Assessment process for the condition of unsealed roads

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An important note for the reader

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Abbreviations and acronyms

AADT	annual average daily traffic
ARE	acronym rich environment
ARRB	Australian Road Research Board
ASTM	American Society for Testing and Materials
BLS	bar lineage shrinkage
GPR	ground penetrating radar
GPS	global positioning system
LiDAR	light detection and ranging
LoS	level of service
MfE	Ministry for the Environment
ONRC	One Network Road Classification
REG	Road Efficiency Group (NZ Transport Agency)
RIMS	Road Infrastructure Management Support

Contents

Executive summary

This project aimed to improve practices related to the asset management of unsealed roads by focusing on the data required to quantify the performance and maintenance needs of unsealed road networks. Data collection and management of unsealed roads are still focused on operational processes because of their fast-changing nature and lack of useful information and guidance on management at the tactical and strategic levels.

The outcome of this research relied significantly on industry input through two workshops and one-on-one interviews with some industry leaders. A total of 31 unsealed roads specialists and stakeholders represented 13 councils and private organisations.

Input during workshops and personal interviews confirmed that:

- Councils recognise the importance of unsealed roads and the need to manage them sufficiently. Unsealed roads play an important part in the community's perception of the effectiveness of the council's services, and feature strongly in satisfaction surveys.
- Management of unsealed roads is undertaken at an operational level, yet councils expressed the willingness and need for management at tactical and strategic levels. The councils commented specifically that they hoped this research would provide the data and information framework to facilitate improved asset management processes on these networks.
- Data collection on unsealed roads is mostly limited to roughness measurements, capturing customer complaints and relying on maintenance supervisors' network inspections. In isolated instances, councils are carrying out annual rating surveys of the entire network as part of performance-based contracts that rely on this level of information. Other councils find the rating of unsealed network of limited value.
- The councils still find it difficult to deal with a request for seal extensions and dust complaints. There is an opportunity for industry groups such as Road Infrastructure Management Support (RIMS) to collate a peer exchange of case studies that document how some councils deal with these aspects.

Despite councils undertaking sufficient management of their unsealed road network, there are opportunities to improve tactical and strategic level decision making on these networks. Business cases substantiating the investment needs for unsealed roads are lacking in most cases. There is also little evidence to demonstrate that optimal gravel use and blading frequencies are being used on the networks.

Feedback from the workshop recommended better decision making at strategic and tactical levels. A framework was provided to optimise gravel usage on the network, which includes a pre-knowledge of the performance of the material used in respective locations. It was also observed that blading strategies are often not well documented and evidence based. A case study from Central Otago is presented as an example of how to develop a more pragmatic and efficient blading programme.

A performance framework was developed to cover all three asset management levels across the following performance areas:

- Provide safe property access.
- Provide affordable and sustainable property access.
- Provide an acceptable journey experience.
- Minimise the environmental and social impacts.

The framework is consistent with the One Network Road Classification (ONRC), but there are some additions suggested for the ONRC: these are listed in the recommendations.

The resulting data collection framework for the unsealed roads is presented in the following table.

ES1 Recommended data requirements for unsealed roads

Data category	Data item	Comments
Network definition, inventory and asset description	Classification (ONRC)	Refer to Austroads data standard (section 6.1). (Austroads 2016)
	Location referencing	
	Asset description including geospatial and criticality	
	Gravel properties Grading distribution Plasticity (either plasticity index, or bar linear shrinkage	It is proposed to set up a relational data structure that links material properties from borrow pits to the respective borrow material used on a given road section
Demand	Traffic and loading Annual average daily traffic % heavies	Counts done at least once every three years, supplemented with estimates based on adjacent roads
Performance safety	Crash statistics	Link into crash management system
	Peak roughness	Refer to roughness condition below
	Vehicle kilometres travelled (VKT) exposed to unacceptable dust (PM10 mg/m^3)	Basic level – qualitative measure Advanced – measured dust level
	Width (km < acceptable width)	Width standard to be developed by a functional requirement for the road and recorded in inventory properties. Assessment of under-width to follow through safety inspections
	Sight distance standard for speed environment	Recorded during safety inspections
	Permanent and temporary hazards	Recorded in safety inspections and regular network inspections
Performance resilience	Road closure (# of 24h+ closure/yr)	Unsealed road data need to be linked to customer complaint logs
	Cost of emergency/flood repairs	Repair cost has to be recorded alongside storm properties (rainfall, intensity and duration)
	Drainage adequacy and condition	Recorded during regular network inspections
Performance customer satisfaction	Smooth travel exposure	Processed from roughness data
	Condition/performance complaints (# /VKT)	Need to be processed from complaints call recorded data. Coding of complaints is possible with applications such as Ndivo,

Data category	Data item	Comments
		which allows for specific performance analyses. Also, useful to record the specific complaints that resulted in treatment responses.
	Unacceptable dust emissions	Basic – sourced from complaints system Advanced – measured dust levels
Performance – condition	Roughness (international roughness index – IRI)	Collection aspects are discussed in section 6.4
	Surface profile (advanced)	
Works and costs	Gravelling Date Thickness Borrow pit source	Should be recorded as part of maintenance management process (eg Pocket RAMM – a tool to manage and record maintenance in the field)
	Blading	
	Routine maintenance	
	Drainage investment	

The recommendations resulting from this research were:

- Councils should focus on enhancing strategic and tactical asset management for unsealed roads. This research has provided a framework to achieve this, but industry groups such as RIMS should facilitate and advocate this transition further.
- The research has developed a reporting process that is consistent with the ONRC framework. There are, however, some limitations that need to be considered for ONRC reporting such as more focus on measures including:
  - customer satisfaction/complaints
  - dust
  - environmental impacts.
- The Austroads data standard provides an excellent framework for setting up an unsealed road database and data structure. Given the slight variation in the condition data approach, we recommend forwarding this research report to Austroads for consideration in the next version of the data standard.
- The priority data areas to improve at councils include:
  - traffic data
  - recording maintenance costs
  - safety inspections.
- Further development work to assist councils comprises:
  - systems and processes to facilitate the performance reporting
  - systems to assist with the analytics for tactical planning.

Abstract

Unsealed roads remain the backbone of the New Zealand's economy. Less than 40% of local roads in New Zealand are unsealed, yet most of New Zealand's farm produce, important tourism and forestry harvest start their journey to the international market on unsealed roads. It is therefore essential to plan the investment into this network based on appropriate data. Traditional data collection using visual assessments was not sustainable given the fast-changing nature of unsealed roads. This has left councils not knowing what data to collect on the network, thus necessitating this research project that aimed at developing data collection processes to facilitate better decision making and performance reporting. This report recommends frameworks for decision making at strategic and tactical asset management levels alongside a performance framework consistent with the One Network Road Classification process. These frameworks were the primary input into the process for condition data collection and broader data requirements for unsealed roads. The outcome of this research needs to be further supported by industry groups such as RIMS to facilitate the ongoing development of tools and implementation by councils.

1 Introduction

1.1 Background

Unsealed roads remain the backbone of the New Zealand economy. Less than 40% of local roads in New Zealand are unsealed, yet most of New Zealand's farm produce, important tourism and forestry harvest start their journey to the international market on unsealed roads. Although much cheaper to maintain than sealed roads, the optimal expenditure on gravel roads is difficult to determine, and there is no national programme for local councils to adhere to.

There are some successful sealed-road management systems used around the world, yet the same cannot be said for unsealed roads, where successful applications are limited. While there is a significant number of management and maintenance guidelines available for unsealed roads, only a limited number of these are widely used for maintenance decisions and systems. Research into unsealed road management systems has revealed that one of the main stumbling blocks of the systems is the significant reliance on intensive data collection. The issues with data sourcing for these management systems are (Henning et al 2015a):

- Material-specific characteristics typically do not exist for individual unsealed roads.
- The condition of unsealed roads changes rapidly, often leading to data being out of date soon after it is collected.
- To make a sufficiently robust management system, the frequency of data collection should be increased. However, more frequent data collection may not be cost effective and may be significantly onerous from an administrative perspective.

This report covers the development of data requirements to be followed in New Zealand to enable a practical and consistent approach to collecting information for the asset management planning of unsealed roads.

1.2 Objectives

A robust data collection regime is one that is developed for the purpose it is supposed to fulfil. Therefore 'what will the data be used for?' was the paramount enquiry at the first stage of this research. Ultimately, we aimed to develop a condition data collection framework that would address two critical asset management areas (for unsealed roads the requirements for these areas may not always be the same):

1. Data that is processed to provide information to councils for making the best decisions for investment in unsealed roads
2. Data that could be processed into information to be used for the long-term performance monitoring and communicating level of service (LoS) achievements for public and government stakeholders.

The principles of our research were:

- The data collection process has to be simple and effective.
- The technology has to be within reach of all councils, irrespective of their size.
- The data collection process has to be technically robust and repeatable.
- The data collection items will be kept to a minimum.

According to the above criteria, the objectives of the research were:

- To comprehensively understand the data needs of local councils who are managing unsealed roads. In particular, we needed to know:
  - What are the maintenance drivers on unsealed roads?
  - What part of the decision-making process causes some difficulty for local councils?
  - How comprehensively do they currently report on unsealed roads?
  - What data do they currently collect, what is it used for and what value do they get from it?
  - How do they plan maintenance for the respective road categories – LoS and response times?
- To understand international best practice on data collection in this domain, including taking account of the significant research collected by the research team.
- To understand the requirements of industry policy and requirements from an asset management perspective including:
  - Austroads metadata standard (Austroads 2016)
  - One Network Road Classification (ONRC) and performance framework, in particular understanding customer and technical LoS and their relationships.

1.3 Research methodology

The methodology for this research project is illustrated in figure 1.1. It shows methods that are founded on both practical experience and prior research. Allowance was also made for consultation with the industry to ensure a pragmatic approach that would be accepted by the industry. The research steps included:

1. Capturing international best practice in a comprehensive literature review
2. Liaising with local councils by way of workshops, and interviewing other stakeholders about their experience with unsealed roads in the various regions of New Zealand
3. Integrating the learnings from the steps above with the wealth of research and experience from the team members into:
   a. processes and algorithms for decision making
   b. performance monitoring and management framework
4. Fully understanding and defining the current data, completing the data requirements plus further data collection protocols for the respective collection methods.

