Acknowledgements
This manual is primarily bases on the references:

- UK Roads Board (July 2005): SCANNER Surveys for Local Roads, Quality Assurance and Audit, Volume 4 and 5.

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CoPPTM</td>
<td>Code of Practice for Temporary Traffic Management</td>
</tr>
<tr>
<td>CQP</td>
<td>Contract Quality Plan</td>
</tr>
<tr>
<td>dTIMS</td>
<td>Deighton Total Infrastructure Management System</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>IRI</td>
<td>International Roughness Index</td>
</tr>
<tr>
<td>LOS</td>
<td>Levels of Service</td>
</tr>
<tr>
<td>NAASRA</td>
<td>National Association of Australian State Road Authorities</td>
</tr>
<tr>
<td>NZTA</td>
<td>NZ Transport Agency</td>
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<tr>
<td>RCA</td>
<td>Road Controlling Authority</td>
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<tr>
<td>TMP</td>
<td>Traffic Management Plan</td>
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<td>RAMM</td>
<td>Road Assessment Maintenance Management</td>
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<tr>
<td>RTRMS</td>
<td>Response Type Roughness Measuring Systems</td>
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Note to reader:

Version 2 contains amendments to Section 2.4 Survey Suppliers and Appendix 3
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1 INTRODUCTION

Condition assessment is a key measure of road network performance and a major determinant of road user costs. Condition data is used in pavement management systems to monitor the network condition and predict its future condition.

Condition data is used to support a range of asset management decisions which aim to provide an efficient and effective road network. It is also one of the primary indicators for network level maintenance programming, and for monitoring the network’s performance, managing term maintenance contracts, benchmarking among Road Controlling Authority (RCA) networks, research and fatal crash investigations. Therefore, it is essential to ensure the quality of the condition data is not compromised and a high standard is maintained.

This manual provides a common approach to high speed condition assessments on local authority roads in New Zealand. It provides an overview of factors that should be considered before condition assessments are undertaken, the limitations of survey equipment and survey procedures.

The manual also discusses the collection of roughness and rutting using laser profilometer and Response Type Roughness Measuring Systems (RTRMS) and provides specific contract procurement guidelines, and calibration and validation criteria that will ensure appropriate equipment is used to collect pavement condition data.

This information will help RCAs make well-informed decisions about procuring high speed data collection services for surveying roughness and rutting on the network. It includes a survey methodology to improve the quality and consistency of measurements in successive surveys so they are comparable. There is also a full data collection specification included in Appendix 1 which can be used or modified to suit individual RCA requirements.

Automated non-contact profilometers are used to collect roughness and rutting data while operating at high speed. These profilometers measure longitudinal and transverse profiles from which the roughness and rut depth are calculated. The longitudinal road profile is summarised by the International Roughness Index (IRI). This is then converted to National Association of Australian State Road Authorities (NAASRA) counts - the summary index historically familiar to practitioners in New Zealand. The transverse profile measurement provides the depth and extent of rutting in the wheelpaths.

This guideline and appended specification is intended for both network level and project level surveys.
2 BACKGROUND

Having a basic understanding of what data is to be measured, how it is recorded, and the complications associated with these measurements is essential if appropriate contract documents are prepared. This section gives a brief overview of the data and how to ensure appropriate methods to collect the data can be adopted.

2.1 Overview of Validation Requirements

The quality of the pavement condition data collected is only as good as the equipment chosen and the procedures adopted to measure the data. Variations in profiling may arise due to dissimilarity in equipment, inappropriate operating procedures, calibration and validation, and aspects of the road network and measuring environment.

To ensure the collected data’s quality and uniformity, the survey equipment used to collect pavement roughness and rutting must at least achieve the standard described in Appendix 1 of this manual. This validation procedure is correlated against a reference instrument and a 10 km field test. Full details about how to undertake this procedure are detailed in Austroads Test method AG:AM/T004 Pavement Roughness Repeatability and Bias Checks for an Inertial Profilometer, and Austroads Test Method AMT12:2005 Pavement Rutting Verification Tests for Multi Laser Profilometer.

Reference data collected under NZTA Project 09/543 Data Collection on Long Term Pavement Performance Sites can be used for the validation exercise. Currently there are 146 such sites throughout New Zealand. Appendix 2 contains a full list of the sites and their location. Roughness and rutting data is available from NZ Transport Agency (NZTA) Head Office, their consultant Beca, or from the data collection contractor R&D Consultants NZ Ltd.

Note: Reference data is collected annually between September and April each year, and is available for immediate distribution.

Additional repeatability and bias tests of the survey-equipment are required at 30 day intervals to ensure the same level of quality is maintained throughout the data collection programme.

These procedures consider variation in outputs about the mean (repeatability), and ensure the equipment does not systematically under or over report (bias).

Provided survey equipment has proof of current NZTA approval to survey the state highway network, there is no need for it to undergo the additional validation checks. For all other equipment, the validation checks described in this document must be undertaken.

2.2 Overview of Roughness and Rutting

2.2.1 Roughness

Roughness primarily refers to unevenness or undulations in the road surface that affects the ride quality, comfort, safety and accessibility (a structurally sound road can be inaccessible if its surface is extremely rough). Roughness also has an impact on vehicle operating costs due to added vehicle maintenance, wear and tear of tyres and fuel consumption. Pavement roughness also induces dynamic loading which can affect a pavements life. Since it is not practical to build perfectly smooth roads, RCA set acceptable Levels of Service (LOS) for roughness on their networks. The LOS depend on factors such as the pavement use, hierarchy, type, geotechnical condition, traffic and its maintenance regime.

The following are Internet links summarising pavement roughness and measurement:

www.fhwa.dot.gov/pavement/smoothness/rough.cfm

Austroads also produce an excellent overview of roughness measurement (Austroads, January 2006). This is covered in Part 5B: Roughness (Austroads Publication AGAMOSB/06, cost (in 2012) AUS$36.96).
2.2.2 Longitudinal Profile

The longitudinal profile is measured primarily to obtain the pavement’s ride quality (roughness). By measuring the road elevation in the survey vehicle’s wheelpath, the pavement’s roughness can be captured.

The longitudinal profile is measured using non-contact sensors fitted to a survey vehicle; and is recorded as the survey vehicle travels along the road at normal traffic speed. Sensors measure the distance travelled, the distance between the sensor and the road, and the vertical motion of the vehicle. Data processing algorithms on-board the survey vehicle, process these signals to obtain the longitudinal profile.

2.2.3 Rutting

Rutting is a pavement deformation in the form of a longitudinal depression, usually in the wheelpath due to repeated loading. It is characterised by permanent deformation in one or more pavement layers, which can accumulate over time. The possible causes of rutting include poorly compacted structural layers, deformed surface layers, heavy loading, improper asphalt mix and inadequate lateral support from unstable shoulder material. A useful Internet link summarising pavement rutting and how to measure it is at www.thrc.gov/pavement/ltpp/pdf/01027.pdf

Austroads has also produced an excellent overview of rutting measurement (Austroads, June 2005). This is covered in Part 5C: Rutting.

2.2.4 Transverse Profile

Transverse profile characterises and quantifies the severity and extent of ruts over a pavement surface. Transverse profiles are measured using non-contact sensors mounted on a support beam extending across the width of the survey vehicle. The survey vehicle travels at normal traffic speed and measures the transverse profile. The rut depth under a two or three metre straight edge is calculated from the profile using a mathematical algorithm within the data collection software.

2.3 Road Condition Rating and Roughness

Land Transport New Zealand’s RAMM Road Condition Rating and Roughness PFM6 manual was released in 1997. It is the current industry standard for measuring and recording pavement defects on both sealed and unsealed roads. Roughness is measured using a response meter, and a visual rating assessment is used to measure rutting, shoving, cracking, potholes, edge-break, flushing and water channel faults. Since its release in 1997, there have been no major changes to survey procedures, data collection, quality assurance, and advancements in survey technology; however it is currently under review and is likely to be upgraded. Therefore in addition to the specifications for roughness and rutting Appendix 1 includes specifications for road geometry, GPS, and video recording which can be included if required.

