Providers of Innovative Technology for Measuring and Managing Roads.

ROMDAS

Laser Crack Measurement System (LCMS)

Technical Overview

Pavemetrics

Manufactured by Data Collection Ltd, a Moog Inc. company

8C Bentinck Street, New Lynn, Auckland 0600, New Zealand.

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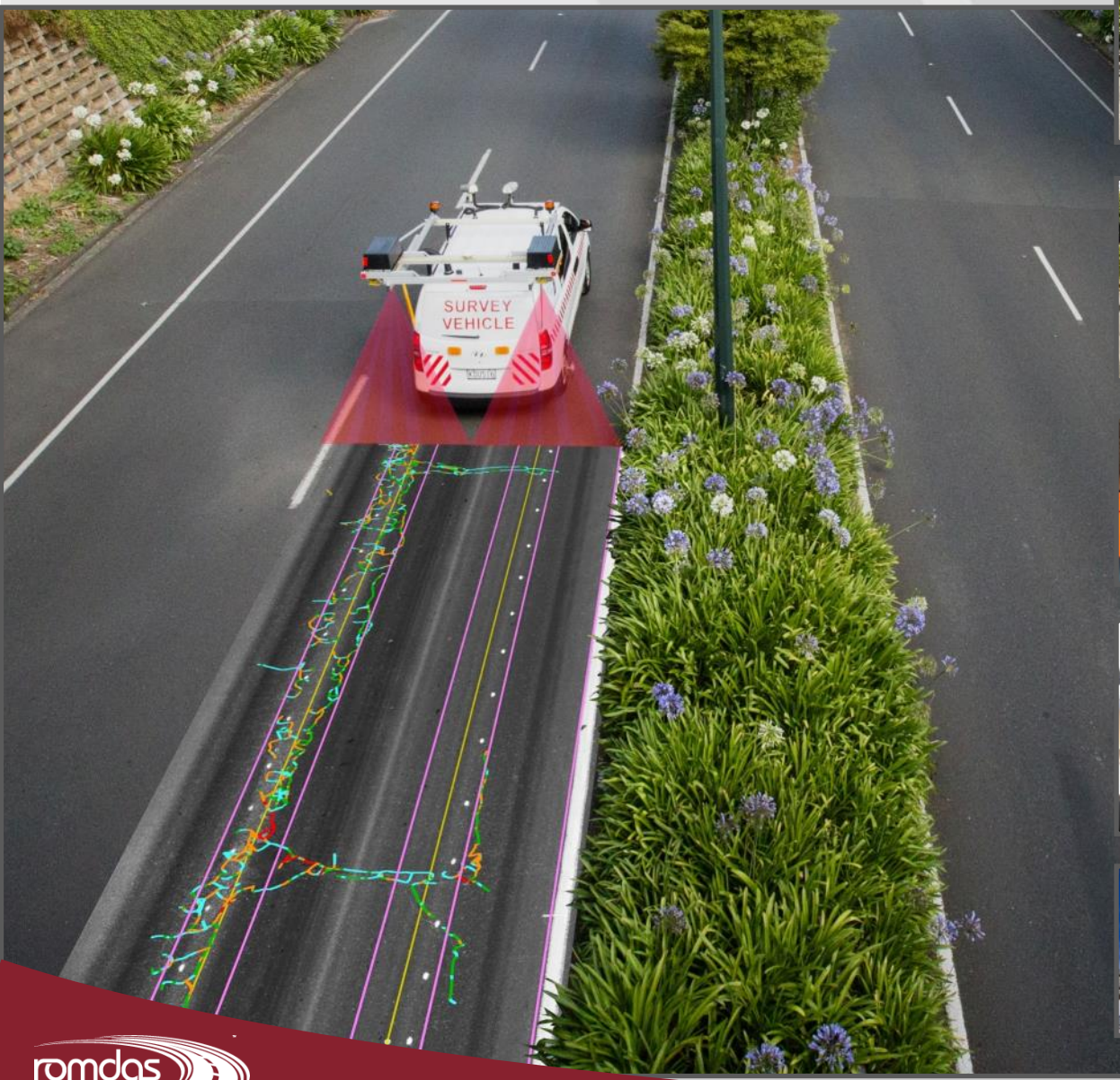
The Basics...

The ROMDAS LCMS module is one of the most advanced tools for recording pavement condition. The vehicle mounted LCMS module is connected to a central ROMDAS system and controlled by the ROMDAS Acquisition Software. Utilising 3D scanning lasers from Pavemetrics™ and advanced processing algorithms, the LCMS acquires high resolution road profiles and automatically detects cracking, macrotexture, potholes, rutting, ravelling and other surface defects.