1.4 Context for the international reader

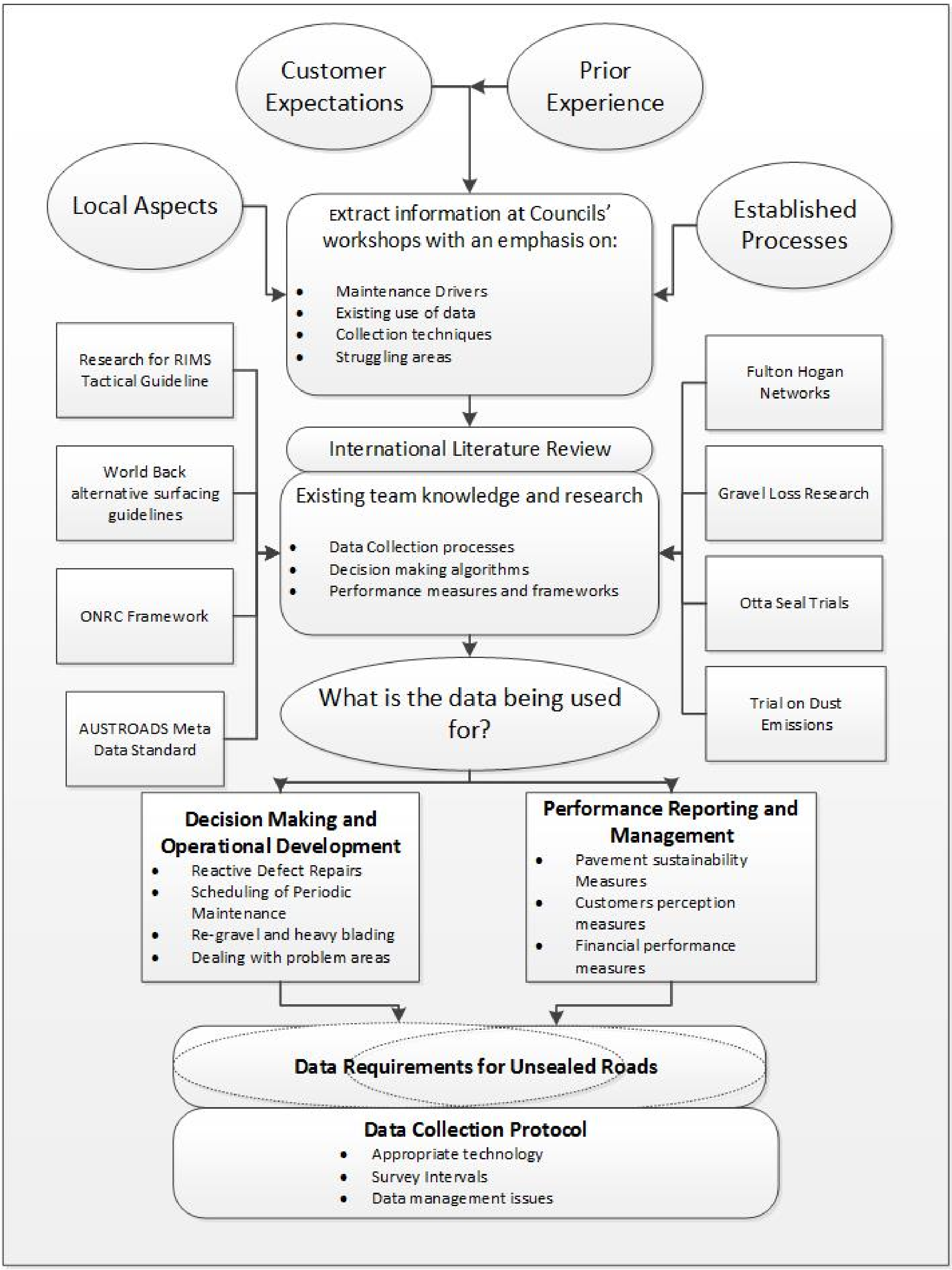
Unsealed roads across the world are being managed differently given the environment, availability of funding and the typical use of unsealed roads. This report, its findings and recommendations applies primarily to New Zealand’s unsealed roads network and may not be universally applicable or practical for other countries. For this reason, the users need to be aware of the specific reference to New Zealand unsealed roads:

- New Zealand unsealed roads carry significantly low traffic volumes:

  - Few unsealed roads carry more than 500 vehicles per day
  - Most unsealed roads carry less than 250 vehicles per day
  - A significant portion of unsealed roads carry less than 50 vehicles per day.
- New Zealand has significant rainfall throughout the year with most of the country having more than 2,000 mm per year.
- New Zealand has drier summers with most of the rainfall expected during winter months.
- Unsealed roads are well maintained. Significant political pressure is applied on maintaining unsealed roads at a relatively good condition level.
- As part of network management contracts, regular inspections occur on unsealed roads.
- Given the relatively young geological age of New Zealand materials, high-quality material for unsealed roads a scarce. Therefore the material and rainfall combination results in roads having significant condition changes during high rainfall periods. Whereas the unsealed road networks in most other countries deteriorate at a slow rate, the unsealed roads in New Zealand show little deterioration over time, but can suddenly change following rainfall. Therefore, from a relative perspective, environmental deterioration has a stronger influence on the performance of unsealed roads than say traffic induced deterioration.

As a result of the above factors, New Zealand's unsealed roads are traditionally managed by a strong operation and reactive maintenance approach. For this reason, this report focuses on adopting more long-term practices and planning processes.

Figure 1.1 Methodology for this research



2 Literature review

2.1 Purpose of the literature review

The difficulty and complexity of managing unsealed roads are reflected by the wealth of literature on how to design, construct and maintain these roads. There are also several guidelines suggesting how to monitor and assess the condition of unsealed roads. The purpose of this literature review was not to document yet another version of existing material, but to critically review data collection practices and relate them to how the data is used and what information is of greatest value. The scope of the literature review included:

- international data collection practices
- automated data collection techniques
- a discussion on information use in decision making and performance monitoring.

2.2 Data collection practices

Data collection processes from most relevant countries and regions are summarised in table 2.1. Apart from specifically targeting well-known countries and areas, the literature search also included information on sectors that were well documented.

Table 2.1 Data collection international practices

Country/region	Reference	Condition data approach	Other items assessed	Evidence of automated data	Indication of data utilisation
Australia	Giummarra (2009)	Two-level approach with minimum performance data requirement including: • LoS – roughness • structural – cross fall and profile • gravel thickness Advance level goes into specific defects	Dust Drainage Safety	Roughness Ground penetrating radar (GPR)	Maintenance priority (short-medium terms Long-term forecasting models
South-Africa	Jones et al (2003)	A five-point rating of overall quality items such as gravel quality and quantity.	Moisture Material type Dust	None	Convert assessment into a composite index to monitor performance and prioritise investment.
Sweden	Alzubaidi (2001)	Predominantly a visual rating system	Gravel thickness Drainage	None	Maintenance prioritisation
Canada	Chong and Wong (1989)	A visual rating system that is recorded for both the severity and extent of the defects.	Shoulder condition and features	Other documents do suggest some automated measurements	The rated data is converted into a composite score to determine maintenance needs.
USA – Wyoming	Huntington and Ksaibati (2010)	Comprehensive options for visual rating to automated collection	Maintenance history Safety Functional performance	Roughness	Maintenance scheduling and prioritisation (using maintenance intervention standards)
Namibia	Tekie (2002)	Visual assessments District inspections	Safety	No	Network monitoring Maintenance scheduling

A more detailed summary of typical defect recording by the different countries is summarised in table 2.2. It is noted from the table that assessment of unsealed roads is mostly visual. However, this publication is more than 17 years old and technology has developed significantly since then.

Table 2.2 Comparing rated items for unsealed road rating (Alzubaidi 2001)

Country	No. of condition classes	Distresses to be evaluated																	Based on		Reference
		Corrugation	Rutting	Potholes	Loose gravel	Crossfall	Dust	Shoulder	Ditching	Roughness	Channelling	Gravel size	Overgrowth	Cracks	Ponding	Wearing course	Breakup	Distortion	density	severity	
Sweden	3	V	V	V	V	V	V			V									+	+	[SNR 96]
Sweden	3 4	V	V	V	V		V			V										+	[AND 76]
Sweden	3 4 5	V	V	V	V	V	V			V									+	+	[JOH 83]
Finland	5	V	V	V	V	V	V	V		M				V						+	[ISO 87]
Finland	5	V	V	V	V	V	V	V						V						+	[PEN 94]
Canada	5	M	M	M	M	V	V	M					V		M		V	V	+	+	[CHO 89]
USA	5	V	V	V	V	V	V		V							V			+	+	[TIC 94]
USA	7	M	M	M	M	V	V		V				V		M				+	+	[EAT 87] [EAT 92]
New Zealand	?	M	M	M	M	M		V	M		M	M							+	+	[TNZ 96] [TNZ 94]
New Zealand	?	M	M	M	M	M		V	M		M	M							+	+	[HAL 94]
New Zealand	5	V	V	V		V	V			V										+	[FER 86]
Australia	?	M	M	M	M						M	M							+	+	[NAA 87]
Australia	?	V	V	V	V		V				V					M			?	+	[MUL 91]
Australia	?	V	V	V	V	V			M	M	V					M		V	+	+	[ARR 93]

V Visual assessment
M Measurement
? Not clearly mentioned

A general observation from this section is that although most documents describe data collection in detail, it is not always clear how the data has been used. In most cases, the defect data is converted into a composite index that is used to prioritise maintenance on unsealed roads and in some cases the defects feed directly into a decision algorithm for safety versus asset preservation. The data is also used to identify the types of maintenance appropriate for the various conditions.

2.3 Automated data collection techniques

2.3.1 Roughness

According to ASTM E867-87, pavement roughness is defined as 'the deviations of a pavement surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic loads, and pavement drainage' (ASTM 2006). Roughness is perhaps one of the most important LoS measures of concern for the travelling public. By design, the surface of unsealed roads will always be rough compared with sealed roads, and it is supposed to be, given the material composition of larger aggregates, some loose material and unevenness caused by deterioration such as corrugations. The aim of the design, specifications and maintenance standards is to keep the unsealed road at an acceptable average roughness level. Obviously part of managing the roughness is to measure the roughness levels to assist in planning and monitoring blading cycles.

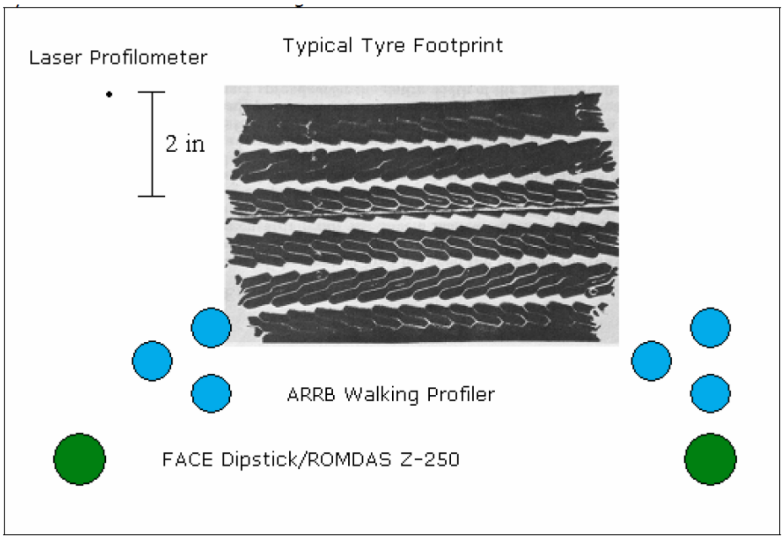
Roughness measurements for unsealed roads differ significantly from roughness measurement on sealed roads because of the actual surface composition. The occurrence of large aggregates, loose material and defects such as corrugations, dust and vibrations cause precise measurements using such equipment as high-speed laser measurement of roughness to be challenging.

The ASTM E 950-94 standard classifies roughness devices into precision classes listed in table 2.3 (ASTM 2004). Realistically, roughness on unsealed roads only becomes meaningful for class III and IV roughness devices. The reason for this is attributed to the footprint size of measurements as illustrated in figure 2.1. The small measurement footprints would not yield give a consistent result as one measurement might be taken on the top of a large aggregate protruding from the surface and the next measurement taken in the valley of a corrugation. The height difference between these two points would result in an extreme roughness that might not be representative of the road section or represent the unevenness felt in a vehicle.

Table 2.3 Examples of roughness measurement techniques classified for ASTM E 950-94 standard (Bennett et al 2007)

CLASS	EQUIPMENT
Class I Precision profiles	**Laser profilers:** Non-contact lightweight profiling devices and portable laser profilers **Manually operated devices:** e.g. TRL beam, Face Dipstick/ROMDAS Z-250, ARRB Walking Profiler
Class II Other profilometer methods	APL profilometer, profilographs (e.g., California, Rainhart), optical profilers, and inertial profilers (GMR)
Class III IRI estimates from correlation equations	Roadmaster, ROMDAS, Roughometer, TRL Bump Integrator, rolling straightedge.
Class IV Subjective ratings/uncalibrated measures	Key code rating systems, visual inspection, ride over section

Figure 2.1 Footprint of roughness measurement techniques (Karamihas 2004)



The roughness devices used for unsealed roads are summarised in table 2.4.

