Draft Keynote Address

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Let’s be Practical about Road Profile Data!

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Best Practices – Smart Systems – Canny Tools: A Practitioner’s Approach

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Let's be practical about road profile data!

1 Introduction

This paper has been written as the direct result of enquiries following a presentation to the Data Collection Workshop of The Sixth International Conference on Managing Pavement – Brisbane 2004.

The theme of that presentation was “Format Follows Function” at which time the writer argued, based on a quotation by John Hallett of Beca Carter (New Zealand), that “we must be careful if we are going to dig out a section of road for repair with a backhoe, mark it out with a can of spray paint, that we don’t measure it with a micrometer”.

Sadly this is often true. The purpose of this paper is to postulate some ideas for the measurement, analysis and verification of road condition data based on the theme of “Format Follows Function”.

The paper has been prepared in the writer’s capacity as a Fellow of the Australian Academy of Technological Sciences and Engineering (ATSE) and not in the capacity of Founder and Chairman of Pavement Management Services Pty Ltd, although many of the ideas and postulations are from that source, in particular the experiences gathered from acting as pavement managers to the successful Sydney RTA Performance Specified Maintenance Contract (PSMC).

2 Concepts

Two concepts are germane to this discussion, the “Characteristic Value” and “Level of Service“. These concepts impact on the approach to calibration of equipment, measurement of parameters, analysis of results and verification of outcomes.

2.1 Characteristic Value

This concept is based on the characteristic value concept of Chapter 6 of The Austroads’ Guide to the Structural Design of Pavements (2003), and is defined as: -

Characteristic Value = ? ? f.?

Where:

? Is the population mean
? Is the standard deviation of the population and
f is given by: Table 1

Road Class	“f”	% Of all values that will be covered by this characteristic value
Arterials	2.00	**97.5**
Collectors & Distributors	1.65	**95**
Local Access and Residentials	1.30	**90**

Table 1 Values of “f” in the characteristic value for Road Classes

2.2 Level of Service

Three Levels of condition measurement are proposed as a function of need, or as a path to providing road condition data that is "Fit for Purpose".

1 **Level 1** The basic level, providing data and outcomes suitable for ranking sections or sub-networks. The outcomes are not generally suitable for either demonstration of "duty of care" or preparation of a maintenance works programme (an Operational Works Programme) because they provide insufficient engineering properties.

2 **Level 2** The intermediate level, measurements at this level are sufficient to demonstrate "duty of care" and to allocate sections of a network as candidate sections for further analysis. These measurements may be used to prepare a pavement management system, but would be unlikely to support the modelling desirable for a Performance Specified Maintenance Contract or a long-term maintenance programme involving Key Performance Measures.

3 **Level 3** The most detailed level of measurement, this level permits the allocation of levels of risk.

Level 3 requires highly sophisticated equipment operation, and evaluation by engineering professionals. It provides defensible evidence of road management plans and for litigation.

Level 3 is the preferred option for "Project Level Investigation".

The writer has previously written a monograph, on behalf of Pavement Management Services entitled "The principles of Pavement Condition Measurement", together with accompanying specifications. This booklet provides examples of "levels of service" environmental factors, measurement factors, and outcome factors of pavement condition monitoring.

For example; under "Environmental Factors", the topography necessary to be taken into account for any of the four measured conditions of Structural Capacity, Longitudinal & Transverse Profiles, Skid Resistance and Visual Inspection may be:

Level	Purpose	Criteria
Level 1	Ranking	General national climate, geology , topography
Level 2	Selection & Allocation	Local Climate, rainfall, temperature, geology
Level 3	Prioritisation & programming	Seasonal changes, surface condition, drainage, water table, road geometry

Table 2 Levels of topography necessary for Pavement Condition Monitoring

Under "Measurement Factors "- The minimum number of sample intervals in a section may be:

Level	Purpose	Criteria
Level 1	Ranking	5
Level 2	Selection & Allocation	8
Level 3	Prioritisation & programming	12

Table 3 Minimum Number of Sample Intervals in a Section

Notes:

A minimum of 5 measurements is required for each section being evaluated. They must be distributed homogeneously or by some predetermined pattern. Less than 5 measurements do not allow verification of the statistical hypothesis as a normal distribution. In this case, the statistical parameters of **MEAN and STANDARD DEVIATION cannot be calculated.**

With less than 12 measurements, the risk of wrongly affirming that a series of measurements is taken from a normal distribution is high, therefore the uncertainty that the statistical parameters of **MEAN and STANDARD DEVIATION** is large.

The number of test points should be considered jointly with the test point spacing parameter, if deflection measurements are used to define homogeneous sections.

The number of test points must be chosen to be able to assess homogeneity.

