f, note the lever force at each additional click.
 - c) If the park brake unit remains stationary at any point in b) hold the pull test force for 1 minute.
 - d) If the park brake unit remains stationary, repeat steps 11, 12, 13, and 14 a) if required in the reverse direction.
 - e) If the park brake unit moves during any of the tests in reverse repeat 14 b).
 - f) If the park brake unit remains stationary in reverse at any point in step 14 b) hold the pull test force for 1 minute.
 - g) Record all results on the data sheet. Disconnect the test equipment, hand the vehicle back to the driver with an information pack, place a sticker on the windscreen and clear the vehicle from the area.
15. If the park brake unit continues to move in forward or reverse direction after step 14 b);
 - a) The driver will be advised the vehicle has a very poor park brake performance and it should be attended to immediately, the test equipment is to be removed.
 - b) The CVST officer may give a compliance notice to the driver if they believe the vehicle is not up to CoF standard.
 - c) The driver will be handed the information pack and the vehicle cleared from the test area.
 - d) Ensure all results are recorded on the data sheet and the questions are complete.
16. If the vehicle moves in forward or reverse direction during any of the procedures described above and the wheels are skidding on the test surface;
 - a) The test is to be suspended, the test equipment removed, the driver given the information pack and the vehicle cleared from the test area.
 - b) Ensure all results are recorded on the data sheet and the questions are complete.

All vehicles tested where the park brake unit has held the vehicle stationary will have a sticker attached to the left-hand corner of the front windscreen to ensure it is not tested again during the operation.

Incomplete Criteria

1. Where a vehicle moves but the wheels are skidding with the manufacturers lever force, the vehicle may not have enough load for a conclusive test (if possible, retest with more load).
2. Where a vehicle moves but the wheels are skidding with any other lever force up to the maximum of 5 extra clicks or 50kg lever force, the vehicle may not have enough load for a conclusive test (if possible, retest with more load).
3. Where a park brake unit moves during a test but during the following test the wheels skid, the vehicle may not have enough load for a conclusive test (if possible, retest with more load).

Appendix 2 – Questionnaire and Data Capture Check Sheet

The first questions for the driver will need to confirm their agreement to:

- Have someone else sit in the cab during testing (in order to get consistency for the lever force)
- Have a force applied to both the front and the rear of the vehicle

Note: Through the CVIR the following information is automatically collected:

- Day/Date/Time
- Location
- Driver licence no.
- Driver name
- Class and endorsements
- Transport Service Licence information:
- Vehicle Registration number
- Make
- Model
- Year
- Vehicle licence expiry date
- Registered owner
- Vehicle licence type
- CoF expiry data
- Hubodometer Reading

APPENDIX 2: STATISTICS RESEARCH ASSOCIATES FULL REPORT

Note: the supporting graphs and datasets referenced in this report can be found on Infohub at the following link:
<https://infohub.nzta.govt.nz/otcs/cs.dll?func=ll&objid=46168395&objAction=browse&sort=name&viewType=1>

Cardan Shaft Brake Testing by NZTA
Summary of Design and Initial Analysis

Alistair Gray,

Statistics Research Associates Limited

November 2020

Sample size calculation

Initially the requirement was to estimate the proportion of trucks which failed the braking tests: a stall test, a pull forward test, and a pull rearward test. As there was not much information about the approximate size of these failure rates in the population, it was decided to take a two-stage approach to the sampling. The first stage would be a small sample to estimate likely failure rates and their variability, and then from these sample estimates calculate a sample size which would achieve the required accuracy. For example, estimate a failure rate of 10%, with a 95% confidence interval (5%, 15%).¹

As well as considering the statistical cost, i.e. how accurately do we need to estimate the failure rate, the economic cost of doing the brake testing needs to be considered and how much can be afforded. This suggested an upper bound on the sample size of around 100.

The sheet Proportion of Failures in the spreadsheet [twostagesampling.xlsx](#) has two tables one for an initial sample of 30, the other for an initial sample of 50 which give the sample sizes required for a range of failures for a specified coefficient of variation (cv).² The cells in red are sample sizes larger than the 100 which could be afforded. The cells in yellow indicate that the initial sample size is large enough.

In that sheet there are also two tables giving the 95% confidence intervals³ for a range of failure rates for a sample size of 30, and a sample size of 100.

Subsequently it was decided that in addition to simple failure rates a distribution of force applied to failure rate should be estimated, say the mean force, and standard deviation of the force. In the absence of further population information about the distribution a useful starting point is to assume that this mean force to failure follows a Weibull distribution.