Table 2.4 Measuring techniques for determining roughness on unsealed roads

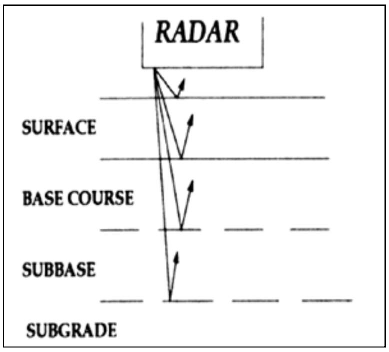
Techniques	Most common devices	Advantages	Limitations
Manual assessment	Subjective rating of roughness from inspectors Assessed comfortable driving speed using a standard vehicle	No additional cost to inspections No specialised skills required	Subjective and biased to inspector Strong function of speed environment, eg: • winding roads give an impression of being rougher • narrower roads cause safety concerns for drivers resulting in speed reduction, again leading to perceived rougher roads
Response type vehicle systems	Australian Road Research Board (ARRB) Roughometer ROMDAS	Relatively inexpensive Gives repeatable results	Needs specialist training/skills (low level) Needs to travel a certain speed to excite the accelerometers Specific calibration is required for each vehicle
Cell phone technology	RoadRoid, RoadLabPro, etc	Cost effective Simple to use Integrated with GIS Processing and data storage in the cloud Multiple devices could be used (ie all inspectors could have one in their vehicle)	Needs specialist training/skills (low level) Specific calibration is required for each vehicle Needs to be uniformly attached to the vehicles Low level of repeatability
LiDAR		Accuracy and repeatability Integrated with other measurements (see section 2.3.5) 3-dimensional and global positioning system (GPS) image of full road width	High costs Sophisticated device High training/skills demand High level of data processing required Significant computer storage space required

The uptake and use of the devices mentioned in the table are further discussed in chapter 3.

2.3.2 Ground penetrating radar

GPR was originally developed in the geotechnical area to determine the thickness of geological formations. After mobilising this technique, it became possible to scan roads at 70 km/h. It transmits electromagnetic pulses into the pavement and records the travel time back to a receiver (refer to figure 2.2). The travel time of the pulses is then converted into a graphical display that indicates the density of the matter being scanned. This technology could, therefore, be used to determine layer thicknesses, including thicknesses of base course material on unsealed roads.

Figure 2.2 Concept of the GPR measurement (Giummarra and Siggins 1999)



Giummarra and Siggins (1999) researched the specific application of GPR on unsealed roads and identified the main benefit as quantifying the base course thickness. This study also highlighted limitations to this technology including:

- ‘Not all pavement features can be identified with sufficient accuracy and reliability.
- GPR works best where there are distinct differences in pavement layers’ dielectric constants.
- Survey results can be affected by water content as it will affect the radar signal.
- Adequate core sampling will be necessary to calibrate the GPR signals to ensure the reliability of data interpretation.
- Appropriate expertise is required to interpret the results from the GPR readings.’

The literature review yielded minimal full-scale implementation of this technology. Further to the limitations mentioned above, a potential reason for the lack of uptake of the technology is the fact that the technology produces graphical outputs from the surveys but has limited analytical processing to provide the user with data that could be used in management systems.

2.3.3 Dust monitoring

As evident from many councils’ complaint systems, dust is one of the main concerns on unsealed roads. Dust is also one of the strong arguments against unsealed roads because there is enough scientific evidence substantiating its potential harm to human health, plants, agricultural/forestry and freshwater ecosystems. It is also an amenity/nuisance issue for people living next to the road. In addition to these concerns, there are legislative pressures to manage excess dust emissions from unsealed roads. Some of these include (MfE 2001):

- The Clean Air Act 1972
- The Health Act 1956 (section 29)
- The Resource Management Act 1991 (sections 9, 15 and 17).

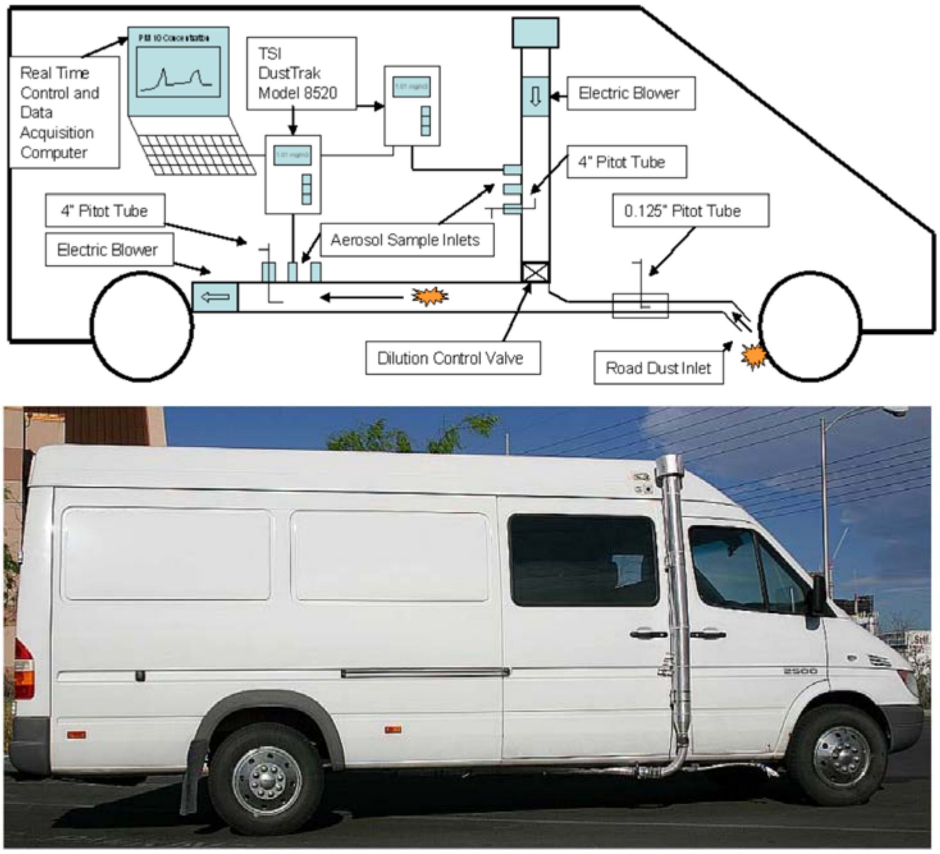
Dust is, therefore, an undebatable issue for councils to manage, making data collection and proactive managing of dust issues necessary. This section details some data collection techniques while later sections will consider additional management and planning aspects related to dust.

The literature documented two techniques for dust monitoring:

- use of stationary detection devices
- mobile dust monitoring using systems such as the Traker System (refer to figure 2.3).

Dust monitoring in New Zealand is largely limited to stationary monitoring.

Figure 2.3 Traker II dust monitoring system (Langston et al 2007)



2.3.4 Strength testing

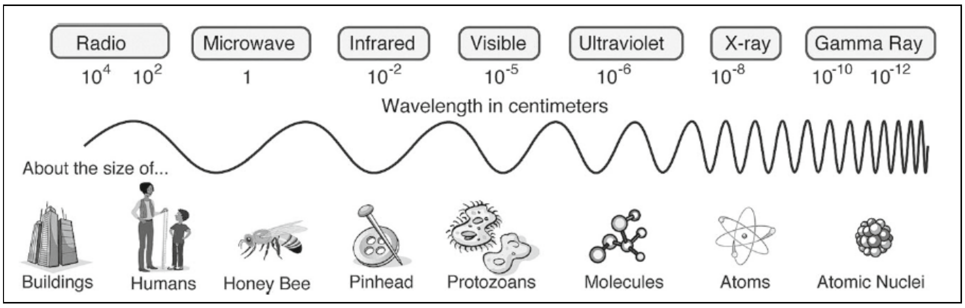
Strength testing on unsealed roads is mostly undertaken as a design/rehabilitation tool only with limited evidence of network-wide strength monitoring. The two devices most commonly used include a dynamic cone penetrometer/Scala (DCP) or the Clegg Hammer. The DCP, in particular, is extremely effective for differentiating between the thicknesses of layers within the road, pavement bearing capacity and the strength of the underlying subgrade.

2.3.5 LiDAR

The best explanation of the light detection and ranging (LiDAR) techniques is described in Schnebele et al (2015). 'Similar to RADAR technology, which uses microwave or radio waves, LiDAR captures details by illuminating an area using light from the near-infrared region (approximately 1.0 μm) and measuring the travel time between the transmission of the signal and its reflection or scatter back. The infrared light is commonly emitted at a rate of 5,000 pulses per second'.

To put it into context, figure 2.4 illustrates the different electromagnetic wavelengths and the objects that can be observed at these various wavelengths. The infrared zone is, therefore, able to observe an area the size of the pinhead of a needle. By having scanning lasers that repeat millions of these measurements in a sweeping fashion, a comprehensive image of the entire surroundings becomes possible.

Figure 2.4 What we can observe at difference electromagnetic wavelengths (Schnebele et al 2015)



Arnold et al (2016) completed some research for the NZ Transport Agency to determine the most effective techniques for determining moisture issues on roads. In their research, a combination of a GPR and scanning laser was used to investigate the drainage condition both on top of and below the road surface (refer to figure 2.5).

Figure 2.5 Surveying the potential moisture issues on road pavements (Arnold et al 2016)

Laser scanner, video and GPR survey

Scanning data

There are also different platforms for LiDAR surveys including vehicles such as the van indicated in figure 2.5, aeroplanes and drones. The LiDAR data can be used to determine roughness and identify specific defects such as potholes, corrugations and stoniness. It is also capable of determining the effectiveness of surface and side road drainage. The use this technology for managing unsealed roads has also been described in Schnebele et al (2015).

2.4 Discussion: information use in decision making and performance monitoring

The preceding sections of this literature review have detailed some possible data collection processes and techniques. The core question for this research project was, 'What will the data be used for?'

The research looked at these questions from a current practice perspective and investigated which additional processes would have the potential to simplify planning processes for authorities. It further explored what additional information and analytics would result in resource preservations and/or cost savings. During a workshop held by the United States Environmental Protection Agency 'five core questions' relating to asset management were raised (Allbee 2007):

1. *What is the current state of our assets?*
   a. *What do we own?*
   b. *Where is it?*
   c. *What condition is it in?*
   d. *What is its remaining useful life?*
   e. *What is its economic value?*
2. *What are the required levels of service?*
   a. *What is demanded by users and stakeholders?*
   b. *How do actual conditions differ from those desired?*
3. *Which assets are critical to performance?*
   a. *How do they deteriorate and fail?*
   b. *What is the likelihood of failure?*
   c. *What is the consequence of failure?*
4. *What are good strategies for operation and maintenance ,and a capital improvement plan?*
   a. *What management options exist?*
   b. *Which are most feasible for our agency?*
   c. *How do they impact on the level of service?*
5. *What is a good long-term funding strategy? Does it align with the agency's policy goals?*

In summary, the main findings from the literature review were:

- There are many publications about different data collection frameworks for unsealed roads; fewer publications document what the data is used for.
- Evidence suggests many unsealed road data collections are predominantly used for short-term maintenance prioritisation and scheduling.
- Two decision frameworks are being favoured including:
  - decision algorithms that take account of individual defects for making decisions on maintenance
  - converting defects into a composite index to prioritise and assign appropriate maintenance treatments.
- Few processes and systems aim at optimising resources for unsealed roads. One exception is the World Bank HDM-III and later HDM-IV modelling approach that uses sophisticated deterioration models.
- There are interesting measurement techniques, but ultimately the usefulness of the data has to be balanced with the cost and effort of collecting it.