Under outcome factors for the analysis of texture depth data the requirements may be:

Level	Purpose	Criteria
Level 1	Ranking	Section Mean
Level 2	Selection & Allocation	Characteristic Texture Depth @ 10m intervals
Level 3	Prioritisation & programming	Critical Areas- Characteristic Texture @ 1m intervals

Table 4 Analyses of Texture Depth Data

This monograph and accompanying specifications are in the public domain and available “free of charge “ to interested persons or organisations.

3 Scope

This paper, covers the measurement of both longitudinal and transverse profiles of a road pavement system.

Longitudinally, the two parameters are:

> **Roughness** with wavelength of between 0.5 and 50m and frequency between 20 and 2000 Hz and
>
> **Macrotexture** with wavelengths less than 0.5mm and frequencies greater than 2000 Hz

Transversally the parameter is **Rut depth** defined as “the maximum vertical pavement displacement, in the transverse profile, either across the wheel path (wheel path rut) or across the lane width (lane rut) measured from a reference plane”.

Each of these parameters can be measured by mechanical or non-contact distance measuring transducers such as acoustic or laser methods.

3.1 Rationalisation

The three above parameters have undergone considerable evolution over the past three decades, yet today we are plagued by the heritage of methods which were developed in the era before personal computers, transducers, analytical techniques coupled with enormous processing power and occupational health and safety awareness.

This writer advocates expunging three former tests for their measurement in favour of current technology.

Each of these methods has an algorithm for converting the new technology to the obsolete. Such practice inevitably introduces a potential error into the analysis. It is important that we, as technologists, embrace the new technology and those who favour the old technology, for whatever reason, still have the resources to analyse backwards to their preferred system. However, all new specifications and test procedures must be linked to the new.

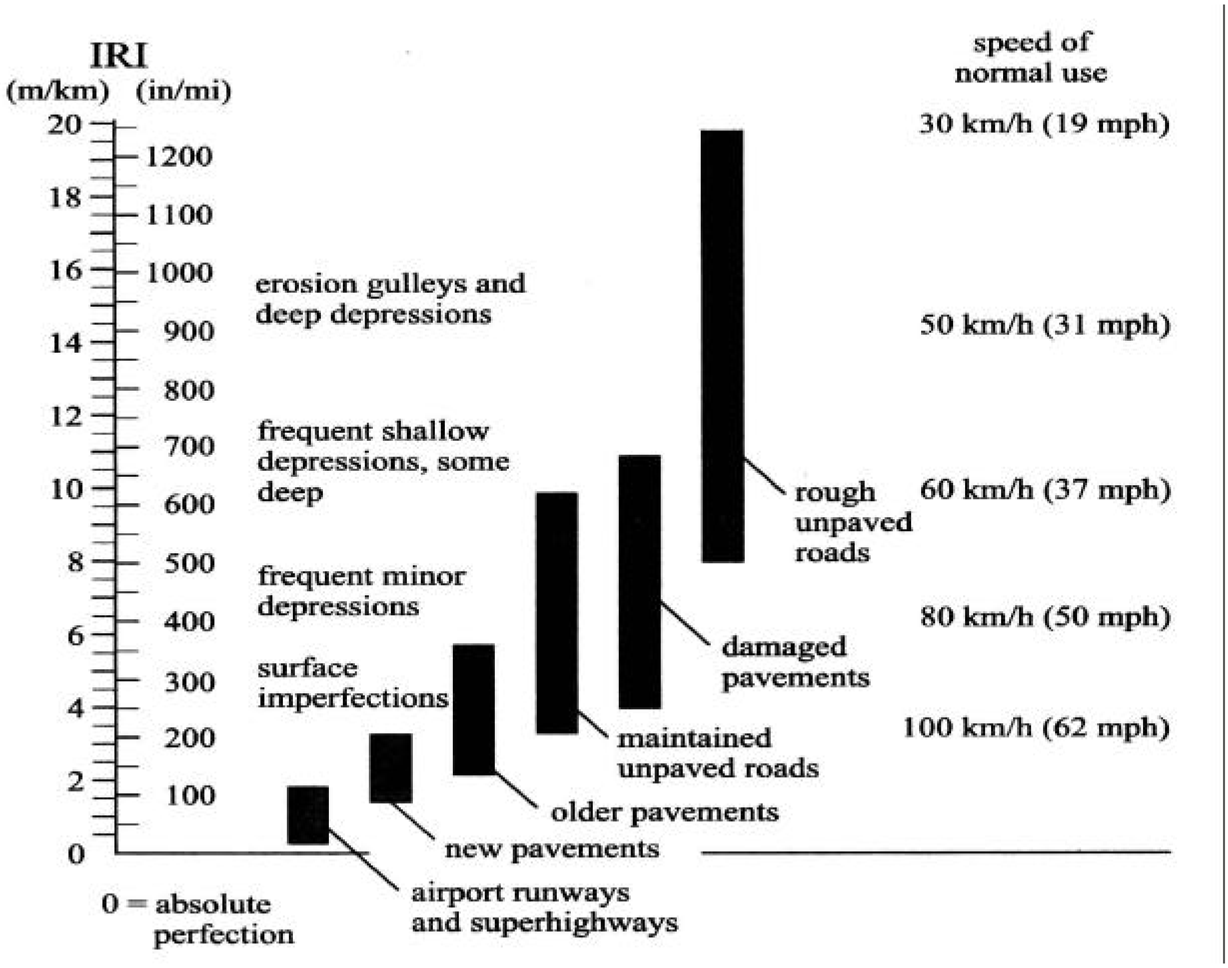
3.1.1 Expunge NAASRA Roughness (NRM) in favour of the International Roughness Index (IRI)