2.4 Survey Suppliers

Several organisations in New Zealand have vehicle-based laser equipment and/or response type roughness measuring systems (RTRMS) available for measuring roughness, with the laser equipment able to measure also rutting and texture and more.

A current table of vehicle-based laser and RTRMS New Zealand based suppliers is held in the RIMS Book of Knowledge web Page. Access to this can be requested via a link provided in the RIMS Knowledge Page of the IPWEA website.

The web address is http://www.ipwea.org/newzealand/home

If you wish to be included in this list of suppliers or you have any updates to the list, please contact the RIMS Group.
3 CONTRACT PROCUREMENT GUIDELINES

The following contract procurement guidelines are for roughness and rutting using laser profilometer systems. More detailed Terms of Reference for data collection (including specifications for all condition features) are included in Appendix 1.

3.1 General

The contract procurement guidelines provided in this Section and in Appendix 1 can be used to prepare the scope of services for vehicle-based condition surveys for roughness, rutting and other condition parameters.

There are several New Zealand-based consultants with specialist contract preparation and performance monitoring skills. These consultants can help local authorities develop specific contract documents, evaluate equipment validation results, and monitor contractors collecting data.

3.2 Preliminary

The Scope of Services should be read in conjunction with the Conditions of Contract, other contract documents and specifications. The contract should be carried out according to the specifications.

3.3 Roles of Parties to the Contract

a) Client – road controlling authority for which the data is being collected
b) Engineer – representative of the Client
c) Contractor – organisation conducting the survey and providing the resultant data.

The Engineer will audit the Contractor’s systems, procedures and documentation to ensure an appropriate quality assurance regime is demonstrated and contract requirements are met. The audits will concentrate on identifying and correcting non-conformance.

3.4 Nature and Extent of Services

This contract is completing high speed road condition surveys using a laser profilometer on the (Name of Client) sealed network. The contract includes the associated data processing, compliance monitoring and reporting of:

a) The longitudinal profile for roughness in both wheelpaths
b) The transverse profile for rut depth in both wheelpaths.
c) <Other> specify/include as required.

3.4.1 Location

The survey site is located within area encompassed by the (Name of the Client) boundaries. The locality diagrams are shown in (Specify where in the Contract documents these are located).

3.4.2 Extent

The contract work includes providing all labour, plant and material required to complete the work described in the specifications summarised in the Schedule of Prices, and includes:

a) Providing and agreeing the Contract Quality Plan (CQP), the programme for the completion of the contract, all reports and the Traffic Management Plans (TMP)
b) Supplying all survey equipment and required software
c) Calibrating and validating all survey equipment and providing calibration certificates
d) Complying with quality assurance procedures and liaising with the Engineer
e) Carrying out surveys on the network
f) Providing processed data in a format that can be directly loaded into the Client’s Road Asset Maintenance Management system

g) Entering the processed data into the Client’s RAMM (Road Assessment Maintenance Management) database (if required). Note where the data is to be entered into the Client database access to RAMM database will be provided

h) Converting IRI into NAASRA counts/km

i) Reporting - Refer to Section 3.8.

3.4.3 Survey Requirements

Where the Contractor chooses to use two or more survey vehicles then the survey equipment and operators must undergo additional validation to demonstrate that all the data they collect can be matched to the same road furniture and road features. The proposal shall also include details on how the surveys will be conducted and in which order. Irrespective of the survey direction, all data is to be referenced in terms of increasing chainage and kilometre post identification.

The standard survey procedures shall be:

a) On narrow single carriageway roads - the survey vehicle travels in the direction of increasing chainage, with the measurements taken in the normal driven wheelpath. Where roads are particularly narrow this is likely to straddle the road centreline. Data processing techniques should account for instances when the vehicle deviates from the road onto the shoulder.

b) On single carriageway two-lane roads with lane delineation - both increasing and decreasing lanes will be surveyed. The measurements will be taken in the wheelpaths; where no obvious wheelpath is visible the measurements of the outside wheelpath will be taken 50–70 cm from the edge of the pavement.

c) On divided carriageway roads and service lanes - both increasing and decreasing lanes will be surveyed. The measurements will be taken in the wheelpaths; where no obvious wheelpath is visible the measurement outside wheelpath will be taken 50–70 cm from the edge of the pavement.

d) On dual carriageway roads - the increasing and decreasing lanes on both carriageways will be surveyed. The measurements will be taken in the most heavily trafficked wheelpaths.

e) On multi-lane roads (four or more lanes) - only two lanes will be surveyed, one in each direction as per (d) above.

f) Where GPS coordinates are specified - the Contractor will ensure the coordinates are offset so that the road centreline is obtained. Note the method chosen for this offset must be agreed by the Client.

Note there may be situations where it is desirable to have all lanes surveyed. Where these circumstances arise the RCA should define these separately.

It is recognised that survey equipment has operational limits. These include a minimum speed below which the quality of the data collected is compromised. Therefore the Contractor must advise the Client of the minimum speed and other conditions that adversely affect the data quality and advise how the data may be flagged when these situations are encountered.

During the survey the survey vehicle should collect data at the normal road speed or at the equipment manufacturer’s recommended speed. If this is not possible and the data quality is either compromised or not recorded, the sections affected should be surveyed as follows:

a) An estimate of the roughness and rutting value must be provided, and flagged with a suitable event code. This estimate, often just the average of the preceding and following sections, must be defined by the Contractor and agreed by the Client or Client’s Engineer.

b) Where the Contractor is unable to collect the data in the way outlined above, the Contractor needs to specify other methods in the tender. These must also be approved by the Engineer prior to work being carried out.
3.4.4 Skill Requirements

The team put forward by the Contractor will have relevant experience and accreditation credentials, and:

a) Include a trained operator and driver familiar with the proposed laser profilometer survey equipment
b) Be experienced in carrying out field pavement assessments to establish estimates
c) Have sound and approved quality assurance systems and procedures for data collection and processing
d) Be conversant with NZTA safety procedures when working on local authority roads
e) Have extensive experience in undertaking high speed data collection
f) Have a thorough understanding of pavement behaviour and surfacing treatments
g) Have an understanding of the condition data to be collected and the Client’s road management systems.

3.5 Contract Objectives

This Contract’s objective is to obtain reliable and repeatable condition data in which Client can have confidence when implementing and reporting asset management policies and practices.

3.6 Contract Quality Plan

3.6.1 Purpose

The Contract Quality Plan (CQP) will integrate the Contract document’s requirements and the Contractor’s quality, health and safety and environmental management systems to deliver the contract works.

3.6.2 Minimum Requirements

The CQP must include:

a) Systems, procedures, and methods to deliver the Contract Works and ensure compliance with the contract documents
b) Audits to ensure data integrity, including comparisons with historic data, an analysis of the event codes used, and data processing
c) Compliance Monitoring describing the proposed methods to ensure contract compliance, including the daily pre and post survey checks, equipment calibration, and data quality checks. It will also describe
   Data sampling, including sample sizes, method of sample selection and assessing and recording compliance
   Developing, implementing and determining the effectiveness of all corrective actions.
d) Health and Safety Compliance ensuring compliance with the Health and Safety Compliance Notice, see section 3.1.2
e) Environmental Compliance, ensuring compliance with the Environmental Compliance Notice, see Section 3.1.3
f) Contingency Planning ensuring adequate back-up equipment and systems are in place so the impact of events such as equipment breakages or system malfunctions do not prevent the survey work from being completed within the specified time frames
g) Distance Measurement equipment describing on-going distance measurement system checks
h) Equipment Calibration information – see Appendix 1
i) A Survey Equipment System description detailing the functionality of all components that comprise any part of the measurement system and its suitability for surveying short sections, surveying at low speeds, and including any performance or speed limitations. The description may also include, for example, any filtering showing band-pass response and cut-off frequency detail, and whether the transducers are sampled with respect to distance or time.
j) Software Validation including procedures for
   Verifying all processing algorithms
   Tracking software changes
   Verifying all software used in the data collection and data processing

k) Equipment and Data Validation – see Appendix 1 and Section 5. This should include procedures that ensure all collected data
   Is accurate, (refer Data Collection Terms of Reference) valid, and fits within the reference station length
   Has been processed into a form which can be imported into the Client’s RAMM system. In addition this procedure must detail the steps taken to process the raw data for loading into RAMM
   Verify the processing algorithms

l) Road Conditions Surveys – including procedures that ensure
   The event code is recorded and is correct
   The correct lane is identified and recorded
   Accurate distance measurement is undertaken
   Accurate adjustment of data to account for differences between measured distance and true distance
   Daily calibration requirements are met.

m) Training – including procedures for ensuring all operators, drivers and data processing personnel are adequately trained to undertake their roles proficiently.