3 Industry workshops

3.1 Recommendations from the workshops

Based on the outcome of the workshops the following recommendations were accepted as principles for the further development of these guidelines:

1. Manual condition surveys are of little value and are not recommended as part of a standardised collection framework. The only exception is for authorities that use performance-based contracts for the management of unsealed roads. Surveys for these contracts are customised to facilitate monitoring aspects. An example of such surveys is depicted in appendix B.
2. Roughness surveys are commonly used and provide value from a customer LoS perspective, but could also be used to identify outlier roughness locations and serve for annual performance monitoring.
3. Data collection and decision processes should be produced to facilitate better decision making and general asset management practices.
4. An approach to deal with dust aspects is needed.

3.2 Workshop format

The objectives of the workshops were derived from a combination of findings from the literature review and some specific questions from the research team. These objectives were:

1. To gain a comprehensive understanding of current practices for managing unsealed roads, including data collection and decision-making processes.
2. To provide an opportunity for local councils to state their data collection needs for unsealed roads.
3. To gain a specific understanding of how dust issues are being dealt with at council level and what specific data collection needs may assist in the process.

Two formal workshops were held to solicit information regarding current practice in managing unsealed roads. Both these workshops were well attended given that they coincided with some industry events including the RATA coordination meeting and IPWEA NZ conference in Dunedin during June 2017. A total of 31 unsealed road specialists and stakeholders representing 13 councils and private organisations participated. The workshops were supplemented by specific consultation with unsealed roads specialists who reviewed and commented on the framework recommended in this report.

As a prompt to discussions the following questions were posed to the attendees:

- Current practices
  - Does your council really pay much attention to unsealed roads? Is there a genuine intent to do things better?
  - What data do you currently collect?
  - What is useful about it and what do you use it for?
  - Share general experiences on the actual data collection technology
  - What are your current needs?
- What information do you need for:

- maintenance planning
- asset management plans
- performance monitoring

- Dust complaints:
  - What is your current strategy for managing complaints about dust?
  - Do you collect any data to substantiate your investment in dust reduction?

3.3 Discussion

A summary of the workshop findings is presented in appendix A, with a summary of the main items repeated in this section.

The main themes resulting from the workshop and discussions were:

- It was encouraging to note that councils do take the management of unsealed roads seriously. It was evident though that they were sometimes uncertain about the best practice to follow.
- A limited number of councils are undertaking scheduled full network visual condition ratings. What seems to be common practice is regular inspections as part of blading programmes or based on contractual requirements. Full network rating surveys are common practice for performance-based contracts.
- There are several authorities that do regular roughness surveys, either using cell phone technology and/or response type roughness surveys.
- It was generally accepted that better data and information would be useful to improve tactical and strategic decisions. Uncertainty about the approach and data collection regimes confirms the value of this research project.
- Not relevant to this project but still something worth noting is the on-going need for good grader operators. Training for these operators remains a challenge.

Dust and the treatment of dust was a significant discussion point at all the workshops. There was an acceptance that dust will be an increasing concern for councils. The Health and Safety issues raised in the MfE (2001) report are recognised, yet the management of dust remains a challenge. Some strategies for dust management include:

- prioritising complaints about dust
- requesting the complaining party to contribute towards seal extension and/or dust control
- controlling settlement next to the road
- using crushed rock close to homes or other sensitive areas (for these situations prevent rock types that may result in future dust issues particularly limestones and hard shales).
- waste oil and Otta seals have been used.

A common issue at the workshops was that few authorities undertake dust monitoring, mainly due to practical and repeatability aspects.

Councils were open about their lack of pro-active planning on unsealed roads and lack of certainty on whether they were maintaining the unsealed road to an optimal level. It was obvious that any assistance in this regard would be helpful and of value to them. Any approach to save money while still delivering the necessary LoS was welcomed.

Several authorities have already implemented the South African approach to material selection and performance classification (Henning et al 2015b). This specification would be helpful to promote the use and application of these guidelines.

4 Better decision making

4.1 Recommendations for better decision making on unsealed roads

The fast-changing nature of unsealed roads lends itself to management at an operational level – an approach that is frequently used. The limitations of adopting only operational management of unsealed roads are:

- There is not enough information and data to substantiate the investment need for unsealed roads. Business case questions that go unanswered are:
  - Is the investment level appropriate for the network?
  - Linked to that, is the LoS provided for a specific road appropriate?
  - Does the management of unsealed roads ensure sustainability in preserving the road capacity plus optimising the gravel replacement? The continuous replacement of gravel lost due to traffic and climate is a problem from an environmental and sustainability viewpoint.
- It limits the opportunity for realising savings on the network.
- There is no feedback loop to test the efficiency and effectiveness of a given maintenance strategy.

This chapter proposes an overall decision framework to provide input across the three asset management levels: strategic, tactical and operational. At the strategic level, councils present the motivation for adapted LoS and consequential investment requirements for unsealed roads. The information at the strategic level is collated from the outcomes of tactical level analytics and input from the operation and maintenance levels. Performance monitoring is also an important input into strategic business case motivation.

The objective at a tactical level is to maximise the performance of the network at minimum cost. Blading cycles need to be determined based on a policy that results from customer's input, the performance of specific parts of the network and the classification of the network. Development of the re-gravelling programme relies on material type, climatic effects and traffic use, and the performance of the road sections aims at choosing the right material type for the specific situation and condition.

Operations and maintenance are normally managed on an ad hoc basis, with regular inspections highlighting most of the needs for intervention at this level. The main challenge for routine maintenance is identifying the optimal point where a different alternative needs to be considered in order to optimise the life-cycle costs.

4.2 Decision-making framework

4.2.1 Asset management planning level

Chapter 3 confirms that decisions on unsealed roads are often made at an operational level only. This is not surprising as a common trend in asset management is that the level of planning and management is directly related to the life-cycle of the asset. Sealed roads last approximately 40 to 60 years and have a typical surfacing recycle rate of approximately 15 years, thus suggesting a typical planning horizon of up to 10 years. Unsealed roads, on the other hand, have a typical wearing course life of approximately 5 to 10 years and the periodic treatments such as blading are undertaken once to three times a year. This short life expectancy combined with a rapid change in condition leads to a very short-term view of how unsealed roads should be managed.

However, with stronger strategic and tactical planning, unsealed roads offer significant opportunities for savings in maintenance costs. It is possible to realise three to four times savings in blading and gravelling costs by using materials more suitable for the prevailing operating conditions of the unsealed road (Henning et al 2015b). There is also pressure on councils to have a stronger business case on the investment into unsealed roads. The workshop reported in section 3.3 confirmed that councils do not have strong evidence in their business cases for the investment into unsealed roads. This does, however, not imply that they are not managing these networks adequately.

The recommended evidence for decision making at respective asset management levels is summarised in table 4.1.

Table 4.1 Evidence for asset management decision-making levels for unsealed roads

Asset management level	Key considerations/questions	Evidence for business case	Management process
Strategic investment planning	Providing safe access Managing networks in an affordable and sustainable manner Providing an acceptable LoS to travelling customer Minimising environmental and social impacts	Crash rate performance over time Annual maintenance and renewal costs Public complaints monitoring Addressing dust concerns and/or complaints	Performance monitoring process Collective input from tactical and operational forecasts
Tactical management	Optimal use of gravel resources Blading strategy	Gravel consumption and loss rates Blading cycles	Decision algorithm Policy settings (eg blading cycles per ONRC)
Operational management	Procurement process to manage unsealed roads Dealing with public complaints Dealing with problem areas	Contractual performance Public complaints monitoring vs cost to address issue Specifics of issue and remedial actions	Policy settings Contractual requirements Maintenance strategy

Subsequent chapters contain additional detail on decision making, while performance monitoring is discussed in chapter 5.

4.2.2 Decision aspects

The decision framework for unsealed roads can be split into two areas:

1. At a tactical and operational level, the aim is to develop a programme of works
2. At a strategic level, the aim is to determine the appropriate LoS to maintain with the associated required investment.

Sections 4.3 and 4.4 discuss these two planning areas in more detail.

The decision aspects and the factors considered for each aspect are summarised in table 4.2. These factors are of particular importance in this research as they feed directly into the data requirements discussed in chapter 6.

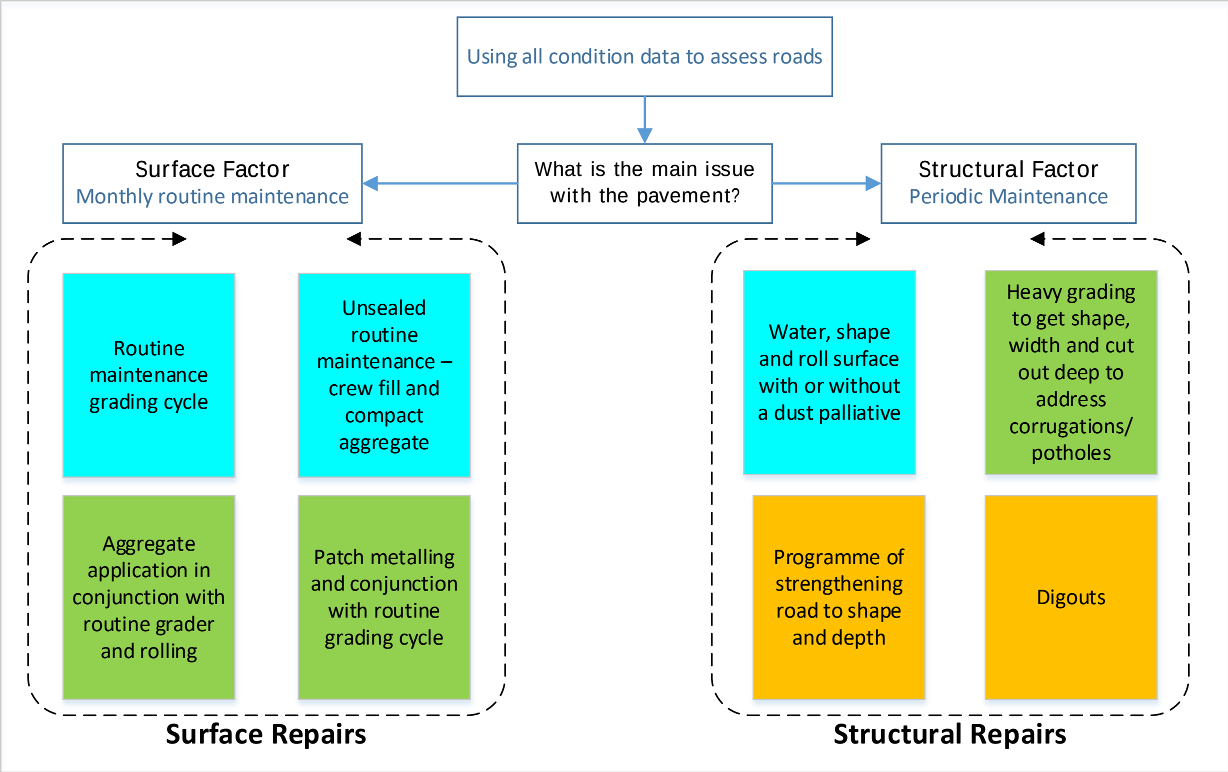
Table 4.2 Decision aspects and associated factors

Decision aspect	Factors considered
Re-gravelling	Rate of loss Traffic volume Material type/properties Profile/shape Relative performance in relation to blading cycles Blading strategy, type and operator skill Seasonal variation and other climatic effects
Blading	Roughness Customer complaints Southland work on axle complaints Seasonal variation and other climatic effects
Chemical treatment	Dust complaints Special road sections, eg next to school/farm Safety considerations Life-cycle costs
Seal extension	Traffic demand Political pressure Private investment Life-cycle costs
Safety	Geometric aspects Applied to all maintenance categories (above)

4.3 Development of a programme of works

Unsealed road inspections, public complaints and existing maintenance records are the primary inputs into the programme of work. The most commonly used process at councils involves a cyclic planning for each sub-region or district within a council. The supervisor and/or grader operator inspect the sub-region to confirm the roads that require maintenance for the cycle under consideration. They will typically use a decision framework illustrated in figure 4.1.