It is proposed, that it is about time that Australia and New Zealand remove the National Roughness Measurement (NRM) or NAASRA as it more commonly known from all specifications, for several reasons:

- Most reliable deterioration models are based on roughness in terms of The International Roughness Index or IRI.
- In Australia and New Zealand we, generally, compute roughness predictions in terms of IRI and then convert to NAASRA counts.
- Apart from introducing an opportunity for error in calculations, NAASRA counts (being approximately 30 to the IRI unit of metres per km) give a false sense of accuracy to interpretation, with some users insisting that changes of two or three NAASRA counts are significant, that is in the order of 0.03IRI

If we refer to the original hypotheses of Sayers and Gillespie [2] it is clear that the interpretation of IRI is a reasonably coarse measurement.

Figure 1 – Characterisation of IRI (after Sayers & Gillespie – Ref 2)



Ranging from IRI =2 (2m per km - a fairly smooth pavement) being one that a vehicle can travel reasonably comfortably at 100kph to IRI =16 (16m per km- a pavement that it would be difficult to control a vehicle at 50kph). Speed humps in suburban streets are frequently in the order of IRI=16.

Both measurement and calibration techniques are characterised by numerous potential errors produced by the cumulative effect of measuring the base condition.

I am advised that the limit of reading either by staff and level or a walking profilometer is ? 2mm depending on the macro-texture of the surfacing. Given that a calibration section is specified under "the Transit NZ specification" as being a minimum of 500m, there will be at least 1500 measurements taken to determine change in height of the profile.

The procedure for calculation of IRI as a function of this raw data is fraught with difficulties and even the developers (UMTRI) say it was never intended for calibration, not the least of which is the wave length filtering necessary to obtain reasonable results. The so-called "Jaws of Prem" or auto spectral density analysis is a good tool for analysis but does not compensate for the inherent errors accumulated in the base measurement and filtering process.

3.1.2 Expunge the Manual 1.2m Straight Edge for rut depth in favour of non contact measurement at highway speeds and analysis by lane width under a taut wire

OH&S awareness means that placing personnel on the roadway to collect rut depth data under a 1.2m straight edge "10 times per 100metres" is almost a non-event. The only reasonable means becomes to collect the transverse profile at traffic speed using a system of distance measuring transducers set in a plane above the road surface. Providing a sufficient number of offsets from the planar surface are measured, then the transverse profile for the whole lane can be defined. Deviations from the plane define the depth and width of ruts.

Wheel path ruts can be measured in the same way (for Level 3 or Project Level analysis). In this case the 1.2m straight edge becomes obsolete technology given, the width of tyres, traffic wander and magnitude of loads compared with those of thirty years ago.

3.1.3 Expunge "Sand Patch " for macro-texture in favour of Mean Profile by non contact measurement at highway speeds

As with manual measurements for rut depth, OH&S awareness makes the collection of texture on the road surface, using the sand patch method, both unwieldy and expensive, if traffic management issues are included in the cost.

We must therefore look to an automated methodology, the use of very accurate distance transducers becomes the preferred method. The major decision becomes one of matching the frequency of the transducer to the level of reading required.

4 Calibration Methodology

4.1 Accreditation Agency

There should be only one agency accrediting profilometer devices in Australia and New Zealand. The National Association of Testing Authorities (NATA) is such an agency in Australia and IANZ in New Zealand. Government constitutes both, both are internationally accepted and both have reciprocal rights, i.e. a unit accredited in Australia by NATA is accepted by IANZ in New Zealand.

Providers should be required to obtain accreditation for testing and analysis by these organisations at the **level of service** they plan to offer, clearly the higher the level of service for which accreditation is held, the more rigorous and stringent are the calibration requirements.

4.2 Calibration of Devices

4.2.1 Calibration of Components

All parameters require the measurement of displacement from a plane surface. *Primae facie* evidence that each transducer measures accurately should be via the "block test" derived for the original 3 beam laser profilometer developed by ARRB-TR as a research project for Pavement Management Services.