3.6.3 Contract Quality Plan

The Contractor shall submit the CQP within two weeks of acceptance of Tender.

3.7 Contractor’s Programme

The Contractor shall develop a programme for the contract works and submit this with the CQP. The programme must be approved by the Engineer. The Contractor shall carry out works in a timely manner in accordance with the programme set out under this contract.

The survey must not start until all calibration and validation activities are completed and agreed with the Engineer.

3.8 Contractor’s Reports

The Contractor shall provide information about the progress and the procedures adopted for the survey work, the following reports are required:

a) Calibration and Validation report. This report must be submitted before the start of survey.

b) Data format and Definitions Report. See paragraph XXX Data Format and Definition Report for minimum requirement.

c) Weekly Report – this shall include:
   i. the updated survey programme’ equipment failure information, errors in distance closures, and how these have been resolved
   ii. weekly progress claim.

d) Incident report. This shall include details of all incidents that occur including:
   i. near misses and/or crashes, (within 24 hours of the incident)
   ii. public complaints.

e) Final Report. The report shall be submitted within 10 working days of the date of completion of the survey and shall include:
   i. errors omissions, or mismatches in the database
   ii. distance measurement discrepancies
iii. equipment failures or equipment replacements; actions to address problems encountered and steps taken to ensure the quality and reliability of the supplied data.

3.9 Contractor’s Responsibilities

The Contractor must:

a) Work in a cooperative environment with the Client and the Engineer to provide the highest quality data possible
b) Comply with all reasonable directions given by the Client and Engineer
c) Complete all work safely according to an agreed traffic management plan
d) Minimise interference and inconvenience to road users and members of the public
e) Comply with quality assurance standards set in the project specification
f) Complete all the surveys within the specified time and within the contract tendered sum.

3.10 Traffic Management

All traffic management is to be provided according to the NZTA Code of Practice for Temporary Traffic Management (CoPTTM), Local Roads Supplement, or other traffic management specification as advised by the Client. The Traffic Management Plan (TMP) establishes the minimum requirements for traffic management that will be implemented during the road survey operation.

When working on the road, the Contractor shall at all times carry out the work in a way that will not endanger the public or the workers.

All staff working on the road shall wear high visibility day-glow jackets. All necessary signs, markings, traffic cones and other traffic management equipment shall be used. Any vehicle operating on or in close proximity to the road shall be fitted with and operate an amber revolving light on top of the vehicle, to make it clearly visible to approaching vehicles. In addition, the vehicle shall be fitted with a “Road Inspection/Road Survey” sign, or equivalent to advise motorists of the purpose of the vehicle.

3.11 Location Diagrams

Client to provide suitable location diagrams/maps

3.12 Health and Safety Compliance Notice

A Health and Safety Compliance Notice must be submitted by the Contractor as part of the CQP (section 3.6).

3.13 Environmental Compliance Notice

An Environmental Compliance Notice must be submitted by the Contractor as part of the CQP (section 3.6).
4 SPECIFICATION FOR SURVEYS

4.1 General

The guidelines provided in this section set out the minimum requirements expected for roughness and rut depth road condition surveys using a vehicle-based laser profilometer. It also includes the requirements for equipment, calibration, validation checks, survey procedures, measurements, data formats and reporting.

A detailed data collection specification is included in Appendix 1.

4.2 Equipment Requirements

Pavement condition data is an important performance indicator for road engineers and asset managers. It has wide-ranging network management applications. These include using economic analysis as a key factor in determining road user costs and as a maintenance decision driver, modelled in road management systems such as the Deighton Total Infrastructure Management System (dTIMS).

Consequently all data obtained from road survey equipment must sufficiently accurate to facilitate its intended use.

For safety reasons, all equipment housings fitted to survey vehicles must meet NZTA legal width and height specifications.

4.2.1 Roughness

Survey equipment to measure roughness usually consists of an inertial laser profilometer or response type roughness device. A laser profilometer has the following components:

A vehicular platform able to support and transport the profile measuring equipment while travelling at normal road speeds

Accelerometers(s) to record the vertical motion of the vehicle as it travels along the survey route assessing the pavement profile

A displacement transducer (laser device) which measures the distance between the accelerometer and the travelled surface. The displacement transducer(s) should be set to mid-range operation when the vehicle is stationary

Note: A laser transducer/accelerometer combination shall be used for each wheelpath. The lateral distance between the displacement transducers to measure the wheelpaths should be 1.65 m (i.e. 0.825 m from the centreline of a lane).

A distance measuring transducer capable of measuring the distance travelled to an accuracy of ±0.3%. The transducer shall provide input to the data logger to record the distance travelled from the start of the collection survey

A data logger capable of capturing the output data from the transducers at a known equal intervals, not greater than 25 mm, within the range of wave lengths between 0.5 and 50 m

A processing computer to analyse the profile data, and by applying the quarter car model to obtain IRI for a single track and lane IRI

Facility to record and identify the location of events.

4.2.2 Rutting

Survey equipment to measure rutting should include the following:

a) A multi laser profilometer consisting of:
- A vehicular platform to which the transverse profile measuring equipment is mounted that is capable of travelling at normal road speed.
- A minimum of 13 displacement transducers (laser or ultrasonic device) in each wheelpath which measure the distance between the laser and the travelled surface. The displacement transducers(s) shall be mounted to ensure mid-range operation during normal operation.
- A distance measuring transducer capable of measuring the distance travelled to an accuracy of ±0.1%. The transducer shall provide input to the data logger to record the distance travelled from the start of the collection survey.
- A data logger capable of capturing the output data from the transducers at known equal intervals not greater than two metres.
- A processing computer to analyse the data by applying the relevant analysis technique to the surface profile measured.

A facility to record and identify the location of events.

b) The survey equipment may also have the following measuring capabilities:
- Measurement of road centreline GPS coordinates
- Right of Way (ROW) Video
- Road Geometry (Crossfall, Grade and Curvature).
- Texture
- Skid Resistance.

4.3 Survey Procedure

4.3.1 General Requirements

The survey should be carried out according to the contract and the Client’s specifications. There are limiting factors with all survey equipment and there will be situations where the equipment is unlikely to or unable to provide valid data on parts of the network. The Contractor should detail conditions where valid data cannot be collected and also endeavour to minimise these occurrences. For example surveying in the evening to minimise low speed on congested road sections, avoid surveying when the road is wet. Where invalid data has been recorded this must be flagged within the database and agreement sought from the Engineer to exclude invalid data and provide alternative survey results on those parts of the network.

4.3.2 Location Referencing

The Contractor must agree the method of locating the start point of each road with the Engineer before commencing the survey. Survey data for each section must start at the road start point and include the entire length of the road section. If the distance measurement at the end of the road is not within the specified tolerance, (see paragraph 4.3.3), the Contractor must re-survey the road. The re-survey must note any difference in the measurement point locations.

If the second survey confirms the initial survey distance, the Contractor must notify the Engineer immediately and reach agreement on the “true” measured distance. Remedial action may include adjusting the database distance or requiring the Contractor to recalibrate the survey distance measuring device.

4.3.3 Location Tolerance

The Contractor must record and report the distance of all road condition survey data to an accuracy of ±(0.5% x D + 10m) of section length, where

D = is the distance travelled.