Figure 4.1 Determining the maintenance needs of an unsealed road network (based on Henning et al 2015a)



More details on unsealed road defects, and the maintenance treatments to address these, fall outside the scope of this research. Further reading and guidance on unsealed road maintenance includes Giummarra (2009) and Henning et al (2008).

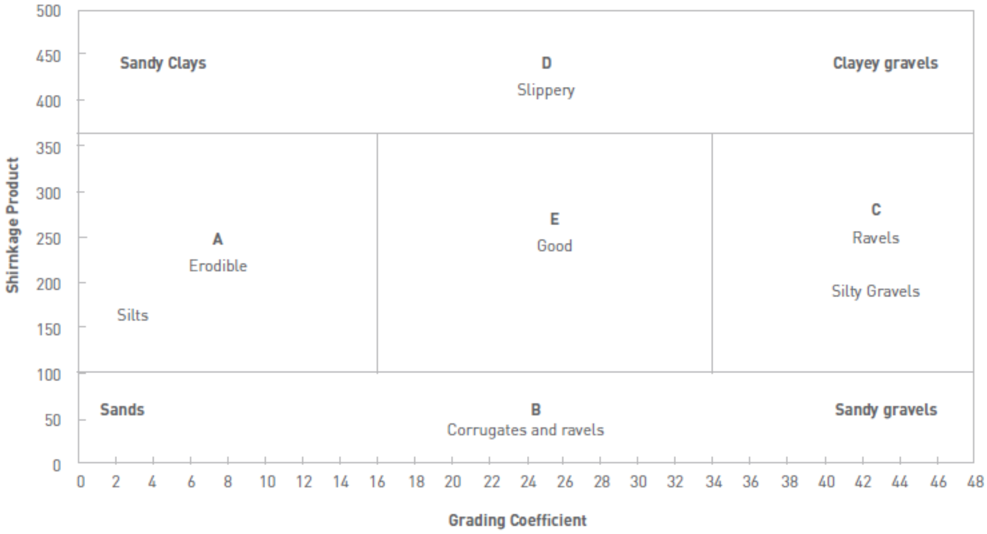
4.4 Undertaking strategic investment planning

4.4.1 Optimising gravel use

Henning et al (2015a) introduces the South African (Paige-Green 1989) material classification concept as one component of a network management process for unsealed roads (refer to figure 4.2). Given its simplicity and robustness, this process has been adopted by a number of councils in New Zealand. Using this approach allows the council to answer the following questions:

- What is the expected performance from respective roads within the network (based on the material properties and traffic use)?
- What opportunities for cost savings exist, through selecting the most economical material options for given roads?
- What is the long-term cost for gravelling and blading on the network?

Figure 4.2 Material classification and expected behaviour (modified after Paige-Green 1989)



Legend

A	Erodible	Comprises sandy and clayey silts with insufficient plasticity to provide tight bonding. Erosion sensitive withcrosfall runoff and inclines
B	Corrogates and ravels	Comprises sands and sandy gravels with little plasticity, therefore aggregate becomes loose (ravelling) and corrogations develop from vehicle suspension oscillation. Can also erode in high rainfall areas.
C	Ravels	Comprises coarse gravels with little fines or plasticity to bind the aggregate and therefore ravels quickly.
D	Slippery	Comprises silty clays and clayay gravels with high fines content producing slippery surfaces when wet.
E	Good	Comprises well-graded soil aggregate mixes with sufficient plasticity to find aggregate fractions into a hard wearing tight surface. Higher fines content can produce a dusty surface.

One of the success factors for adopting this approach is the relatively limited amount of data required to predict the performance of the materials. Table 4.3 lists the data items and their relevance to the decision framework.

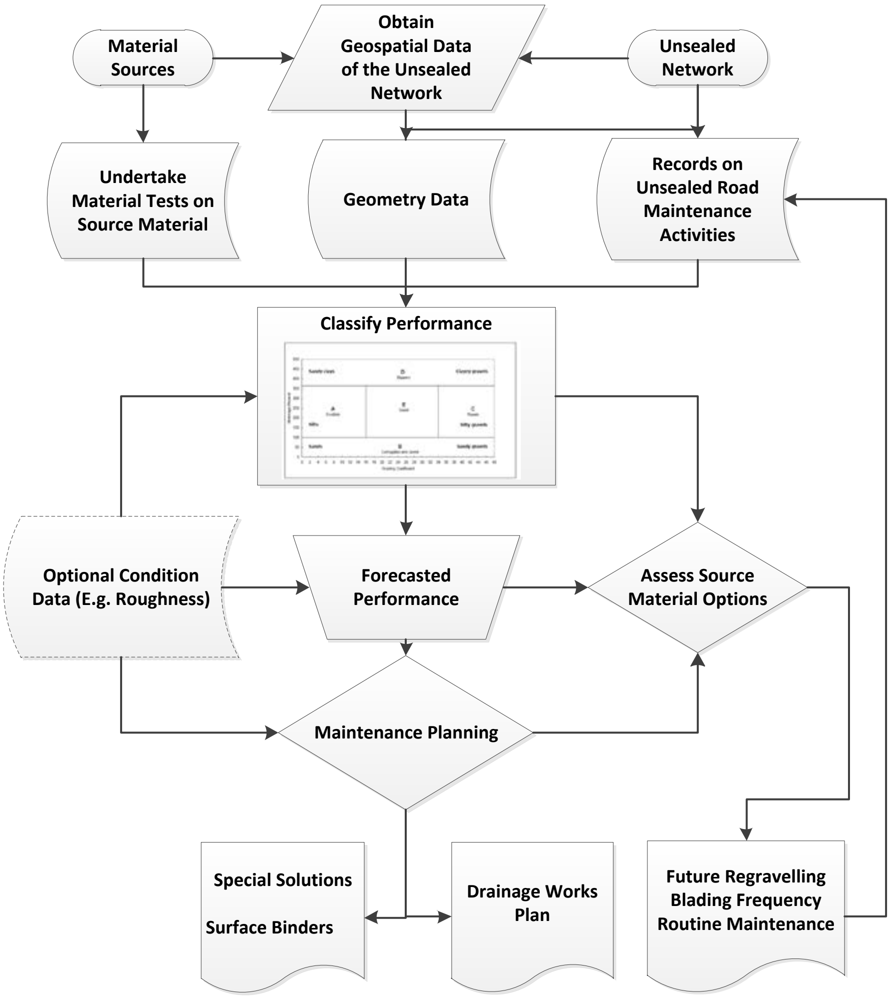
Table 4.3 Data requirements for strategic and tactical decision-making framework

Data items	Details	Function for data item
Maintenance cost	Historical maintenance needs and costs including: • blading frequency • re-gravelling interval • routine repair costs	This is core information to link material type, traffic use, and cost.
Material properties	Laboratory tests on gravel pit material: • particle size distribution • plasticity (BLS) or the plasticity index	Primary use: • To cluster/group borrow pits into performance categories. Councils need to develop traffic, material and cost relationships for each material grouping. Other applications on the tactical and operational level: • Identify problem material types – the grading and plasticity are used to classify the material in terms of how it will perform.

Data items	Details	Function for data item
		• Provide input into blending different sources of material – it could assist with optimising the material performance by identifying how it could be improved.
Maps	Could be geospatial or ordinary road maps, linking road to the material source borrow pits.	Basic use: • To link a road to the material source borrow-pits. Knowing the source material properties, now links the property to a specific road. • To classify the roads into geometry and alignment categories (hilly, rolling, flat). Advanced application • Geospatial optimisation could be used for trade-off analytics for gravel cost, distance to road and life-cycle costs.
Traffic information	Traffic count information including • ONRC classification • AADT • Percentage heavy commercial vehicles	• Cost/traffic relationships are developed for respective material types. This allows for selecting the appropriate, most cost-effective material for the re-gravel project. • Determine medium to long-term cost forecasts for given material and traffic use.
Climatic and/or seasonal data	• Rainfall (quantity and seasonal) • Seasonal aspects such as freeze-thaw • Climatic sub-regions within one district	Cluster roads into peer performing groupings. Material, cost and traffic relationship needs to be developed for each climatic sub-region.

Figure 4.3 illustrates how the information from the table is used to derive the medium-to-long-term forecast of maintenance needs.

Figure 4.3 A framework for medium to long-term maintenance planning of unsealed roads (Henning et al 2015a)



4.4.2 Developing a blading strategy

The way to determine blading frequency (within a region) varies significantly throughout New Zealand. Some of the techniques include:

1. Develop a blading frequency as a function of traffic volume
2. Use public complaints to set frequencies
3. Use a cyclic programme to blade all roads within a sub-region/district
4. Specify performance outcomes and let a contractor work out how much blading is required to keep the roads in good condition.

All of the blading strategies above have merits and limitations, yet they all suffer the same downfall so it is difficult to determine what the optimal blading frequency is for each road. Table 4.4 presents a case study of Central Otago District Council, which devised a blading strategy to relate the blading programme to a target LoS per ONRC, while allowing for extra blading where needed.

Table 4.4 A case study for developing a blading strategy – Central Otago District Council (Muir 2015)

Item	Central Otago District Council approach
Procurement	• partnership model • fence to fence contract • cost plus agreed margin • improved customer service • reduced costs.
Improving customer service	The number of public calls received by the council are monitored and are a vital indicator of its performance in achieving improved customer service. The council's objective is to reduce calls over time by improving work practices. The council has about 1,400 km of unsealed roads in Central Otago which are spread over a vast land area of close to 10,000 square km. There are extreme variations in climate with winter temperatures commonly below freezing and dry, hot summers where temperatures are often around 30°C. These temperature extremes and the dry climate make it a challenging environment in which to maintain unsealed roads. Public grumbling about unsealed roads is a long-standing situation and has existed across different network management structures and physical works contractors. This had got to the point where it was considered normal. With the council's new objective of reducing calls, it was clear that if it wanted to make a difference, then it needed to understand the causes of dissatisfaction better and change its approach.'
Identifying the problem	**What was real?** In order to find a place to start, the council analysed all the calls it had in its RAMM contractor system. The council looked at what people were ringing up about. • Were there a few particular roads that were an issue, or was it a particular area? • Was the problem just a few persistent callers or particular customers or was it widespread? • Was the issue with a particular grader operator or was it a system's problem? • How much grading could one grader achieve each month? • How often was the road getting graded compared with how often it needed grading. **Myth busting** There were a number of surprises. Despite the council's perceptions, the calls were widespread, from a lot of people, and about a lot of roads. There were fewer calls for issues that were going to be costly to address or weather related, like scouring or freeze/thaw, or gravel and dust, and most were just for grading. They were for all areas of the district. A number of complaints were about the grading that had been undertaken. Some of these were to tell us we were grading some roads too often, or dissatisfaction with the grading method. The calls that were about the grading method were for things like the transitions through accessways and intersections, forming of cutouts, or the depth of cutting to remove deeper potholes.
Shift in focus	From working through this, the council found there was a disconnect between what it believed was important and what the contractor thought was important to the council. A lot of these behaviours came from working on a unit rate contract with a focus on meeting the budget. Council staff had traditionally given little thought to how costs were built up, as under a unit rate the cost of grading per kilometre was the same year-round regardless of how many graders were needed.