Three sets of calibration plates are required, all of which must have measurements traceable to the National Measurement Laboratory.

The Roughness Calibration Plate is a block on non-corrodible metal with dimensions of 25mm by 50mm by 100mm. The calibration block is placed on a planar surface and the offset measured and recorded, at least 10 times, by the distance transducers for each of the three block dimensions. The ***Maximum Error*** defined as the greatest residual (absolute value), can be thus determined. This enables the computation of the ***Percentage Error*** for the instrument at each of the known offsets

For Rut Depth Measurement a block of non corrodible metal of dimension 7.5 mm thick, by 15.0 mm wide and 30.0 mm long, (accurate to 0.1mm) shall be placed directly under each laser in the profilometer device and both standard errors and percentage errors determined as the greatest residual of say 10 readings. The lower the percentage error, the higher the level of service that can be offered.

Calibration for **Mean Profile Depth** will be a little more difficult. It is relatively easy for a machine shop to manufacture metal plates of known texture depth, which could be used under the "texture lasers". A suite of these plates, measured by or traceable to the National Measurement Laboratory, would appear to be a suitable pathway. However at this time this approach has not been fully exploited.

Verification of the accuracy, at speed, is an issue with the relative wavelength consistent with the texture depth defining the velocity of collection as a function of this wavelength together with the frequency of the laser pulses.

This method requires further investigation and resolution.

A typical example of results from a block test calibration and calculation of the greatest residual and percentage error is shown in Table 5, where the residual value is given by the difference between the block dimension and the reading. The greatest residual is the maximum value (absolute) of all residuals and the percentage error is the greatest residual divided by the block dimension.

Table 1 Example for determination of Maximum and Percentage Errors

Reading	Block Dimensions in mm		
	7.5	15.0	30.0
1	6.8	15.2	30.0
2	7.1	15.3	29.9
3	7.7	15.0	29.6
4	7.3	14.9	30.4
5	6.3	15.3	30.0
6	6.8	14.7	29.9
7	7.7	15.6	30.1
8	7.8	14.3	30.0
9	8.0	14.8	29.4
10	7.4	15.0	31.3
Greatest Residual	0.7	0.7	1.3
Percentage Error	9%	5%	4%

4.2.2 Calibration of the System

The second calibration test is designed to ensure that the measurement transducers are measuring the same offset from the pavement, and that the gyroscopes will maintain a planar surface under operational conditions.

Tests developed by the manufacturers are suitable for these purposes.

ARRB-TR developed the “Bounce test” whereby the device is set running in the static mode and a large deflection (bounce) induced on the front of the test vehicle; the measurement trace must return immediately to the static planar surface.

Greenwood Engineering have developed “the Milk Bar Test” to test the same conditions. A tray of milk is placed under the laser beam configuration. Milk ensures an opaque surface and being liquid guarantees a planar surface. The test is used to measure the offset of each transducer and the reliability of the gyroscopes.

Dynatest follows a similar procedure. A stiff bar of aluminium is suspended on stirrups below the bar containing the laser beams and readings obtained for each individual laser. The aluminium bar is then raised by 25mm and the test taken again to ensure that the offset has been reduced by 25mm. This test is repeated several times to obtain measurements over the range of offsets likely to be encountered in the condition assessment profile.

Providers must calibrate devices on a regular basis (say monthly) or following replacement, reconfiguration or maintenance to the measurement bar or transducers. Records must be maintained demonstrating compliance with general NATA regulations.

4.3 Validation

It necessarily follows that even if both components and the system can be shown to provide accurate and meaningful results, the major element in the collection of pavement condition is the human element required for driving vehicles hosting equipment and for the analysis and interpretation of field results. This last task often requires a degree of “déjà vu” when comparing analytical outputs with reality. Two different results can be obtained if the start point is offset both laterally and longitudinally

4.3.1 Personnel

The technology involved in the operation and maintenance of this type of equipment and the analysis requires Engineering Assistants and Technologists that have a theoretical understanding of the equipment involved, the limitations of the outputs and the nuances of the analytical procedures. In addition they must be exceptional drivers, in order to maintain a "consistent driving line". They must maintain a high standard of fitness in order to concentrate for long hours under fatiguing conditions and be prepared to work away from home base for long periods of time.

Such persons are not widely available in the workforce, and no training programmes are available for these specialists. Once found, employers are required to pay salaries commensurate with experience to retain them.

It needs to be firmly understood that, if a client expects quality data, then providers must equip themselves with these professionals and they should not be treated lightly with respect to their ability to do the job.

Specifications need to address this level of expertise; else cheap prices with shoddy results will result.

Our experience is that the best operators are recently graduated engineers, or two year trained Engineering Officers, within the definitions of Engineers Australia or IPENZ. Two years is the limit of their endurance in the position, but in that time they will survey and analyse between 10,000 km and 30,000 km of pavements.