For example, a section length of 1000 m has a tolerance of 15 m.
4.3.4 Rubber Banding of Data

The lengths of the road section surveyed shall be matched to the Road Management System (RMS) database and adjustment made to all readings where the error is within specific tolerance, (see paragraph 4.3.3). To ensure all readings are recorded in the correct road sections, any errors within the acceptable range shall be distributed on a percentage basis over the displacement data for the full section length.

4.4 Data Delivery

4.4.1 Data

All data must be reported to reflect standard practice for countries driving on the left.

a) Data processing algorithms must be defined and approved for use by the Engineer
b) Data processing must be completed in tandem with the surveys. This will identify any potential problems as early as possible.

4.4.2 Minimum Data Requirements

The Contractor must record all data at intervals, which will allow the indices to be calculated to the desired degree of accuracy. Data must be stored in database files in a way that makes recalculating the indices possible. The sampling interval and format of the data is detailed in Appendix 1.

The Contractor must ensure data for all sections surveyed as detailed in the scope of work is provided.

The Contractor must supply the following:

a) Raw longitudinal profile data in both left and right wheelpaths
b) Detailed and aggregated roughness data in each wheelpath in IRI (m/km) reported at 20 and 100 m intervals
c) Lane roughness NAASRA (counts/km), where NAASRA = 26.49 x lane IRIqc – 1.27; where IRIqc is quarter car IRI
d) A record of event codes in accordance with to the parameters defined in Table 2. Note specific events affecting the data collection and data quality must be flagged.
e) Raw transverse profile data
f) Detailed rut depth data, including the mean rut depth under a two-metre straight-edge in (mm) and measured in both left and right wheelpaths. The measurement system and processing algorithms must correct data when narrow roads, kerbs or narrow bridges result in the outer sensors measuring artificially high values on both the left and right hand side of the vehicle.
g) Individual rutting readings binned to give a frequency distribution as detailed in Table 3. Note Bin 1 is for all rut depths less than 5 mm bin 2 is for rut depths between 5 and 10 mm and so on.
Table 2: Event Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Post survey added value (estimated)</td>
</tr>
<tr>
<td>B</td>
<td>Bridge abutment end (both end to be recorded)</td>
</tr>
<tr>
<td>D</td>
<td>Detour route</td>
</tr>
<tr>
<td>E</td>
<td>End of run</td>
</tr>
<tr>
<td>G</td>
<td>Grid</td>
</tr>
<tr>
<td>H</td>
<td>Speed humps (or vertical deflecting traffic calming devices)</td>
</tr>
<tr>
<td>I</td>
<td>Intersection (side road)</td>
</tr>
<tr>
<td>P</td>
<td>New pavement surfacing begins</td>
</tr>
<tr>
<td>S</td>
<td>Stop (compulsory, stock etc)</td>
</tr>
<tr>
<td>T</td>
<td>Traffic impeding</td>
</tr>
<tr>
<td>U</td>
<td>Unsealed road begins</td>
</tr>
<tr>
<td>WW</td>
<td>Road works</td>
</tr>
<tr>
<td>X</td>
<td>Railway crossing</td>
</tr>
<tr>
<td>Z</td>
<td>Raised zebra crossing (cobble stones etc)</td>
</tr>
</tbody>
</table>

Table 3: Rutting Bin Limit

<table>
<thead>
<tr>
<th>Bin</th>
<th>Rut Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>2</td>
<td>5 - 10</td>
</tr>
<tr>
<td>3</td>
<td>10 - 15</td>
</tr>
<tr>
<td>4</td>
<td>15 - 20</td>
</tr>
<tr>
<td>5</td>
<td>20 - 30</td>
</tr>
<tr>
<td>6</td>
<td>30 - 50</td>
</tr>
<tr>
<td>7</td>
<td>&gt; 50</td>
</tr>
</tbody>
</table>

4.4.3 Post Survey Added Values

Any short intermediate road sections and speed humps, which have not received a roughness or rutting value during the survey, shall have an appropriate value entered. The value must be calculated from the value recorded in either the previous or the following road section.

Note: short road sections occur when it is not possible to maintain the minimum survey speed. A cul-de-sac is an example of where this might occur, as the survey vehicle has to slow down and stop at the end of the road.
Another example is when the survey vehicle is travelling over a speed hump. The Contractor must document the procedure used to include this data.

The Contractor will be required to include assessed roughness or rutting data for any road or section of road, where invalid data has been recorded as a result of the specific road or traffic conditions. The event code ‘A’ shall

### 4.4.3 Post Survey Added Values (cont)

be recorded against such assessed data. In these cases, an assessment of the roughness must be made by an experienced surveyor using data from the previous section. It must be reported using the following measures:

**Roughness:**
- Good – 80 NAASRA counts
- Average – 95 NAASRA counts
- Poor – 110 NAASRA counts
- Bad – 125 NAASRA counts

**Rut Depth:**
- Good – <10mm
- Average – 10-20mm
- Bad – >20mm

No more than 5% of the distance to be surveyed should have estimated roughness or rutting values (Section 6.4.1).

### 4.4.4 Data Delivery

All data must be submitted on one set of CD’s or DVD’s. If required by the Client, the Contractor shall load the data into RAMM database. The data should be submitted with the final report (refer section 3.8) and include the following information:

a) The completed compliance monitoring – including data quality check failures and the level of dropouts observed

b) Distance measurement discrepancies from the RAMM data.

### 4.4.5 Data Delivery Time

The Contractor should submit the data to the Client no later than 10 working days after the survey’s completion.

### 4.4.6 Review of Data

If the Engineer’s review of data reveals discrepancies or other problems with it, the Contractor must correct the error and redeliver the data within five working days or as instructed by Engineer. If the Engineer directs the Contractor to re-survey the sections and provide the required data, the Contractor must do so.

### 4.5 Reports

The Contractor must provide all reports within the specified time frames or as agreed with the Engineer. The final content and form of the reports will be agreed with the Engineer before the survey is undertaken.

#### 4.5.1 Incident Report

The Incident report must include the details of all incidents that occur. These include near misses and/or crashes, public complaints, and errors in distance closures. This report must be submitted within 24 hours of the incident occurring.

#### 4.5.2 Validation Report

The Validation report should be submitted before the start of survey. Refer to Section 5 for details of validation.
4.5.3 Data Format and Definition Report
The Contractor shall prepare a full report which will be used as a reference document, with sufficient detail to enable the processed data to be replicated by another survey provider. It should be submitted within 10 working days of completing the survey. The report should cover:

   a) Equipment descriptions and specifications
   b) Sensor spacing
   c) Principals of the algorithms used for processing data
   d) Distance rubber banding procedures
   e) Format and description of all raw data
   f) Factors affecting the results such as filters applied (This may include, for example, the response of any filtering showing band-pass response and cut-off frequency detail, whether the transducers are sampled with respect to distance or time.)
   g) The correction procedures and application methodology.

4.5.4 Weekly Reports
At weekly intervals, the Contractor shall report the issues encountered as the survey progresses. The report should include:

   a) The updated survey programme
   b) Public complaints received and actions taken (if any)
   c) Equipment failures (if any).

4.5.5 Final Report
When the survey is completed the Contractor shall prepare a final report summarising the issues encountered during and actions taken. This report should be submitted within 10 working days of the survey’s completion. The report should cover:

   a) Traffic management; Any accident or incident reports
   b) Public complaints received and actions taken
   c) Daily operations – e.g. average daily survey achievement, operational problems
   d) Any errors and mismatches in the database
   e) Distance measurement discrepancies
   f) Equipment failures or replacements
   g) Quality assurance and non-conformance issues that arose
   h) Issues relating to data processing
   i) Recommendations for changes to future surveys.
5 Quality Control

5.1 Purpose and Scope

This Section sets out the Quality Control requirements for pavement condition surveys, with particular emphasis on roughness and rutting survey equipment and data collection procedures. The purpose of Quality Control is to ensure the data collected is valid and accurate and collected in a repeatable and consistent manner. It gives Clients the confidence in the results achieved from the survey.