Item	Central Otago District Council approach
	Reducing public calls is also a contract performance measure, so the contractor needed to understand that what the council might think if the customers were not happy. All of this needed to happen fast and within a constrained budget. **Changing perspective** The reality was the council did not have the money to spend on purchasing more graders to reduce calls. Instead it needed to lose a grader to keep the programme within budget. Added to this, the council needed to grade each area more frequently to get around the higher demand roads more often, and it needed to spend more time shaping at accessways and intersections and on cutouts. When roads did get deep potholes then the council needed to cut deep and compact the road to meet customers' expectations or in extreme cases do isolated manual repairs. Because the budget was capped, the council stopped grading its lowest classification of roads which get one grade a year while it worked out how it was going to deal with this seemingly impossible problem. **Joint focus** The council then started with a clean sheet and a joint focus. The first step was to look at the predictability of demand on roads. The council found this was far more predictable than first thought. With the exception of extreme weather events, activity across the network is relatively consistent from one year to another. The council also found t there was a fairly significant amount of housekeeping required to tidy up the unsealed road classifications, as the classification of a lot of roads was inconsistent with their use. This needed to be tidied up before the council could start preparing a grading programme. There is a subclassification system for gravel roads which sits under the ONRC access and low volume access classifications. This splits the access roads into two sub-classifications, and the low volume access roads into 3, giving a total of 5 subclasses of gravel roads.
The result	**Grading smarter** The objective was to come up with a programme where the council graded less but still targeted to demand. Each classification has a defined number of grades per annum. The council added an extra grade for high use roads over summer months, and for roads that needed metalling. Instead of leaving the decision of when to grade up to the individual grader drivers, the council prepared an annual programme, which has resulted in the establishment in each area of a two-month cycle instead of the previous 3–4-month cycle. The high demand roads are programmed every second month. Other roads in the area are programmed around these to keep the programme balanced over the year. This is required so the plant and programme can be optimised over the full year, and while there are still peaks and quieter times, these are not as extreme as they used to be. The grading areas were then reviewed so the workload was more evenly allocated. This ensured that each operator had sufficient time to grade deeply on the problem spots and spend extra time at access ways and intersections. Walk and roll roller attachments were added to the graders to enable compaction after deeper grading (during periods when road have sufficient moisture content). For the first 12 months, a council staff member inspected all the roads on the programme each month, and also inspected any road the public had called about to see if these needed grading and if so why. The council looked at where it had deferred road grading. Unless it could drop a full grade out, deferring for a month would cause scheduling issues. A minimal number of roads needed to have the frequency of grading increased, but these were exceptional cases. **The outcome** The council explained the process to the community boards and councillors, and to members of the public who rang.

Item	Central Otago District Council approach
	The council was prepared for things to get worse for a couple of months and for calls to increase while the programme was implemented. The council reduced the length of road graded by 33%. It virtually eliminated calls in its first test area from the first month. An impressive result was the reduction in public calls requesting grading, which dropped off by 64%. This was then backed up by phone calls from frequent customers reporting the roads were the best they had seen them. This was a real shock as the council usually needed to brace itself for these phone calls. The programmes were put on the web, and the elected members and the public seemed to like to be able to look these up and find out when roads were next getting graded.

Table 4.5 Blading strategy developed for Central Otago District Council (Muir 2015)

ONRC	Classification	Number of Grades
Access	Major	8 or 10 grades per annum
	Intermediate	6 or 4 grades per annum
Access Low Volume	Minor	3 grades per annum
	Lane	2 grades per annum
	Track	1 grade per annum

Notes:

The blading programme is developed for the medium expected frequency within a road class.

Frequencies are specific to the Central Otago District Council – other councils will most likely require different blading rates to allow for different soil types, climatic conditions and traffic loading.

4.4.3 Dealing with special cases

There are certain situations where unsealed roads are not able to provide the required level of service. These situations often occur in sensitive locations such as close to homes, schools and sensitive agricultural areas. Difficult terrain such as steep inclines, some corners and intersections often cause poor performance and/or high routine maintenance costs. It is not always possible to seal these road sections, and other solutions such as chemical treatment or alternative surfacing options then become viable. The challenge with these alternatives is to know which technology will work for the given situation and how cost effective it is. For example, in choosing dust palliatives, it is essential to realise that these products are useful only if the right product is being used for the given material. A detailed description of alternative surfacing options fell outside the scope of this research and recommended further reading includes:

- *A rational process for management of unsealed roads* (Andrews and Sharp 2014)
- ARRB *Unsealed roads manual – a guide to good practice* (Giummarra 2009)
- FHWA *Unpaved road dust management: a successful practitioner's handbook* (Jones et al 2013)
- World Bank *Guidelines for selecting surfacing alternatives for unsealed roads* (Henning et al 2007)

5 Performance monitoring framework

5.1 Recommendation for performance monitoring of unsealed roads

It is recommended that councils significantly improve their performance reporting of unsealed roads. This recommendation stems from the review of some asset management plans and the outcome from workshops reported in section 3.1. Because unsealed roads are managed from a strong operational focus, and because forecasts are often based on current experience, sufficient performance monitoring and reporting are essential.

A review of the ONRC process has led to the following recommendations:

- Unsealed roads will typically fall into one of three ONRC classifications (secondary collector, access and low volume access roads). This research project concluded that these classes are appropriate from a national road network perspective. Some councils may want to consider a further breakdown of unsealed roads into more classes for planning and management purposes.
- The ONRC reporting tool needs to capture more performance measures on unsealed roads. Recommended additional reporting measures are the impact of unsealed roads on:
  - the environment
  - human health.

The recommended performance framework was developed on the basis of the current ONRC performance framework with the overall purpose of 'To provide safe, affordable nearly all-weather property access by road'.

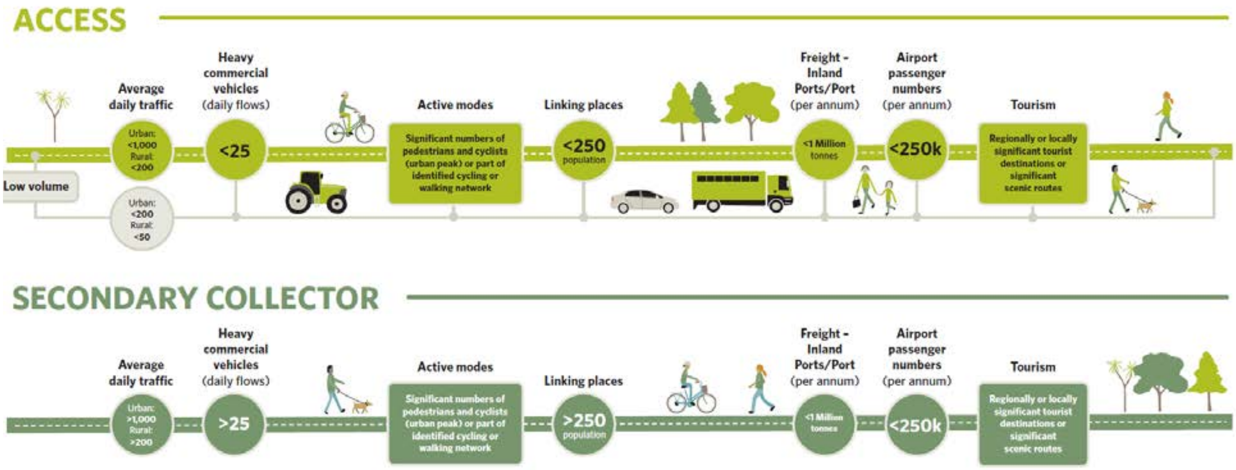
5.2 A review of the ONRC performance reporting for unsealed roads

5.2.1 Classification system

> *The One Network Road Classification (ONRC) was designed to standardise the performance of roads throughout New Zealand, aiming to address historical inconsistencies, and promote economic growth.* (REG 2016)

Figure 5.1 illustrates the three classifications that are most applicable to unsealed roads, including access (further divided to include low-volume access) and in isolated situations, unsealed roads could also be secondary collectors. Traffic volumes on these roads are usually well below 200 veh/day with typical truck volumes of approximately 25.

Figure 5.1 ONRC classification for unsealed roads (REG 2013)



From a national perspective, the ONRC classification is appropriate, and there are a number of authorities that have incorporated it into the asset management processes. This research project also concludes that the ONRC is appropriate and no changes to the classification are recommended. It is realised though that some councils may have a considerable length of unsealed roads within these road classes. At the tactical and operational levels the classification may appear to be too coarse, and further classification into sub-region and/or subclasses may assist in more efficient planning processes. A further breakdown is recommended for cases where it could assist within the planning processes.

5.2.2 ONRC performance framework

The quote in the previous section emphasises that the primary purpose of the ONRC process is to drive consistency in the performance of roads throughout New Zealand. The ONRC performance monitoring framework was tested in this section to determine:

- how effective it is in reflecting the performance of this network type
- how complete it is in managing the strategic investment in unsealed roads
- what data items are required to populate the performance framework.

Table 5.2 lists all ONRC performance measures with an assessment of their applicability to unsealed roads and data requirements for the framework.

Table 5.1 Relevant ONRC measured for unsealed roads

Outcome measure	Relevant to gravel roads?	Data collection needs
Safety – Customer outcome performance measures		
1 The number of severe and fatal injuries on the network	Yes	Crash statistics
2 Collective risk (severe and fatal injury rate per kilometre)	Yes	Crash statistics
3 Personal risk (severe and fatal injury rate by traffic volume)	Yes	Crash statistics
Safety – Technical output performance measures		
1 Permanent hazards	Yes	Safety inspections
2 Temporary hazards	Yes	Safety inspections

Outcome measure	Relevant to gravel roads?	Data collection needs
3 Sight distances	Yes	Safety inspection
4 Loss of control on wet roads	Yes	Crash data
5 Loss of driver control at night	Yes	Crash data
6 Intersections	Yes	Crash data
7 Hazardous faults	Yes	Inspections, crash data
8 Cycle path faults	N/A	
9 Vulnerable users	Yes	Crash data
10 Roadside obstructions	Yes	Inspections
Resilience – Customer outcome performance measures		
1 The number of journeys affected by unplanned events	Yes	Record instances
2 The number of instances where road access is lost	Yes	Record instances
Amenity – Customer outcome performance measures		
1 Smooth travel exposure (STE) – roughness of the road (% of travel on sealed roads which are smoother than a defined threshold)	N/A developed explicitly for sealed roads	
2 Peak roughness	Yes	Roughness measurement
Amenity – Technical output performance measures		
1 Roughness of the road (median and average)	Yes	Roughness measurement
2 Aesthetic faults	Yes	Roughness measurement
Accessibility – Customer outcome performance measures		
1 The proportion of network not available to class 1 heavy vehicles and 50MAX vehicles	N/A	
Accessibility – Technical output performance measures		
1 Accessibility	Yes	Inspections
Cost-efficiency performance measures		
1 Pavement rehabilitation	N/A	
2 Chipseal resurfacing	N/A	
3 Asphalt resurfacing	N/A	
4 Unsealed road metalling	Yes	Metalling cost
5 Overall network cost, and cost by work category	Yes	Periodic and routine maintenance costs

The observations from the table include:

- The ONRC performance measures are functioning at a strategic level, and for that reason, it is generic to allow it to be applicable across the network spectrum. From this perspective, it is also directly applicable to unsealed roads in most instances.
- The framework is not onerous in terms of the data requirements and in most cases, no additional data collection is required when compared with the current practice followed by councils.
- The specific safety aspects are comprehensive and should be included and reported explicitly following network inspections.