One experienced Officer should always be placed with one in training.

Under these circumstances, the choice of validation procedure should recognise the skill and professionalism required for operators be outcome directed rather than recipe specific.

4.3.2 Systems

Today all major systems provide the capability for measurement of all three surface parameters. Providing it has been established that distance measurement transducers can resolve distances to the required accuracy, then it remains only to verify that the system (including driver and operator) can determine the condition of the surface apparent to the average motorist.

4.3.2.1 Validation of Roughness Devices

There are two major methods for calibration of profilometer devices in Australasia, that by Transit New Zealand and that adopted by State Road Authorities in Australia, based on the RTA (NSW) test track or "race track" as it is affectionately known.

4.3.2.1.1 The Transit NZ Method

The Transit NZ method requires accurate measurement of a road profile, both longitudinally and transversely using an ARRB –TR walking profilometer or Face Dipstick to measure changes in elevation. This data (around 1500 readings for a 500m test section is then fed into the University of Michigan Transportation Research Institute (UMTRI) software in order to obtain the "true" roughness profile for the calibration section.

Rut Depth is determined by conducting the same manual survey transversely to the direction of traffic, every twenty-five metres.

Mean Profile Depth is determined transversely using a single, high-resolution laser beam.

Five sites demonstrating a range of roughness, rut depth and texture are then selected, and the System is required to survey these sites a number of times.

The survey equipment is validated when:

?? The spectral analysis demonstrates the equipment is able to measure over the wave length range of 0.25m – 100m; and

?? The difference in the mean roughness between any combination of two different survey speeds is less than 0.2IRI for any segment; and

?? **A** is within the range 0.9 and 1.1 for each validation section and within the range 0.98 and 1.02 for all validation sections for each combined; and

?? The 95% confidence interval of **A** passes through 1.0 for each validation section; and

?? **B** is within ? 0. 5 m/km for all validation sections and within ? 0.05m/km for all validation sections for each speed combined; and

?? The 95% confidence interval of **B** passes through 0.0 for each validation section; and

?? The r^2 correlation is at least 0.90 between the data sets for each validation section, and at least 0.975 for all validation sections for each speed combined; and

?? **S_n%** is not greater than 5% of the mean, **X_n**, for each series of five repeat measurements on each 100m segment; and

?? The r^2 correlation is at least 0.95 for the five individual roughness values on each 100m segment regresses against the mean 100m segment value; and

?? BE_n% is not greater than 2.5% for each value of n from 1 to 5, within the validation section.

Where:

A = regression equation slope.
B= regression equation intercept.

S_n% is the coefficient of variation (%)

BE_n % is the bias error as the average of the errors from many measurements throughout the survey – The calculation is provided in reference 2.

Whilst these conditions are commendable for low-volume roads, are they achievable? ; Does the end justify the associated cost?

Wavelength filtering creates a division of opinion, which must be resolved, before calibration commences. We do not understand the impact of this filtering process on the actual roughness.

Even once the “true“ roughness for calibration sites is agreed upon the difficulty of measuring the roughness profile adds dimension to the accuracy including.

?? Driving style of operators. -It is difficult to get two drivers that will drive the same driveline each time.
?? Locating the exact “start line” on the pavement is difficult - given that even at 50kph the vehicle is travelling at 14m per sec, the operator must recognise the start line, and trigger data collection in 0.07 seconds to be within + or - 0.5m of the start line.

- Road Geometry is an issue - Does one select a test site that is straight and flat with little or no cross fall, where it is easy to obtain repeatability of results, or does one chose sites representative of the road geomorphology, where road conditions make it difficult to obtain repeatability between the same driver, let alone between drivers.

A full calibration of equipment, drivers and operators, by this procedure costs around $50,000 annually. This cost must be amortised over the cost of data collection with many providers ignoring the requirement.

4.3.2.1.2 The RTA (NSW) Method

For this validation procedure, a provider must survey five times a circuit of around thirty km of pavement varying from an old surface, with tight curves (< 40kph) and variable cross fall to a section of freeway with multiple lanes. Both members of the team are required to be able to survey individual sections to within 5% of the average values obtained by the RTA over many years, many devices and a multitude of drivers and operators.

Other State Road Authorities not only insist that Drivers and Operators pass the RTA test ground but also require the same people to pass a "local test ground"

5 Sources of Error

5.1 Roughness

The International Roughness Index (IRI) is calculated using the following steps (Ref 5):

"*The measured profile is filtered with a 250mm low-pass moving average filter*
The filtered profile is then filtered using a quarter-car model
The magnitude of the displacement between the sprung mass (the simulated quarter-car's body) and the unsprung mass (the simulated quarter-car's axle) in the quarter-car is summed.
The sum is normalised by the length of the profile.
Values of IRI are usually quoted in mm/m or identically m/km."