5.1.1 References

The quality control procedures presented in this document are based on:

a) New Zealand Transport Agency project specification for high speed pavement condition surveys (NZTA, 2009).


5.1.2 General

a) The road condition surveys must not start until all equipment is calibrated and validated, and the calibration and validation report is approved by the Engineer.

b) The equipment must be operated in normal survey configuration during the validation.

c) The location of each validation site must be marked so the Contractor can revalidate all equipment and return to the sites for repeat validation if required.

5.1.3 Overview of Validation Method

The validation procedure is detailed in Appendix 1 and consists of two phases:

a) Correlation against a class 1 profiler for roughness and correlation against a reference transverse profile beam or 2 m straight edge and wedge for rut depth

b) Repeatability and bias checks over a 10 km loop performed not more than 30 days prior to each survey

c) There are 140 calibration sites throughout New Zealand which are surveyed annually with class 1 or equivalent survey equipment as part of the NZTA Long Term Pavement Performance Project. The majority of the sites are 300 m long, and are surveyed to provide both roughness and rutting data which can be used to validate survey equipment. A list of the sites and their location is provided in Appendix 4 and 5 of the Data Collection Manual

This purpose of these procedures is to:

a) Ensure the profilometers (including host vehicle and installed instruments) are giving good quality accurate and repeatable data

b) Assess the ability of the driver to track consistently

c) Assess the ability of the survey organisation to accurately correlate road condition data with its physical location of the road.

Where equipment has a current certification equivalent to those set by the NZTA requirements for operation on the New Zealand State Highway they should not be required to repeat this validation procedure.
5.2 Roughness Validation - Loop Method

This method of validation is based on the loop method of validation as proposed by Austroads (Austroads, January 2006).

5.2.1 Initial Validation

5.2.1.1 Survey Procedure

a) Using the survey equipment, measure the single track IRI in both the left and right wheelpaths and record the location on the benchmarked loop.

b) Repeat step (a) until five sets of profile measurements are made (giving a total survey distance of approximately 150km±10%.

c) Calculate roughness data in terms of 100m segment lengths.

5.2.1.2 Calculations

a) Exclude data for sections shorter than 100 m or data that is invalid (e.g. due to overtaking, dampness, or road sections repaired/resealed after completion of the benchmark surveys).

b) Calculate the average roughness value for each of the 100m segments for the five repeat runs.

c) Determine the overall line of best fit and correlation coefficient (r) of the five averages from the device under test with the benchmark (i.e. complying NZTA) device.

\[ r_{avg} = A \cdot r_{ref} + B \]

Where:

- \( r_{avg} \) = average roughness of the five repeat runs
- \( r_{ref} \) = reference roughness (from benchmark device).
- \( A \) = regression equation slope.
- \( B \) = regression equation intercept.

b) Determine the average percentage difference between the roughness measured by device under test and the benchmark device.

\[ \text{Average Percentage Difference} = \frac{1}{n} \sum_{i=1}^{100} \frac{r_{avg} - r_{ref}}{r_{ref}} \]

Where:

- \( r_{avg} \) = average roughness of the five repeat runs for the 100m sections.
- \( r_{ref} \) = reference roughness of the 100m section (from benchmark device).
- \( n \) = the total number of 100m sections in the analysis.

5.2.1.3 Reporting

a) Date and time of the validation checks

b) Identification of the laser profilometer used

c) Driver of the profilometer vehicle

d) Operator of the profilometer equipment
e) The slope (A), intercept (B) and correlation coefficient (R2) of the overall correlation equation determined in 5.2.1.2 c

f) A statement as to whether the test profilometer passes the overall correlation check, with an R2 of at least 0.95 representing a pass

g) The average percentage difference determined in 5.2.1.2 d

h) A statement as to whether the test profilometer passes the average percentage difference check, with an average percent difference of less than or equal to 5% representing a pass.

5.2.2 Repeatability and Bias Checks

5.2.2.1 Repeatability Survey Procedures

a) Select a clearly defined section of 10 km total length from the 30 km that was used for the initial validation; it must have a range of roughness at the 100 m segment level

b) Using the inertial profilometer, measure the single track IRI in both the left and right wheelpaths, and determine the average lane IRI

c) Repeat b) until five sets of measurements have been made.

5.2.2.2 Bias Survey Procedures

a) Select a clearly defined section of a lane of 10 km total length with a range of roughness at the 100 m segment level. (It is recommended to use the same section of pavement as used for the repeatability checks.)

b) Using the inertial profilometer, measure the single track IRI in both the left and right wheelpaths, and determine the average lane IRI. This data forms the reference data

c) Repeat b) within 30 days of a survey to produce the comparison data.

5.2.3 Calculations – Repeatability

Exclude data that is less than 100 m in length or is invalid (e.g. due to overtaking, dampness, or road sections repaired/resealed after completion of the benchmark surveys).

5.2.3.1 Repeatability Requirement 1

Determine the coefficient of variation (i.e. the standard deviation expressed as a percentage of the mean), $S_n\%$, for each 100 m segment for each series of repeat measurements as follows:

$$S_n\% = \left( \frac{S_n}{\bar{X}_n} \right) \times 100$$

where

$$S_n = \sqrt{\frac{\sum_{i=1}^{N} (X_n - \bar{X}_n)^2}{N-1}} = \text{standard deviation}$$

$$\bar{X}_n = \frac{\sum_{i=1}^{N} X_n}{N}$$

$n = \text{segment number.}$

$N = \text{total number of measurements on segment} \ n$
\( X_{ni} \) = roughness of segment \( n \) from measurement \( i \) (with \( i = 1 \) to \( N \)).

### 5.2.3.2 Repeatability Requirement 2

Determine the average of the segment coefficients of variation, \( S_{c,\%} \), as follows:

\[
S_{c,\%} = \frac{\sum S_{v,\%}}{n_s}
\]

Where

\( n_s \) = total number of segments.

### 5.2.3.3 Repeatability Requirement 3

Using least squares regression, determine the coefficient of determination, \( R^2 \), when the individual roughness values for each segment (dependent variable, \( y \)) are regressed against the mean values for that segment (independent variable, \( x \)).

### 5.2.4 Calculations – Bias

Calculate the bias error between the comparison data set and the reference (benchmark) data set as follows:

\[
BE = 100 \times \frac{\sum (X_{ri} - X_{ci})}{n}
\]

Where

\( BE \) = the bias error between the comparison and reference data sets

\( X_{ri} \) = reference data mean roughness of segment

\( X_{ci} \) = comparison data mean roughness of segment

\( n \) = total number of segments.

### 5.2.5 Reporting – Repeatability and Bias

#### 5.2.5.1 General Details

Report the following:

a) The location of each test section

b) Date and time of validation checks

c) Identification of laser profiler used

d) Operator and driver of the profilometer system and vehicle.
5.2.5.2  **Repeatability Checks**

Report the following:

a) The IRI for each 100m segment for each of the five repeat runs

b) The coefficient of variation for each 100m segment for each series of repeat measurements as determined in Section 5.2.3.1

c) The average of the segment coefficients of variation as determined in paragraph 5.2.3.2

d) The coefficient of determination when the individual roughness values for each segment are regressed against the mean values for that segment, as determined in paragraph 5.2.3.3

e) A statement as to whether Repeatability Requirement 1 has been passed. A pass is achieved when 95% of all values reported in b) are less than or equal to 5%

f) A statement as to whether Repeatability Requirement 2 has been passed. A pass is achieved when 95% of all values reported in c) are less than or equal to 3%

g) A statement as to whether Repeatability Requirement 3 has been passed. A pass is achieved when 95% of all values reported in d) are equal to or greater than 0.95.

5.2.5.3  **Bias Checks**

Report the following:

a) The reference data set IRI for each 100 m segment

b) The comparison data set IRI for each 100 m segment

c) The bias error determined in paragraph 5.2.4

d) A statement as to whether the bias error check is passed. A pass is achieved when the bias error is less than or equal to 1%.

5.3  **Rutting Validation - Loop Method**

This method of validation is based on the loop method of validation as proposed by Austroads (Austroads, June 2005).