The LCMS operates at normal highway speeds, making it an efficient option to collect data across an entire road network. It comes with custom optics and laser line projectors that allow it to operate unaffected by ambient light, capturing data in day or night-time condition. LCMS is fast becoming the benchmark for pavement surveying around the world and providing the detailed condition data needed for managing modern road networks.

3D PAVEMENT PROFILING

The simplest way of understanding how LCMS works is to break it's functionality into 2 stages, 1) collecting 3D profiles, and 2) analyse the profiles to extract surface defects. While this process might be similar for other 3D scanning systems in the market, LCMS offers unmatched performance during both stages which allow for a wider variety of defects to be automatically identified.



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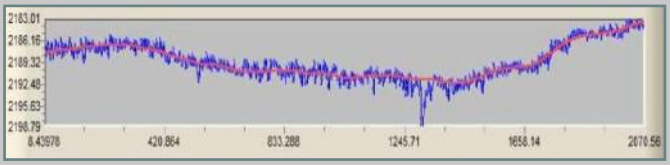
The Way It Works

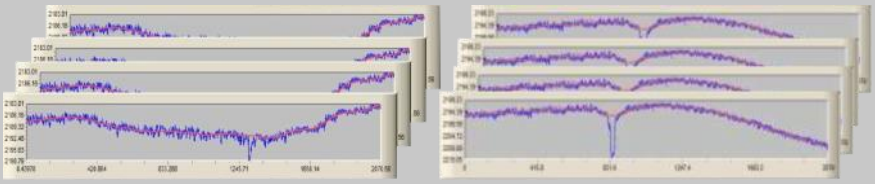
Stage 1: Collect 3D Pavement Profiles

1 A ROMDAS system surveys the road at normal highway speeds, while the LCMS module scans the road surface,

2 It measures +4,000 points across a 4m wide transverse profile. This means a transverse resolution of <1mm.

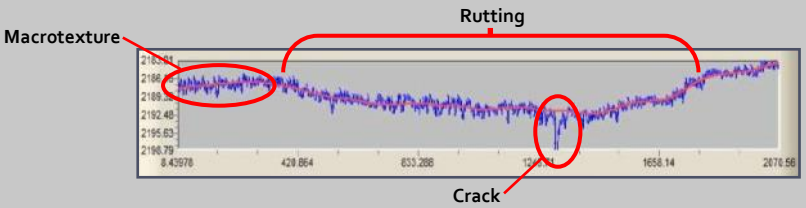


3 Collecting 5,600—28,000 transverse profiles/sec means a profile is recorded every 1-5 mm when travelling at 100km/hr. The transverse profiles are then compiled to create high-resolution 3D profile of the road surface.

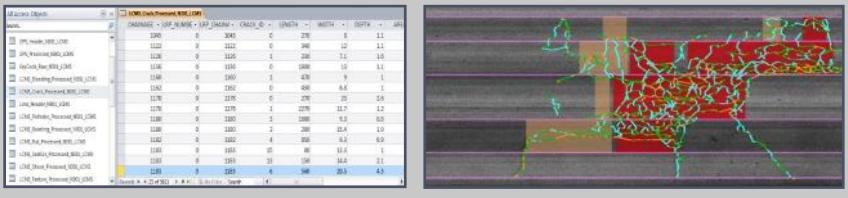


Stage 2: Analyse 3D Profiles to Identify Surface Defects

4 The ROMDAS software uses advanced algorithms to filter and identify patterns which correlate to a wide variety of pavement defects. Including the ability to assess the size, depth, area and severity of specific defects.



5 A full list of defects is created, allowing for detailed analysis and reporting, as well as pavement images with defects automatically displayed.



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Specifications and Type of Data Collected

Due to its exceptionally accurate scans and analysis algorithms, LCMS is able to identify more types of pavement condition from it's 3D profiles than any other road scanning system. The current list of outputs includes the following, however, new algorithms are regularly developed to refine and expand the list of these defects .

TECHNICAL SPECIFICATIONS

Scanning Frequency	28,000 Hz (profiles per second)
Vertical Resolution	+/- 0.10 mm
Laser Type Classification	Class 4
Laser Safety Classification (Complete system)	Class 1 (as defined in IEC 60825-1:2014)
Transverse Range	4m nominal (4160 points per profile)
Environmental Protection	IP-65 (NEMA-4)
Power Consumption	150 Watts (240VAC)
Output File Format	Microsoft Access Files, JPEG image files