The Forum of European National Highway Research Laboratories (FEHRL) Technical Note 2000/X "Theoretical Comparison of Indices" (Ref 5) lists some twelve criteria that impact on the computation of the International Roughness Index (IRI). To that we must include the Truck Index proposed by VicRoads at the recent Sixth International Conference on Managing Roads – Brisbane 2004 (Ref 6), as being a viable roughness parameter.

Clearly each one of these steps carries with it an opportunity for error. Averaging processes have an intuitive understanding that 50% of values lie above the "average" and 50% of values lie below the average.

Fortunately Austroads (Ref 4) has investigated the criteria, and in the face of learned argument to the contrary we should, as practitioners, accept the guide as it stands, complete with errors and the associated risks.

For these several reasons the concepts proposed in section 2.1 and 2.2 above are highly recommended to accommodate this inherent risk in the results.

5.2 Rutting

The FEHRL document (Ref 5) examines “The Influence of Errors on Transverse Indices” inherent in the measurement of Transverse Profile (or rut depth). There are five major sources of error, especially applicable to low-volume roads.

These include (but are not limited to):

The type of non contact transducer – for example the large “sound spot” associated with acoustic transducers compared with the very small “light spot” provided by laser transducers can create large differences on heavily rutted or distorted roads.

The definition of a rut will produce differences in values Figure (2) from reference 5 indicates some possible definitions, whilst the choice of perpendicular from the taut wire, string line etc adds to the confusion

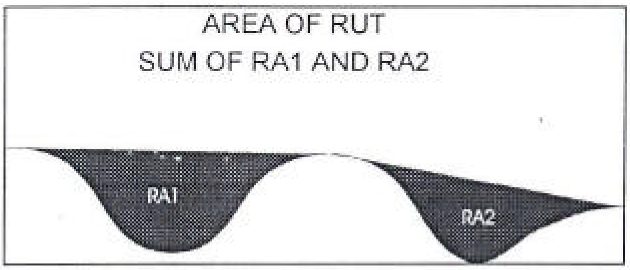


Figure 1 Definition of area of rut.

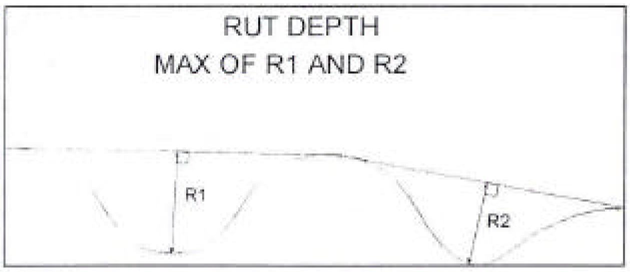


Figure 2 Definition of rut depths

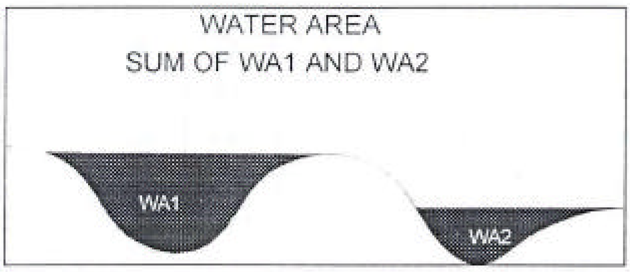


Figure 3 Definition of water area.

The provisional Austroads document (Ref 3) is currently out for public comment and has some limitations with respect to the number of choices available. These should be rationalised (vide section 3.2.1 above). Once ratified, practitioners should accept the document as the benchmark subject to learned comment once the methodology is tested in practice.

The number of transducers is an important consideration in rut depth measurement, causing as much as a 5mm difference in an overall rut depth of 14mm (36%) between 5 and 27-measurement points- see Figure 4 from reference 5.