5.3.1  **Initial Validation**

5.3.1.1  **Survey Procedure**

a) Using the multi laser profilometer, measure the rutting in each wheelpath, and record the location.

b) Repeats step a) until five sets of transverse profile measurements are made (i.e. total survey distance of approximately 150km±10%)

c) Calculate rutting data in terms of 100 m segment lengths.

5.3.1.2  **Calculations**

a) Exclude data for sections shorter than 100 m or data that is invalid (e.g. due to overtaking, dampness, or road sections repaired/resealed after completion of the benchmark surveys)

b) Calculate the rut depth for each of the 100 m segments for the five repeat runs
c) Determine the overall line of best fit and correlation coefficient ($R^2$) of the five averages from the device under test with the reference benchmark (i.e. complying Transit New Zealand) device:

$$r_{\text{avg}} = A \times r_{\text{ref}} + B$$

Where

- $r_{\text{avg}}$ = average rut depth of the five repeat runs
- $A$ = reference rut depth
- $r_{\text{ref}}$ = regression equation slope
- $B$ = regression equation intercept

Determine the average percentage difference between the rut depth measured by device under test and the reference benchmark device:

$$\text{Average Percentage Difference} = \frac{100}{n} \sum_{i=1}^{n} \frac{r_{\text{avg}} - r_{\text{ref}}}{r_{\text{ref}}}$$

Where

- $r_{\text{avg}}$ = average rut depth of the five repeat runs for the 100m segments
- $r_{\text{ref}}$ = reference rut depth of each 100 m segments
- $n$ = the total number of 100 m segments in the analysis.

### 5.3.1.3 Reporting

- a) Date and time of the validation checks
- b) Identification of laser profilometer used
- c) Driver of the profilometer vehicle
- d) Operator of the profilometer equipment.
- e) The slope ($A$), intercept (B) and correlation coefficient ($R^2$) of the overall correlation equation determined in 5.3.1.2(c). For survey equipment lasers of the same configuration of the validation equipment, the suggested limits for the gradient, and intercept are

  $$0.90 \leq A \leq 1.10$$
  $$-0.75 \leq B \leq 0.75 \text{ mm}$$

- f) A statement as to whether the test profilometer passes the overall correlation check, with an $R^2$ of at least 0.95 representing a pass
- g) The average percentage difference determined in 5.3.1.2 (d)
- h) A statement as to whether the test profilometer passes the average percentage difference check with an average percent difference of less than or equal to 10% or an average difference of less than 1 mm representing a pass.
5.3.2 Repeatability and Bias Checks

5.3.3 Procedure

5.3.3.1 Repeatability Checks

a) Select a clearly defined section of a lane of 10 km total length with a range of rut depths from five to 15 mm (or greater) at the 100 m segment level taken from the benchmarked loop used for the initial validation.

b) Using the multi laser profiler, measure the transverse profile and calculate the rutting in each wheelpath or across the lane for each 100m segment.

c) Repeat (b) until five sets of measurements have been made.

5.3.3.2 Bias Checks

a) Select a clearly defined section of a lane of 10 km total length with a range of roughness at the 100 m segment level taken from the benchmarked loop used for the initial validation.

b) Using the multi laser profiler, measure the transverse profile and calculate the rutting across each wheelpath or across the lane for each 100m segment.

c) Repeat (b) within 30 days of a survey to produce the comparison data.

5.3.4 Calculations – Repeatability

Exclude data for sections shorter than 100m or data that is invalid (e.g. due to overtaking, dampness, or road sections repaired/resealed after completion of the benchmark surveys).

5.3.4.1 Repeatability Requirement 1

Determine the coefficient of variation (i.e. the standard deviation expressed as a percentage of the mean), Sn%, for each 100m segment for each series of repeat measurements as follows:

\[ S_n\% = 100 \cdot \frac{S_n}{\bar{X}_n} \]

Where

\[ S_n = \sqrt{\frac{\sum_{i=1}^{N} (X_{ni} - \bar{X}_n)^2}{N-1}} \]

\[ \bar{X}_n = \frac{\sum_{i=1}^{N} X_{ni}}{N} \]

\[ X_n \rightarrow \text{standard deviation} \]

\[ n \rightarrow \text{segment number} \]

\[ N \rightarrow \text{total number of measurements on segment } n \]

\[ X_{ni} \rightarrow \text{roughness of segment } n \text{ from measurement } i \text{ (with } i = 1 \text{ to } N). \]
5.3.4.2  Repeatability Requirement 2

Determine the average of the segment coefficients of variation, as follows:

\[
\bar{s}_s = \frac{\sum s_i}{n_s}
\]

Where

\( n_s \) = total number of segments.

5.3.4.3  Repeatability Requirement 3

Using least squares regression, determine the coefficient of determination, \( R^2 \), for when the individual rutting values for each segment (dependent variable, \( y \)) are regressed against the mean values for that segment (independent variable, \( x \)).

5.3.5  Calculations – Bias

Calculate the bias error between the comparison data set and the reference data set as follows:

\[
BE = \frac{100}{n} \cdot \sum_{i=1}^{n} \left( \frac{X_{ri} - X_{ci}}{X_{ri}} \right)
\]

Where

\( BE \) = the bias error between the comparison and reference data sets
\( X_{ri} \) = reference data mean roughness of segment
\( X_{ci} \) = comparison data mean roughness of segment
\( n \) = total number of segments.

5.3.6  Reporting – Repeatability and Bias

5.3.6.1  General Details

Report the following:

a) The location of each test section

b) Date and time of validation checks

c) Identification of laser profiler used

d) Operator and driver of the profilometer system and vehicle.

5.3.6.2  Repeatability Checks

Report the following:

a) The rutting for each 100 m segment for each of the five repeat runs
b) The standard deviation, $S_n$, for each 100 m segment for each series of repeat measurements, as determined in paragraph 5.4.3.1. Report the standard deviation to the nearest 0.1 mm

c) The average of the segment standard deviations as determined in paragraph 5.4.3.1. Report to the nearest 0.1 mm

d) The coefficient of variation for each 100 m segment for each series of repeat measurements as determined in paragraph 5.4.3.1. Report to the nearest 0.1 percentage

e) The average of the segment coefficients of variation as determined in paragraph 5.4.3.2. Report to the nearest percentage

f) The coefficient of determination when the individual rutting values for each segment are regressed against the mean values for that segment, as determined in paragraph 5.3.4.3

g) A statement as to whether Repeatability Requirement 1 has been passed. A pass is achieved when 95% of all values reported in c) are less than or equal to 1.0 mm or all values reported in d) are less than or equal to 10%. (Note that discretion is required, e.g. due to localised stripping where variations in the track may have a significant effect on the rutting measured. In such instances, it is recommended that a pass should still be awarded if Repeatability Requirement 2 is met and the total number of outliers is less than or equal to 5%)

h) A statement as to whether Repeatability Requirement 2 has been passed. A pass is achieved when the value reported in c) is less than or equal to 1.0 mm or the value reported in e) is less than or equal to 7.0%

i) A statement as to whether Repeatability Requirement 3 has been passed. A pass is achieved when 95% of all values reported in f) are equal to or greater than 0.95. Additionally, slope should be close to one, and intercept close to zero as indicated below:

\[ 0.95 \leq A \leq 1.05 \]
\[ -0.50 \leq B \leq 0.50\text{mm} \]

5.3.6.3 Bias Checks

Report the following:

a) The reference data set rut depth for each 100 m segment

b) The comparison data set rut depth for each 100 m segment

c) The bias error determined in paragraph 5.3.5 reported to the nearest 0.1 percentage

d) A statement as to whether the bias error check is passed. A pass is achieved when the bias error is less than or equal to 10%.

5.4 Reporting

The report should include the following:

a) The fully defined validation sections. A log of operators used, weather conditions, run identifiers and reasons for any aborted runs.

b) The results of all validation activities. Data from all normal survey functions.

c) Information demonstrating all road condition survey and associated equipment complies with this section.

d) The date and time of validation activities.