1 The method is described in Cochran *Sampling Techniques* 3rd edition 1977 John Wiley and Sons pages 78-80.

2 The sample error divided by the sample mean.

3 These are Jeffreys non-informative prior intervals, one of the 'exact' binomial confidence intervals and not the more usual normal approximation intervals because the failure rates could be small and the sample sizes are small. As the population of trucks is around 50,000 the sampling is assumed to be binomial rather than say hypergeometric.

It has two parameters: scale and shape. Scale determines the values over which the distribution has a positive probability. As scale increases the maximum probability decreases and the values of positive probability increase. The shape as the name suggest determines the shape of the distribution. If the shape is greater than 1 then it means the failure increases as x increases. This seem sensible in the case of the brakes where presumably increasing force leads to increasing failure. A location parameter can also be used to define the distribution, but that is equivalent to relabelling the x -axis. For example, if the force applied begins at say 2 kiloNewtons we could relabel the x -axis in a graph of the distribution as starting at 2 instead of 0. Interestingly the population cv does not depend on the scale parameter.

The graphs ([Weibullcdf.pdf](#)) show the cumulative distribution function of Weibull distributions for various shape parameters. The y -axis is the proportion of trucks and the x -axis is the force at which the brake fails. The graph for shape of 1 suggests that some trucks fail with almost no force, while at least 50% fail (the median force to failure) with a relatively small force of .6. Whereas 90% fail with a force of around 3 about 5 times the median force to failure. (The unit for the force is arbitrary. I have labelled them 1, 2, 3 etc for illustrative purposes.) This does not seem that plausible. Considering the curvature of these graphs of the cumulative distribution function of Weibull distributions it is likely a shape in the range 1.7 to 2.3 is quite plausible.

Once an accuracy requirement for the estimate is set, it is the cv that determines the sample size. Hence having decided on a set of plausible force to failure shapes we need to know what their cvs are. The graph [WeibullCV.pdf](#) plots the cv for various shapes. In the range 1.7 to 2.3 the cv decreases from about 0.60 to about 0.45. This is a reasonably narrow range.

The sheet mean force to failure in the spreadsheet [twostagesampling.xlsx](#) provides the sample sizes for various population cvs and relative errors. If the cv is between 0.4 and 0.6 then a relative error of around 10 percent could be achieved for sample sizes around 100 or less. These are the yellow highlighted cells.

However, because of practical issues with measuring a continuous force applied, force was going to be applied at discrete intervals, and the number of clicks on the brake lever to hold the force observed. Hence how to determine the sample size reverted to the first approach outlined above.

Sample versus Population

For economic cost reasons the sampling of trucks could only be carried out at one site, the Plimmerton Weigh Station. The sampling was carried out over two weeks. A common method of sampling traffic, vehicles or people, is to use a systematic random sample. Here the first vehicle is randomly selected as it passes the sampling point. If say based on previous traffic counts, it is expected N vehicles will pass the sampling point and n vehicles are required to be sampled, then we calculate a sampling interval k , which is the integer part of N/n . After the first vehicle we then then count k vehicles and sample the k th one. We do this until we have until we have n vehicles. For example, if 632 vehicles are expected to go past and we need to sample 10 of then $N/n = 6.32$ and $k = 6$, so we sample every 6th vehicle thereafter. Of course, we may get more or less than 10 depending on whether more or less than around 600 vehicles pass by while we are sampling.

However, for practical reasons including not having a line of trucks waiting to be tested, the sampling was not strictly a systematic random sample. Rather the sampling with the sampling interval is approximately random in time as an eligible truck is stopped when an earlier truck has completed the testing. By the end of the two weeks 90 trucks were tested.

Comparing the characteristics of the trucks in the sample with those in the population is sensible to see that no imbalances have occurred which might lead to incorrect inferences. For example, if say a particular make of truck was more prone to brake failure and this truck was underrepresented in the sample compared with the population then we might infer that the population failure rate is smaller than is really is.

Ideally one would have compared several characteristics which could affect brake failure, such as age of truck, time since CoF, New Zealand new, etc. But in the time frame I could look at only model type.

The sheet Sample v Fleet in the spreadsheet [brakedata output.xlsx](#) gives tables of the makes in the Fleet (Population) and the sample. Since the sample was small, I collapsed some of the Fleet make categories as indicated in the column make. For the sample data I have calculated the expected number of each make if the Fleet proportions held in the sample. I did a simple chi-squared test which indicated the make distribution in the sample was not different from that in the Fleet.