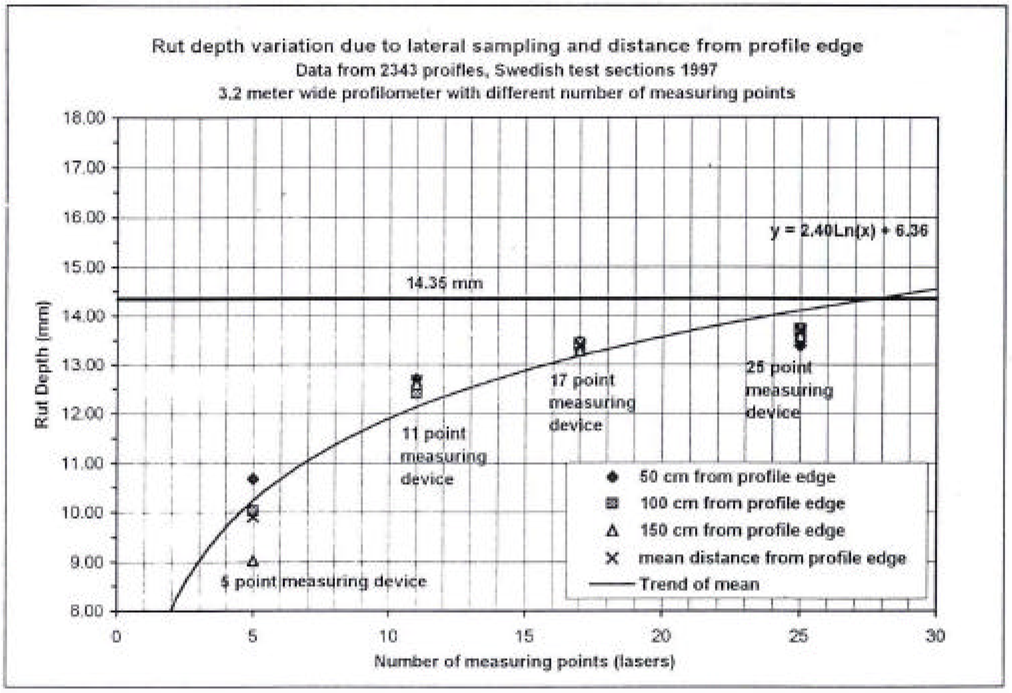


Figure 4 The effect of number of measurement points on obtained rut depth.

Given that each additional laser adds around $25,000 AUS to the cost of measurement and that additional cost must be amortised over the cost of acquisition, then specifiers are challenged to test their accuracy of data against their needs.

The driveline and sampling distance influence the reliability of results. As practitioners we are frequently posed the rhetorical question, “the rut depth for this section (or road) has decreased by 2mm and nothing has been done to it”. What is wrong with your results?

Figure 5 (reproduced from Reference 5) shows how the extremes of driveline (in this case 400mm) can produce a rut depth difference of 2mm in 5 (40%) under a 3m sampling width. This will of course be multiplied if we choose to evaluate the same section of road under a 2m straight edge as the “wheel path“ rut depth.

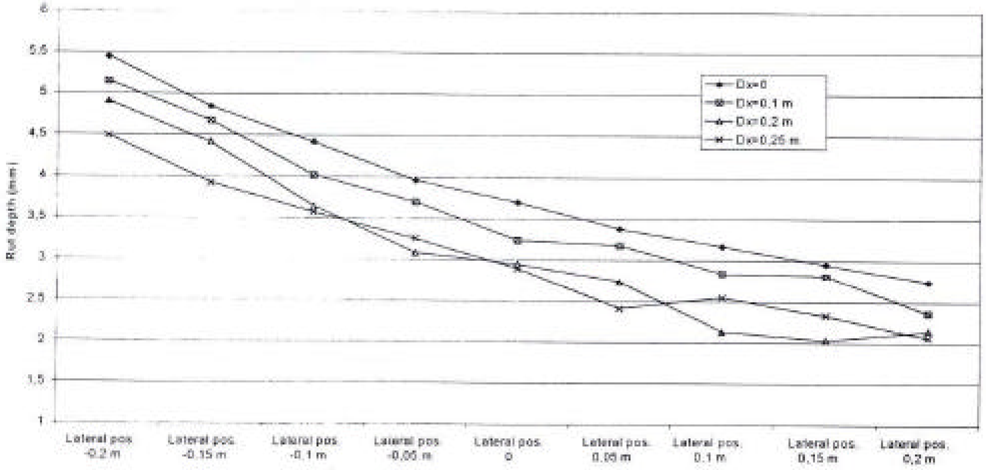


Figure 5 Effect on rut depth in left wheel track when varying lateral position and transverse sampling interval Dx. Negative lateral position values means a deviation to the left. Measurement width 3 m.

The concept of characteristic value is one method that has proven to be effective with Performance Specified Maintenance Contracts where the key requirement is that aquaplaning must be minimised at critical locations.

A proven method is to compute rut depth for the section using the standard deviation (as the spread of results) to account for rutting anomalies. If the “characteristic value” exceeds some predetermined “cut off” say 30mm, the data is reproduced at say 1m intervals, graphed against distance and any anomalies inspected for the cause before any works programming is considered.

5.3 Texture

The accuracy of texture depth has a similar problem of specifying an answer that cannot be achieved, and then condemning the practice. It is quite clear from the fundamental wave theory ? = n?.

Where:

? = the velocity of collection,
n = the wave frequency and
? = the wavelength

That we cannot measure the Macro-texture at highway speeds with conventional 16Khz lasers let alone acoustic transducers. International “wisdom” tells us that to produce 0.1mm accuracy at highway speeds, the frequency of the collecting device needs to be at least 64KHz.