These reports must be accepted by the Engineer before the surveys are undertaken.
5.5 **General Requirements**

The Contractor should operate under an effective and documented Quality Control regime including, but not limited to:

- a) Equipment operation and maintenance
- b) Operator training
- c) Survey operation
- d) Data collection, processing and analyses
- e) Data delivery and reporting.

The Engineer may require the Contractor to demonstrate the Quality Control procedures and documentations at any time.

5.5.1 **Daily Calibration**

Some equipment must be calibrated each day during surveys to ensure it operates satisfactorily. Daily calibration includes factors such as:

- a) Tyre condition, pressure and wear
- b) Distance, sensor height, slope and acceleration measurement
- c) General system operational checks.

5.5.2 **Sensor Monitoring and Re-calibration**

All sensors and other measuring systems must be monitored during the surveys. If a replacement component such as sensor is required, the replacement component must be provided and the repeatability and bias calibration procedure should be repeated.

5.5.3 **Equipment Failure**

The Contractor must notify the Engineer within 24 hours if equipment failure occurs. In addition the Contractor must record the:

- a) Reasons for failure
- b) The road section being tested when the failure occurred
- c) Actions taken to determine the adequacy of the recorded data before the failure
- d) Evidence that the replaced or repaired equipment provides output that is consistent with that prior to the breakdown.

Similar notification must be given to the Engineer for any repairs or maintenance on vehicle components (for example, changes to the vehicle suspension) that could affect the measuring systems’ performance.
6  Operational Guidelines for Profiling

6.1  Introduction
The data quality obtained from a laser profilometer can be significantly influenced by the way the surveyors operate the data collection equipment. It also varies according to the way the survey vehicle is driven. Information on the operating procedures and how the measurement conditions and equipment used can impact the data accuracy and validity are provided below.

6.2  Referenced Documents


6.3  Equipment Used for Measurement Systems

6.3.1  Pre-survey Checks
The following checks should be made daily, before surveying begins.

6.3.1.1  Accelerometers
a)  The accelerometers should be sufficiently warmed up before use
b)  The accelerometers should be checked by performing a “bounce test” or other test as recommended by the equipment supplier. The bounce test simulates normal vehicle suspension travel. The profile output is recorded twice: when there is no suspension travel and when the vehicle suspension is moving. In both cases the output should show a flat profile showing no or little variation. Electronic noise and other factors can cause a negligible value to be recorded, but this should be less than 0.10 m/km.
c)  The “straight edge test” should be carried out to calculate the position of the lasers relative to an imaginary horizontal line in space and to verify the correct operation of the height sensors. This test is usually static, i.e. a reference surface such as a box section straight edge or milk bath may be needed.

6.3.1.2  Height Sensors
a)  The height sensor lenses should be wiped clean before surveying. They may also need cleaning during data collection, depending on the working condition, (because of water splashes or excess dust, for example)
b)  Allow time for the system to warm up before starting the survey. This should be according to the manufacturer’s prescribed time.
c)  The working of height sensors may also be checked to see if they are within tolerance. In this test, a block of known thickness is placed under the sensor and the height is measured. The height measured by the sensors should match the block height, within the manufacturer’s specified tolerance limit.
6.3.2 Post Repair Checks

The following checks should be made if repairs are made to the suspension of the host vehicle or survey equipment:

a) For response roughness measurement systems a full revalidation is required
b) For laser based systems the bounce test and straight edge tests should be sufficient, unless the equipment manufacturer specifies alternative testing
c) The mounting height of the sensors should be checked whenever repairs are carried out, tyres are replaced or the wheels are realigned, to ensure the sensors are positioned at the middle of the operating range when the vehicle is fully loaded.

6.4 Roughness

6.4.1 Requirements

a) The profile’s accuracy must not be affected by the full range of pavement conditions that can reasonably be expected to be encountered on the network.
b) If the equipment is susceptible to errors under slow speed, stop, start and/or conditions of acceleration and deceleration, the Contractor should specify operating procedures which minimise these effects. The Engineer is responsible for approving these procedures.
c) Wherever possible sections should be surveyed at a near constant speed
d) Sections where invalid data may arise due to reduced speed and/or start-stop conditions as result of traffic build up, should be re-surveyed under free-flowing conditions. Where it is not possible to avoid these conditions the Contractor must provide an estimate value and define how the estimate value was derived. No more than 5% of the distance to be surveyed should be estimated.
e) Survey vehicle wander within a wheel track in extreme situations can produce variation in the roughness index of between 5 to 10 percent. Therefore the survey must follow the wheelpath as closely as possible and so minimise this effect.

6.4.2 Surface Distress

Surface distress is a major contributor to transverse variability in the pavement profile. The magnitude of the difference between adjacent values will be influenced by the types of distress present in the pavement.

a) Alligator cracking can have a substantial influence on transverse variability. The IRI can vary by as much as 0.5m/km when repeated runs are performed
b) Transverse cracking on an asphalt surface can cause variation of roughness indices between repeat runs. A major contributor to this variability is whether the laser beam captures or misses a crack in the profile
c) Measurement errors in the data should be flagged - for example where the difference between two consecutive height sensor measurements is too high
d) Measuring roughness on steep gradients where the transition between ascents/descents is not smooth can have a significant affect on the roughness and where this occurs should be marked by an event code.

6.4.3 Roundabouts

Measuring roughness at roundabouts to accurately reflect the true surface condition may prove to be difficult and depends on the physical nature of the roundabout. Errors in roughness indices may occur due to following issues:
a) Several cross-falls merge at roundabout, which may affect the profilometer system
b) Small roundabout diameter can cause impediments in attaining the recommended speed for measurement
c) The geometry of the roundabout approaches can be such that there is insufficient lead-in/out distance.

It is recommended where invalid data is recorded a visual assessment of the roughness must be made and the section marked with an event code identifying that the data is estimated.

6.5 Rutting

6.5.1 Overview

Rutting is normally undertaken using non-contact sensors fitted to a survey vehicle. Typically, the sensors are fitted to a support mounted across the width of the survey vehicle so the sensor measurements can be combined to describe the road’s transverse profile. The measured transverse profile provided by the non-contact sensors is processed to obtain the rut depth.

6.5.2 Equipment-related Errors

Possible errors arising from the equipment include:

a) The transverse profile system is not wide enough for the road being surveyed (as may be encountered on wide roads)
b) Poor layout of the sensors on the survey vehicle transverse profile measurement system
c) An insufficient number of sensors on the survey vehicle's transverse profile measurement system.

6.5.3 Survey-related Errors

Possible surveying errors include:

a) Surveying under conditions where the non-contact sensors do not provide reliable measurements (such as in the presence of surface water)
b) Driving line where the vehicle is driven in relation to the centre of the lane; (either to the nearside or offside)
c) The presence of features that may cause inaccurate measurement of rut depth, e.g. kerbs (Figure 1), verges (Figure 2) and lane edge markings (Figure 3).

Figure 1: Kerbs
6.6 Road Surface and Environmental Conditions

6.6.1 Surface Texture

Laser sensors may experience signal dropout (spikes in the data) on coarse texture surfaces. Error checking procedures should be used on the signal from laser sensors to guard against errors from this source.
6.6.2 Curves and Gradient

Measuring profiles on curves and gradients can tilt the accelerometer and thereby affect its output. The following guidelines should be followed to minimise the effect:

a) The transition of the profilometer through the curve should be smooth.

b) Tight curves should be monitored for errors and if required should be flagged with a suitable event code.