As expected, the strategic level of reporting from ONRC does not (and should not) make provision for the tactical and operational level reporting required for unsealed roads. A framework for the management of unsealed roads is presented in section 5.3. It also gives recommendations for additional measures that may be included in the ONRC framework.

5.3 Recommended performance monitoring framework for management of unsealed roads

Table 5.2 presents the performance framework for the management of unsealed roads. It shows the performance measures at strategic; tactical and operational level. The overall purpose statement is:

To provide safe, affordable nearly all-weather property access by road.

The strategic outcomes are consistent with ONRC framework and include:

- Provide safe property access.
- Provide affordable and sustainable property access.
- Provide an acceptable journey experience.
- Minimise the environmental and social impacts.

The only missing performance area from the ONRC is the impact of unsealed roads on both the environment (specifically related to material for unsealed roads) and human health. It is recommended that this performance area is included in the ONRC.

Table 5.2 Recommended performance reporting framework

Purpose	**To provide safe, affordable nearly all-weather property access by road**								
Strategic outcomes	**To provide safe property access**					**To provide affordable and sustainable property access**			
Strategic measures	**Crash rate (DSI/km)**		**Geometrics**		**No hazards**	**Annual maintenance and renewal cost/VKT**			**Resilience**
Tactical outcomes	A safe surface	Visibility not restricted by dust	Adequate carriageway	Sight distance	A forgiving road	Affordable maintenance cost	Affordable renewal cost	Sustainable asset preservation	Loss of access due to disruptive events
Tactical measures	Peak roughness (P/VP) No loose gravel	VKT exposed to unacceptable dust	Width (km < acceptable width) Note acceptable width also means not too wide surfaces.	Sight distance standard for speed environment	Permanent and temporary hazards	Pavement maintenance costs ($/VKT)	Gravel renewal costs($/VKT)	Depreciation ($/VKT)	Number of instances where road access is lost
Operational outputs	Pavement performance	Pavement performance	Loss of carriageway width (m)	Safe sight distance	Road hazards recorded	Reshaping requirements Ensure adequate drainage	Gravel replacement Ensure roads are not too wide	Pavement preservation	Duration and properties not having access
Operational measures	Material classification (type E)	Material classification (type E)	Carriageway width retained (RAMM width)	Sight distance measured (m)	Temporary hazard recorded	Grading frequency Total length graded/VKT	Total gravel replacement (m^3/VKT)	Total gravel replacement (m^3) /VKT	Number of journeys impacted
	Roughness P/VP				Permanent hazard not marked			Roughness(75% percentile IRI)	Duration of loss of access

Purpose	**To provide safe, affordable nearly all-weather property access by road**			
Strategic outcomes	**To provide an acceptable journey experience**			**To minimise the environmental and social impacts**
Strategic measures	**Customer satisfaction (%)**			**Carriageway dust (PM10 mg/m³)**
Tactical outcomes	A comfortable journey	A reliable journey	Complaints	Minimise negative impacts of dust emission
Tactical measures	Peak roughness (poor/very poor)	Road closure (# of 24h+ closure/yr)	# /VKT	Emission factor (PM10 mg/m³)
Operational outputs	A smooth pavement	Risk reduction	Customer response	Fines retention
Operational measures	Material classification (type E) roughness P/VP	Effective drainage adequate pavement	# Complaints resulting in corrective action	Material classification (type E)

6 Data collection requirements

6.1 Austroads data standard for road management

The *Austroads data standard for road management and investment in Australia and New Zealand* (Austroads 2016) was reviewed as part of this research project. The focus of the review was to ensure the outcome of this project would be consistent with the industry standards, while testing whether the standard allowed for all monitoring requirements established through this project. The outcome of the review is summarised in table 6.1.

Table 6.1 Assessment of the Austroads data standard

Data specification item (Austroads section number)	Consistency with New Zealand unsealed roads requirements	Comments
Network definition (8.1)	Consistent	No variation to recommendations
Classification (8.2)	Consistent, also with ORC	No variation to recommendations
Inventory (8.3)	Consistent	Most of this section would probably not be applicable to the unsealed road environment. Authorities should maintain an inventory of other assets as per council policy.
Condition (8.4) Roughness and specific data items for unsealed roads including: 8.4.74 Unsealed road profile 8.4.75 Unsealed drainage condition 8.4.76 Gravel depth	Findings from this research support the use of roughness as a specifically collected data item. Although road profile, drainage condition and gravel depth are important tactical and/or operational measures for the planning of unsealed road maintenance, the process for data collection of these items seems to be problematic.	Recommend adopting only the roughness as a condition item. For more sophisticated systems that do collect gravel depth and/or profile, these items may also be included in the dataset.
Demand (8.5) (traffic counts)	Consistent	This is a particular area of improvement for New Zealand networks.
Utilisation (8.5)	Not applicable to unsealed roads	
Criticality (8.6) and Resilience (8.9)	Consistent	Indicates an area of improvement for New Zealand networks. Consider criticality specifically to unsealed road network taking account of performance framework (refer to table 5.2).
Risk (8.7)	Consistent, although in limited use at this point	This data area provides an opportunity to record and manage performance areas not currently being considered including: • Health and safety: an asset's ability to deliver the required service level within acceptable health and safety limits (dust) • Socio-cultural: an asset's ability to impact on the social, economic and cultural outcomes of the communities they are servicing.

Data specification item (Austroads section number)	Consistency with New Zealand unsealed roads requirements	Comments
		• Financial: an asset's ability to deliver the desired outcomes within the financial limits • Environmental: an asset's ability to deliver the desired outcomes within the environmental limits. • Governance: an asset's ability to deliver the desired outcomes within the reputational limits and legislative requirements.
Performance (8.10)	Consistent (within ONRC reporting)	This data group provides the opportunity for establishing the performance framework in the data-set (refer to chapter 5). At this point having full reporting of the ONRC process should be the minimum standard.
Access (8.13)	Consistent	Also, refer to criticality and resilience items above.
Works and cost (8.14)	Consistent	An area of significant improvement for New Zealand unsealed road networks

6.2 Fundamental principles for the unsealed road data requirements

Too often data collection frameworks are developed based on 'what is possible to collect' without enough thought around the practicality and sustainability behind the asset management approach. This research's recommended data requirements were developed on the basis of the principles summarised in table 6.2.

Table 6.2 Principles used in the development of data requirements

Principle	Commentary	Impact of the recommended approach
The data items should have a purpose within the asset management process at either strategic and/or tactical management level	When an asset management process and/or system fails, a common reason is that it was too operationally focused. As learned from this project, the operational aspects tend to be self-sufficient in collecting data through inspections prior to developing specific works programmes –there is little need to record this data permanently.	The recommended data collection approach will be solely focused on the tactical and strategic level. Also collect only the data items that are relevant to either decision processes, planning and performance monitoring and reporting.
Data items that change frequently are not worth much in the long term. Exceptions to the rule would have a snapshot for time-based performance monitoring or the need to collect specific condition data items for performance-based contracts.	The traditional approach of annual condition rating on the full unsealed road network has limited value. It is not used in decision making or in annual reporting.	Discontinue the expectation of having a full network rating on an annual basis. Allow for performance indicators that are sufficient to benchmark annual performance over time.

Principle	Commentary	Impact of the recommended approach
Harness other data sources in order to integrate specific data items across systems.	There are so many data sources that are invaluable for managing the unsealed road network. Processes have to be put in place to cross-link these data sources .	This project will specify the number of data items that require sourcing from other systems (eg safety/crash information, traffic counts and customer complaint data).
Keep practicality of data collection in mind when deciding on sophistication.	The mere ability to collect certain data items does not necessarily make it a good idea. For example, this project has recognised the importance of dust emissions. However, that does not warrant starting a blanket dust monitoring programme at significant expense when there are only isolated parts of the network where this really matters.	Data items will be collected at the most basic level possible in order to fulfil the data item's function.

6.3 Data items critical to the asset management process

Table 6.3 provides the important data requirements for unsealed roads resulting from the research. The requirements were developed on the basis of the workshops, recommended decision processes and performance monitoring and reporting.

Table 6.3 Recommended data requirements for unsealed roads

Data category	Data item	Comments
Network definition, inventory and asset description	Classification (ONRC)	Refer to Austroads data standard (section 6.1)
	Location referencing	
	Asset description including geospatial and criticality	
	Gravel properties Grading distribution Plasticity (either plasticity index, or BLS	It is proposed to set up a relational data structure that links particular material properties from borrow pits to the respective borrow material used on a given road section.
Demand	Traffic and loading • AADT • % heavies	Counts at least once every 3 years, supplemented with estimates based on adjacent roads.
Performance safety	Crash statistics	Link into crash management system
	Peak roughness (P/VP)	Refer to roughness condition below
	VKT exposed to unacceptable dust (PM10 mg/m^3)	Basic level – qualitative measure Advanced – measured dust level
	Width (km < acceptable width)	Width standard to be developed on the basis of a functional requirement for the road and recorded in inventory properties. Assessment of under-width to follow through safety inspections
	Sight distance standard for speed environment	Recorded during safety inspections

Data category	Data item	Comments
	Permanent and temporary hazards	Recorded in safety inspections and regular network inspections
Performance resilience	Road closure (# of 24h+ closure/Yr)	Unsealed road data needs to be linked to customer complaint logs
	Cost of emergency/ flood repairs	Repair costs have to be recorded alongside storm properties (rainfall, intensity, and duration)
	Drainage adequacy and condition	Recorded during regular network inspections
Performance customer satisfaction	Smooth travel exposure (STE)	Processed from roughness data
	Condition/performance complaints (# /VKT)	Need to be processed from complaints call recorded data. Coding of complaints is possible with applications such as Ndivo, which allows for specific performance analyses. Also, useful to record the specific complaints that resulted in treatment responses.
	Unacceptable dust emissions	Basic - sourced from complaints system Advanced – measured dust levels
Performance – condition	Roughness (IRI)	Collection aspects are discussion in section 6.4
	Surface profile (advanced)	
Works and costs	Gravelling: • date • thickness • borrow pit source	Should be recorded as part of maintenance management process (eg Pocket RAMM)
	Blading	
	Routine maintenance	
	Drainage investment	

6.4 Data collection frequency and sophistication

A principle for determining data collection frequency is that higher sophistication and accuracy of measurements usually require less frequent measurements. The fast-changing nature of the unpaved road network adds another layer of complexity that nullifies the concept around measurement accuracy at a given point in time. It is, therefore, more important to follow a pragmatic approach to the data collection that still provides the required information for the respective asset management level. This section provides the requirements for data collection for the strategic and tactical planning levels. Additional data collection may also be undertaken for operational purposes. For example, cell phone roughness surveys (Roadroid) could be used efficiently to survey roads during inspections to assist with the scheduling of blading programmes and/or identify isolated rough areas. Table 6.4 provides the recommended data collection requirements that resulted from this research.

Table 6.4 Data collection requirements for unsealed roads

Data item	Recommended frequency		Comments
	Minimum	Ideal	
Roughness	Full network coverage once a year[(a)] (for annual reporting it is important to do them at the same time each year)	Two-to-three planned surveys a year covering different seasonal conditions and maintenance activities[(b)] (for annual reporting it is important to do them at the same time each year).	Surveys could be undertaken using either a bump integrator (ROMDAS and/or ARRB Roughometer) or cell phone technology such as Roadroid.
Traffic	Confirming estimates through a count once every three years	Confirming estimates through a count once every three years supplemented with classified counts on main trucking roads.	Estimates for unsealed roads could be done accurately given that most of these roads feed into the sealed road network with more frequent count information.
Material properties	Once for every borrow pit (representative samples need to be taken in different locations of the pit). Tests need to be repeated once a change in material is observed.	Once for every borrow pit (representative samples need to be taken in different locations of the pit). Tests need to be repeated once a change in material is observed.	The properties on the road may change with time (fines are blown away) and changes in performance can be confirmed with ad hoc testing of material from the roads.
Dust	Qualitative assessment during routine inspections and/or utilising public complaints. Only sensitive areas need to be assessed.	Qualitative assessment during routine inspections and/or utilising public complaints. Undertake dust emission measurements for justifying the additional investment into special treatments.	
Road profile	Qualitative assessment during regular inspections (operational level only, not recorded in database)	Qualitative assessment during regular inspections (operational level only, not recorded in database) Future applications of LiDAR surveys may be considered.	