When comparing results with the “sand patch” method, we must ask ourselves, “How accurate is the sand patch method? How sure are we that the results from this procedure are ? 0.1mm? What are we going to do with the results?”.

If the number of transducers, sampling distance and driveline have an impact on rut depth measurements of around 40% what is the likelihood of Mean Profile Depth (MPD) being any more accurate? Yet as the result of either procedure, we will make judgement on the quantity of bitumen in a spray seal, in an environment of loss of surface texture due to uncontrolled “bleeding”.

As with rutting the concept of “characteristic value” has been effective when dealing with this parameter.

6 Let’s be practical!

6.1 Modernise Procedures

It has already been stated that we should expunge, old and tired procedures from the methodology, providing only a means for translating former procedures to the modern terminology.

6.2 Proposal for Validation of Profile Devices

We must consider this requirement in the light of the three levels of profile investigation Roughness, Rut Depth and Macro-texture. Methods have been provided (above) for providing comfort that the components will measure with reasonable accuracy the offsets from a planar surface that can be used in the analytical process to obtain the measurement parameters. This must be the first step in any validation procedure.

The next duty is to be certain that the system (equipment, host vehicle and driver) can provide accurate and reproducible results at a reasonable cost. For this purpose the RTA (NSW) method is highly recommended.

6.3 Analysis and Reporting

6.3.1 Roughness

6.3.1.1 Analysis

Roughness should be computed at intervals such that there is between 5 and 12 intervals for a pavement management section –vide, Table 3. The mean and standard deviation of the results to be calculated with the characteristic value computed as:

Characteristic Value = ? + f.?

Where:

? Is the population mean
? Is the standard deviation of the population and
f is given by: Table 1

6.3.1.2 Reporting

Let’s be realistic and only demand an accuracy that is meaningful. Let me suggest for debate:

Reporting values for IRI should be:

0.1IRI for values less than 2 IRI,
0.2 for values or IRI from 2 to 4.2, and
integer values for IRI >4.2

6.3.2 Rutting

6.3.2.1 Analysis

Rutting should be computed at intervals such that there is between 5 and 12 intervals for a pavement management section-vide, Table 3. The mean and standard deviation of the results to be calculated with the characteristic value computed as:

Characteristic Value = ? + f.?

Where:
? Is the population mean
? Is the standard deviation of the population and
f is given by: Table 1

6.3.2.2 Reporting

Rut depth should be reported as:

- Less than 10mm to the nearest 1mm - (*there is very little chance that we will do anything about a characteristic rut depth of 10mm or less*),
- 10 to 20mm the nearest 2mm – (*again in only the most extreme circumstances such as approached to traffic light and pedestrian crossings would pavement managers adopt intervention practices for a characteristic value for rutting in this range*),
- More than 20mm – the nearest 5mm –(c*haracteristic values in this range demand further investigation at the Project Level – Level 3 above*)

6.3.3 Texture Depth

6.3.3.1 Analysis

Texture depth should be computed at intervals such that there is between 5 and 12 intervals for a pavement management section-vide, Table 3. The mean and standard deviation of the results to be calculated with the characteristic value computed as:

Characteristic Value = ? - f.? (note the - sign - the worst case scenario)

Where:
? Is the population mean
? Is the standard deviation of the population and
f is given by: Table 1

6.3.3.2 Reporting

Where high frequency lasers are used for measurement of Mean Profile Depth (MPD) the following levels of reporting for the characteristic value are proposed for debate:

- Less than 0.7mm should be reported to 0.1mm
- Greater than 0.7mm should be reported to 0.2mm

7 Conclusion

1. Two approaches to analysis of profile data have been discussed, the concept of characteristic value whereby the level of risk appropriate, the usage is recognised.

2. This conference is about low-volume roads so do we really need to be 99.5% sure that all possible results are included in our analysis.

3. The second concept of level of service is also important. There is little point hiring a high speed, calibrated, validated device operated by specialist engineers, if you only want to rank one road against the next.

4. Your format must follow your function

8 References

1. Austroads 2004, *"A guide to the Structural design of Roads"*.

2. World bank Technical Paper Number 46, "*Guidelines for conducting and Calibrating Road Roughness Measurements",* Sayers, M.W, Gillespie, T.D. , Paterson, W.D.O.- 1986

3. Austroads DRAFT November 2004, *"Guidelines for Road Network condition monitoring* - , *Part 2 Pavement Rutting"*

4. Austroads November 2002, "*Guidelines for Road Condition Monitoring _ Part 1 Roughness"*

5. Forum of European National Highway Research Laboratories (FEHRL) – Technical Note 2000/X , *"Theoretical Comparison of Indices"*

6. Russel K, Non scheduled presentation ICMP6, *"Heavy Articulated Truck Ride Index"*