6.6.3 Environmental Conditions

Environmental conditions in which the measurement is undertaken can influence the data.

a) Severe wind conditions may affect the profile measurement as debris such as sand or leaves may pass under the sensor. Furthermore it may be difficult for the driver to maintain the correct lateral position in the lane.

b) Extreme temperature conditions. Sensors should be used within the manufacturer's recommended temperature range as extreme air and surface temperatures can cause errors.

c) High humidity can cause water to condense on the height sensor lenses and mirrors. The profilometer should not be operated when the humidity level is outside the manufacturer's prescribed value. When operating in highly humid conditions, ensure the height sensors do not have condensed water blocking the beam's transmission path.

d) Profiling should not be carried out when it is raining or when the road surface has free standing water. If a localised section of wet road is encountered, it must be flagged by an event code and if the data is found to be invalid the section should be surveyed when weather conditions are more favourable.

e) The profile measurement should not be undertaken on roads where free standing water is present or where passing vehicles causes surface water to splash.

f) If localised sections of road are encountered with contamination such as leaves and mud, this must be flagged and the data discarded. If required, these sections should be resurveyed when conditions are more favourable.

g) Measurements should not be carried out on icy or snowy roads.

h) Road features that are beyond the sensors' measurement range (e.g. gaps in bridge abutments) must be flagged by an event code.

6.7 Operation and Driving

6.7.1 General

As driving skills can have an impact on the profile measurement, the survey vehicle driver should be trained appropriately.

a) The driver should be trained to pick the correct wheelpath of a lane, and should understand the impact that driving the incorrect wheelpath will have, (see 6.7.2 (b)).

b) The driver should be trained to anticipate traffic conditions so they avoid situations that can interrupt measurements. The following practices can help improve data quality.

Anticipating traffic conditions at merging points to avoid changing lanes.

Avoiding sudden acceleration and braking, as this affects the measuring system response.

Avoid as much as possible driving below the minimum recommended speed.
Minimising stopping the vehicle when surveying.
Using one driver and one operator for the surveys. The driver is then able to take care of safety, speed and position while operator can make quality checks and trigger proper data collection and event codes.

6.7.2 Positioning the Profilometer

The position of the survey vehicle is important during profiling as roughness and rutting can significantly vary across the lane. The following guidelines should be followed.

a) Only avoid pavement defects if they are likely to damage the vehicle and/or jeopardise safety.

b) The normal travel path should be followed irrespective of the position of any ruts.

c) The profilometer lead-in and lead out distance should be allowed for before the survey section’s start point and after its end point. The lead-in distance helps to stabilise the filters used in profile computation.

d) For project level data collection or for studies performed to assess the profilometer’s repeatability, an automated method to initiate data collection may be used. This will ensure the starting location of all profile runs is the same.

6.7.3 Speed

a) The survey vehicle’s operating speed should be governed by speed range recommended by the profilometer manufacturer, legal speed limits and road and traffic conditions.

b) Constant speeds should be maintained for all measurements within specified ranges. Any data collected outside the range should be discarded.

c) Profiling must be terminated if it is difficult to maintain the required position in the lane and/or the minimum operational speed.

d) During measurement, avoid changes in speed that will cause vehicle to jerk or pitch. This may cause measurement errors.

e) Where insufficient lead-in and/or lead-out distance is available, the first and last 50 m of data should be flagged by an event code.

6.7.4 Operational Skills

The operator should be familiar with all the profilometer’s operational and calibration characteristics. This would include the following.

a) Knowledge of all the calibration and daily checks that are required before beginning the measurement.

b) The valid range for collected data.

c) The ability to conduct quality checks during measurements and identify any problems with the data acquisition system.

d) An understanding of the roughness index. The operator should review the roughness index to validate if it is reflecting the subjective judgement of the road condition.

e) An awareness of the importance of event codes and knowledge of all the event codes that can be used.

f) The ability to judge the environmental conditions suitable for undertaking measurement profiles.
GLOSSARY OF TERMS

Bias
A statistical term to indicate whether a device is systematically measuring high or low when compared to a reference set of measures.

Benchmark validation equipment
Survey equipment that has current NZ Transport Agency compliance.

Calibration
Set of operations that establish, under specified conditions, the relationship between the values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or reference material, and the corresponding values realized by (measurement) standards.

Condition assessment
Identifying the condition of the pavement by inspections and monitoring to determine its future maintenance needs.

Condition survey
A process of collecting data on an asset’s condition e.g. the structural or functional condition of a pavement.

Contractor
Organisation conducting the survey and providing the resultant data.

Client
Road controlling authority for which the data is being collected.

Engineer
Representative of the Client.

Inertial profilometer
A road profile measuring system which is capable of collecting data at traffic speed. Its main components include an accelerometer for measuring the vehicle’s vertical motion, height sensors to measure the distance between the vehicle and the road, distance measuring system to measure the longitudinal distance travelled by the vehicle and other data processing equipment.

Longitudinal profile
The shape of a pavement surface measured as vertical distances from a datum horizontal plane along the direction of traffic flow.

Multi Laser Profilometer (MLP)
A Multi Laser Profilometer (or Multi Laser Profiler) is a laser-based vehicular mounted measurement system with a minimum of five (5) lasers that records the transverse shape of the pavement.

Network level
A type of road condition survey where the main purpose is to monitor the network’s performance or assist with network asset management decisions, as distinct from project decisions.

Non-contact
A term to describe a system of measuring without physical contact between the instrument and the object being measured, e.g. ultrasonic or optical sensors are capable of measuring road surface profile without physical contact with the road surface.

Operating speed
The average travelling speed of a vehicle taking traffic congestion into consideration.

Pavement management
A systematic method of information collection, analysis and decision-making, designed to permit the optimal use of resources for maintaining, rehabilitating and reconstructing pavements.

Pavement rutting
A pavement defect that is a characteristic of the transverse profile of a road surface which takes the form of a longitudinal depression, usually occurring in either or both wheelpaths.

Profiler
Some literature, especially from the United States, refers to profilometers as profilers. In Australasia, the term ‘profiler’ mostly...
means a self-propelled machine, which removes a controlled depth of pavement material. An exception is the ‘ARRB Walking Profiler’ which is a commercial name for proprietary technology with international patents.

**Profilometer**
A device for producing a series of numbers related in a well-defined way to a reference profile. Roughness measuring devices, other than mechanical response-type devices and most static devices, are commonly referred to as profilometers.

**Project level**
A type of road condition survey or data analysis where the main purpose is to assist with decisions about proposals for a specific project on a short length of road, as distinct from network decisions.

**Repeatability**
A statistical term to indicate the extent of variation in outputs about the mean.

**RIMS Group**
Road Information Management Systems Group.

**Roughness**
Roughness is primarily unevenness or undulations in the road surface that affect the ride quality, comfort, safety and wear and tear of the vehicle.

**Rut depth**
Maximum vertical pavement displacement in the transverse profile, either across a wheelpath, or across a lane, measured from a reference datum taken at 90º to the road edge.

**Rutting**
A pavement defect in the form of a longitudinal depression on the surface, usually in a wheelpath.

**Shoving**
Bulging of the road surface generally parallel to the direction of traffic and/or horizontal displacement of surfacing materials mainly in the direction of traffic where braking or deceleration movements occur.

**Transverse profile**
The cross sectional shape of a pavement or traffic lane measured generally at right angles to the longitudinal direction of the road.

**State Highway (SH)**
The road network administered by the NZ Transport Agency.

**Surfacing**
The topmost part of the pavement which is designed to resist traffic abrasion and minimise the entry of water.

**Survey equipment**
The vehicle-based laser profilometer intended for roughness and rutting measurements.

**NZ Transport Agency (NZTA)**
The crown entity responsible for New Zealand’s SH network.

**NZTA compliant device**
Survey equipment that has current NZTA compliance.

**Wheelpath**
That portion of the pavement that is subject to passage of and loading from vehicle wheels during trafficking. There are two wheelpaths per trafficked lane - ‘left wheelpath’ (LWP), nearer to the verge, and the ‘right wheelpath’ (RWP), nearer to the middle of the road.
REFERENCES

Austroads, (June 2005): Draft Framework Specifications and Test Methods: Rutting, Part 5C. (Draft viewed only – final version to be published shortly.)


Transit New Zealand (November 2004): Code of Practice for Temporary Traffic Management (CoPTTM), SP/M/010, Edition 3, Transit New Zealand.


Appendix 1:

Specification for Road Condition Data Collection Services
### Appendix 2:
State Highway Calibration Sites

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