Notes:

1 The annual survey is required in order to produce a meaningful trend over a three-year reporting period (3 data points over three-year funding block)

2 Where more frequent roughness surveys such as Roadroid are being used during routine inspections, it is advisable to store all the data. This will allow for more meaningful trend analyses over time. It could also be used more actively in the monitoring and planning of blading regimes.

Note that data reporting and management should occur for homogeneous section lengths; for unsealed roads it is expected to have section no longer than 1 km.

7 Recommendations

The research project developed an assessment process for the condition of unsealed roads, based on a review of current practice at councils, decision making, and performance monitoring and reporting. This resulted in a full set of data requirements for unsealed roads. The main recommendations resulting from the research are summarised in table 7.1.

Table 7.1 Recommendations from the research

Topic	Recommendation	Reference to this report
Asset management approach	Councils should focus on enhancing the strategic and tactical asset management of unsealed roads. This research provided a framework to achieve this, but industry groups such as RIMS should facilitate and advocate this transition further.	Chapter 4
ONRC	This research developed a reporting process that is consistent with the ONRC framework. There are, however, some limitations that need to be considered for ONRC reporting including more focus on measures including: • customer satisfaction/complaints • dust • environmental impacts.	Section 5.2.2
Austroads data standard	The data standard provides an excellent framework for setting up an unsealed road database and data structure. Given the slight variation in the condition data approach, this research report should be provided to Austroads for consideration in the next version of the data standards.	Section 6.1
Focus areas for councils	The priority data areas requiring improvement at councils include: • traffic data • recording maintenance costs • safety inspections.	
Further work	Further development that is required to assist councils includes: • systems and processes to facilitate the performance reporting • systems to assist with the analytics for tactical planning.	

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Appendix A: Outcome from the industry workshops

Question	Response	Additional comments
Does your council really pay much attention to unsealed roads? Is there a genuine intent to do things better?	100 % positive response	Still a lot of pressure for seal extension, due to property value noise dust, safety Value for money perception from councils is an issue Clear indication from council to reduce seal extension Looking to reduce the maintenance cost
What data do your currently collect?	Roadroid roughness Windshield surveys/ Inspections Roughometer Traffic counts Grader GPS monitoring Scanning rutting and roughness All defects assessed once a month (RAMM rating) Historical expenditure	Not much use for formal rating surveys
What information do you need?	Measured profile Source material with date and use of road Operational management of routine maintenance with proper monitoring Real time indication of the shape and condition (roughness) Camera technology showing the conditions (LiDAR survey)	'Good grader operators' Training Go-pro on graders Tool to assist in prioritising the seal extensions Like to be more pro-active – before public complaints Different LoS across the network similar roads some are sealed other not Aggregate binders are expensive If there is an approach to save money and deliver LoS Tool to assist in prioritising the seal extensions

Question	Response	Additional comments
What information do you need for maintenance planning?	Material properties Rainfall Traffic Shape Road use/traffic mix Road alignment Have to check on the achievement of performance-based contracts.	GPR and FWD too variable to be useful If you test different sections – is performance monitoring relevant? Pre-define acceptable triggers for blading Operational management of inspectors – very reactive
What information do you need for asset management plans?	Historical maintenance costs Data processing is a pain – look for trends and areas of significant change Justification would be on consequences of not doing something – risk process	Went through business case highlighted greater care needs for justifying expenditure
What information do you need for performance monitoring?	Customers complaint User satisfaction of LoS for unsealed roads	Reporting on unsealed roads will become important. Too hard – lack of repeatability Sometimes it is not needed giving planning process Because gravel roads change too quickly to report anything meaningful
What is your current strategy for managing complaints about dust?	Prioritise complaints about dust seals May ask complaining party to contribute towards seal extension Matrix around seal extension but they only record it, but it does not necessarily get treated Control settlement next to the road Crushed rock close to homes Waste oil, Otta seals were also looked at.	
Do you collect any data to substantiate your investment in dust reduction	Visual subjective observations	

Question	Response	Additional comments
Bottom line	Guidance is still required for seal extension – people want to know what is the right thing to do Unsealed roads are managed on daily basis Material selection is the key, but in some cases, there is not much of an issue.	

Appendix B: Key performance measures for unsealed road contracts

5 Key Performance Measures

5.3 RAMM Condition Rating Data Collection

The Contractor may nominate their own independent team to undertake data collection surveys. In any case the composition of rating teams shall comply with Maintenance Specification (State Highways), Section 2.3.3 with respect to independence, objectivity and links to the Quality Plan.

5.3.1 General Requirements

All personnel completing RAMM condition rating surveys shall be suitably qualified and shall have attended a road condition rating workshop approved by the Engineer's Representative within the previous 24 months. Copies of rating accreditation certificates must be provided to the Engineer's Representative prior to survey work commencing.

All personnel completing RAMM condition rating surveys shall be independent of the delivery team. For the avoidance of doubt, personnel who work for the Contractor (or its suppliers) but are not located in the contract office and are not directly engaged in contract delivery may be considered to be independent of the delivery team.

All data must be provided in a format that can be directly loaded into the WBoPDC RAMM database without the need for further processing or modification. To demonstrate this, the Contractor must process the data and ensure that the processed data meets the requirements of the RAMM Input Validation Rules.

5.3.2 Survey Requirements (Roads)

Road condition rating surveys must:

a) Be completed in accordance with the version of the NZTA *RAMM Road Condition Rating Manual* current at the time of tender

b) Cover 10% of the sealed carriageway sections each year in each of road groups 1 to 7, using a sampling methodology agreed with the Engineer's Representative

c) Cover 10km of the unsealed carriageway sections each month in each of road groups 1 to 7, using a sampling methodology agreed with the Engineer's Representative, and combined into a total survey length of 120km each year

10% per year

5.3.3 Survey Requirements (Drainage)

Drainage condition (lined and unlined) rating surveys must:

a) Be completed in accordance with the version of the NZTA *RAMM Road Condition Rating Manual* current at the time of tender

b) Cover 100% of the sealed carriageway sections each year in each of road groups 1 to 7

c) Include all surface kerb and channel items (e.g. kerb, kerb and channel, mountable kerb, dish channel), other than where they are part of a raised island not designed to collect water

5 Key Performance Measures

5.10 Surfacing Defects Index (Unsealed)

5.10.1 Data Analysis

Surfacing defects on unsealed roads are to be analysed using the RAMM data collected in accordance with Appendix (WBoPDC Local Roads) 5.3.

The analysis shall exclude the following:

b) Records for roads owned by parties other than WBoPDC (e.g. Crown, Tauranga City Council, Maori or privately-owned)

5.10.2 Calculations

The Surfacing Defects Index (Unsealed) KPM is calculated using the following formula:

$$Surfacing\ Defects\ Index\ (Unsealed) = \frac{\sum_{All\ unsealed\ sections}(Weighted\ Condition\ Index \times Section\ Length)}{\sum_{All\ unsealed\ sections} Section\ Length}$$

where:

- The Weighted Condition Index for each rating section is calculated using the following formula:

$$Weighted\ Condition\ Index = 1.75 \times \sum_{1}^{9}(Condition\ Rating\ \times Fault\ Weight)$$

where:

1. The Condition Rating for each Fault Type are listed in the following table:

Table 5.10.2 a): Unsealed Road Fault Type Condition Rating

No.	Fault Type	Condition Rating				
		1	2	3	4	5
1	Potholes	0	0≤x<2	2≤x<25	25≤x<50	x ≥50
2	Corrugations	0	0≤x<4	4≤x<50	50≤x<97	x ≥97
3	Graded Width	<0.25	0.25≤x<0.5	0.5≤x<0.75	0.75≤x<1	x ≥1
4	Surface Water Channel	0	0≤x<50	50≤x<75	75≤x<100	x =100
5	Rutting	0	0≤x<5	5≤x<50	50≤x<100	x =100
6	Cross-section	0	1	2	3	4
7	Scour	0	0≤x<3	3≤x<50	50≤x<95	x ≥95
8	Shoving	0	0≤x<3	3≤x<9	9≤x<15	x ≥15
9	Loose Aggregate	0	0≤x<50	50≤x<100	100≤x<200	x ≥200

5 Key Performance Measures

2. The Condition Rating and Fault Weight for each Fault Type are listed in the following table:

Table 5.10.2: Unsealed Road Fault Type Weighting		
No.	**Fault Type**	**Fault Weighting**
1	Potholes	20%
2	Corrugations	20%
3	Graded Width	10%
4	Surface Water Channel	5%
5	Rutting	5%
6	Cross-section	5%
7	Scour	10%
8	Shoving	20%
9	Loose Aggregate	5%

3. The value for the Pothole Fault Type is calculated using the following formula:

$$x = \sum (No.of\ Potholes \times Pothole\ Weighting) \times \frac{100}{Inspection\ Length\ (m)}$$

where the pothole weight is based on pothole diameter and depth as listed in the following table:

Table 5.10.2 c): Pothole Weighting				
Pothole Depth	**Pothole Diameter**			
	100mm to 300mm	**300mm to 600mm**	**600mm to 900mm**	**> 900mm**
25mm to 50mm	1	1	2	3
50mm to 100mm	1	2	3	3
>100mm	1	2	3	3

4. The value for the Corrugations Fault Type is calculated using the following formula:

$$x = \sum Length\ of\ Corrugation \times Corrugation\ Weighting \times \frac{100}{Inspection\ Length\ (m)}$$

where the corrugation weight is based on corrugation depth as listed in the following table:

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Table 5.10.2 d): Corrugations Weighting	
Corrugation Depth	**Corrugation Weighting**
25mm to 75mm	1
> 75mm	2

5. The value for the Graded Width Fault Type is calculated using the following formula:

$$x = Width\ from\ RAMM\ Carriageway\ Table - Measured\ Width$$

6. The value for the Surface Water Channel Fault Type is calculated using the following formula:

$$x = (Length\ of\ Inadequate\ SWC\ LHS + Length\ of\ Inadequate\ SWC\ RHS) \times \frac{100}{2 \times Section\ Length}$$

7. The value for the Rutting Fault Type is calculated using the following formula:

$$x = Length\ of\ Rutting > 30mm\ deep \times \frac{100}{Inspection\ Length\ (m)}$$

8. The value for the Cross-section Fault Type is as recorded through RAMM condition rating.

9. The value for the Scour Fault Type is calculated using the following formula:

$$x = Area\ of\ Scour\ (m^2) \times \frac{100}{Inspection\ Length\ (m)}$$

10. The value for the Shoving Fault Type is calculated using the following formula:

$$x = Length\ of\ Shoving \times \frac{100}{Inspection\ Length\ (m)}$$

11. The value for the Loose Aggregate Fault Type is calculated using the following formula:

$$x = \sum (Length\ of\ Loose\ Aggregate \times Loose\ Aggregate\ Weighting) \times \frac{100}{Inspection\ Length\ (m)}$$

where the loose aggregate weight is based on loose aggregate depth as listed in the following table:

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Table 5.10.2 e): Loose Aggregate Weighting	
Loose Aggregate Depth	**Weighting**
< 50mm	0
50mm to 100mm	1
> 100mm	2