Data Analysis

Failure estimates

The sheet Stall and Pull Test results in the spreadsheet [brakedata output.xlsx](#) gives summary results from the 3 main tests: a stall test, a pull forward test, and a pull rearward test.

The stall test cannot be used on trucks which have automatic gearboxes. There were 7 such trucks as indicated by the column <NA> in the stall test table. The estimate of the proportion of trucks in the Fleet which would roll is 13% with a 95% confidence interval of (7%, 22%).

For the pull forward test one truck skidded but did not roll. If we consider only rolling a failure then the Fleet estimate is 27% with a 95% confidence interval of (18%, 36%). But if we include skidding as a failure then it is 28% (19%, 38%).

For the pull rearward test, the Fleet estimate is 21% (14%, 30%).

Although the estimate of failure rate for the pull rearward test is smaller than the pull forward test, the respective confidence intervals overlap, so with this sample size we cannot be confident there is a difference.

The overall mechanical condition of the brake was assessed and assigned to a five-point Likert scale from Excellent to Poor. Collapsing the Excellent, Very Good and Good into a PASS category, and regarding Fair as MARGINAL and Poor as a FAIL, the Fleet estimate of FAIL is 47% (37%, 57%).

Regression

The dataset is rich and worthy of further analysis. I carried out some exploratory data analysis and discussed this with Alex Currie and Mark O'Connor from NZTA. Given the apparent higher failure rates of the pull tests compared with the stall test, they were interested in the relationship between the number of clicks to engage the brake for the stall test and the pull test.

The graph [pftVdstClicks.pdf](#) is a scatterplot for each make of the number of clicks for the stall test against the number of clicks for the pull forward test. There is a graph for each make. There are too few trucks for the Hyundai, Mazda, and Other makes to say much about them.

The x-axis of each graph is the number of clicks (PB setting) on the brake lever used in the stall test. For most trucks this was the initial setting taken from the truck's manual. But for some trucks a higher setting was also used. There was a target pull force for the pull forward test. Generally, this force was attained by increasing the force to this target level through several stages. The number of clicks were recorded at each incremental change in force. The y-axis is the number of clicks at this target, or close to it, except if the truck rolled or stalled at an earlier stage and then the number of clicks at this stage is used. A non-robust simple regression line

$\text{pullforwardtest.clicks} \sim \text{intercept} + \text{stalltest.clicks}$

overlays the set of points

For both sets of graphs, each make with more than a few observations, follows a straight line quite well. In the pull forward graph there is a fairly obvious outlier for the Isuzu, Fuso, and Nissan makes. In the pull rearward graph the Fuso outlier is obvious but no others.

Similar comments hold for the scatterplots [prtVdstClicks.pdf](#) for the stall test against the pull rearward test. In the pull rearward graph the Fuso outlier is also obvious but no others.

I fitted two linear regressions:

$\text{pullforwardtest.clicks} \sim \text{intercept} + \text{stalltest.clicks} + \text{make} + \text{stalltest.clicks} : \text{make}$

and

$\text{pullrearwardtest.clicks} \sim \text{intercept} + \text{stalltest.clicks} + \text{make} + \text{stalltest.clicks} : \text{make}$

This means I am fitting a separate regression line for each make, so the lines could have different intercepts and slopes. This is essentially what the graphs are displaying.

We do not have a large enough sample for each make to distinguish differences in the slopes for the different makes, but there are differences in the intercepts as a stepwise regression shows. That is the reduced model

$\text{pullrearwardtest.clicks} \sim \text{intercept} + \text{stalltest.clicks} + \text{make}$

fits better. This model says the slope of the line is the same for each make of truck, but the intercept term is potentially different. If the variability remained the same, we would need to have about 3 times the sample size to see if the slopes were significantly different by make.

The details of the regression output are in the sheet Click regression in the spreadsheet [brakedata output.xlsx](#). The output for full model is given first then the output for the reduced model.

In summary what the regressions are saying is:

1. To hold the pull forward test on average we need 4 more clicks than the stall test (the intercept estimate) but this could be more or less by make. For example, Isuzu trucks need about 1.4 clicks on average less (the make Isuzu estimate), or only about 2.6 clicks to hold. Thereafter for each stall test click 1 pull test forward click is needed (the `stalltest.clicks` estimate) for any make.
2. To hold the pull rearward test on average we need 5 more clicks than the stall test but again this could be more or less by make. Thereafter for each stall test click a little less than 1 pull test forward click is needed.
3. Generally, Isuzu, Nissan, and Toyota need fewer clicks than other makes.

The interpretation of these results would be that holding the brake at the number of clicks to pass the stall test does not guarantee that the brake will hold the pull tests.