STANDARD OUTPUTS

Cracking	Location, width, depth, length, area, severity, classification
Sealed Cracks	Location, length.
Rutting & Transverse Profiles	Rut depth, width, type and cross-sectional area summarized over user-defined intervals.
Macrotexture	Mean Profile Depth (MPD), Estimated Texture Depth (ETD), Sand Circle Diameter (SCD), Digital Sand Patch
Raveling	Raveling Index (RI), percentage, area.
Bleeding	Bleeding Index (BI), bleeding severity.
Shoving	Location, shove height, shove width.
Pothole	Location, area, depth, width
Concrete Joints & Faulting	Location, length, height
Lane Width	Width (requires the presence of outside lane markings)
Lane Markings	Right and left lane positions, width, length
Curbs, shoulders & Drop-Offs	Position, interval, height
Manhole covers, Storm Drains	Radius in meters (closed or drain type); size of storm drains—inside and outside of lane marking
Roughness	Longitudinal profile, Roughness (IRI) *(Optional Upgrade Required)*
Geometry	Cross Slope, Gradient, Radius of Curvature *(Optional Upgrade Required)*
Pavement Condition Index (PCI)	LCMS automatically outputs some of the PCI distresses mentioned above. Some of the other distress can be measured using the ROMDAS cameras and video rating functionality. DataView post-processing software allows users to measure additional visual distresses from the images.
Pavement Images	JPEG images of the pavement surface with defects automatically overlaid. Images are unaffected by lighting

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Compliance: Industry Standards

While some industry standards were written specifically for traditional technologies, the LCMS has been designed to comply wth many of the established industry standards. The LCMS simultaneously offers many benefits and performance above the specificationsof most existing standards.

ASTM

ASTM E950	Can collect longitudinal profile and compute IRI with the precision and bias of a Class 1 Profiler
ASTM E965	Can collect macro texture and compute MTD
ASTM E1703	Can compute rutting according to standard
ASTM E1845	Can collect macro texture and compute MPD
ASTM E1926	Can compute IRI from longitudinal profile according to standard
ASTM D5340	Can be used for airport condition index surveys
ASTM D6433	Can be used for Roads and parking lot pavement condition index surveys

AASHTO

AASHTO PP67	Can quantify cracking (location, orientation, width, but not "type")
AASHTO PP68	Can collect images of pavement surfaces
AASHTO PP69	Can determine pavement deformations
AASHTO PP70	Can collect transverse profiles
AASHTO R56	Can collect longitudinal profile based on inertial reference system
AASHTO R85	Can quantify network level automatic cracking distress
AASHTO R86	Can automatically collect images to detect road distress

OTHERS

LCPC Methode d'essai No 46	Can measure longitudinal profile of road and airport pavements
NCAT Profiler	Can accurately and repeatedly measure longitudinal profiles
AIE C60825-1:2014	End system complies with Laser Safety Class 1
AUSTROADS Guidelines	Where applicable

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ROMDAS With LCMS

With the ROMDAS LCMS module, combine the power of hardware and software, on a single vehicle. ROMDAS has a flexible approach allowing you to upgrade your system at any point, customise reports and extract more from the raw data collected.

Custom reporting & data formatting

Every country has different requirements and follow different standards, often follow unique classifications for defects like cracking, ravelling, rutting, etc.

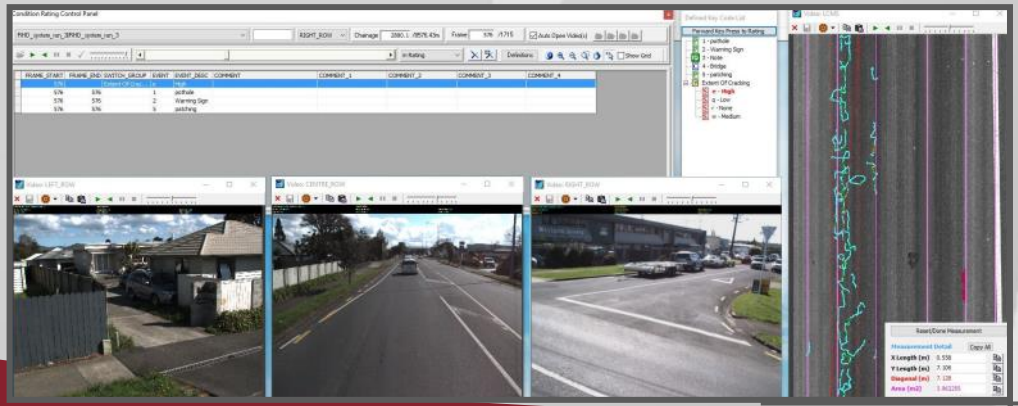
Unlike some manufacturers, who offer a 'one-size-fits-all' data structure, ROMDAS works closely with users to create custom report templates and data formats to match local requirements. Thanks to our non-proprietary data formats, ROMDAS data can also be easily formatted and imported into existing databases. If required ROMDAS can develop processing algorithms to output your exact data structure at the touch of a button and ensure new data is comparable to your historical data.

Future proofing through scalability

ROMDAS offers a modular approach to design your own system configuration. You can choose the modules based on your requirements and budget. There is no need to install the modules at the same time. In the future when your needs expand, you can add more modules later – either in 3 months or over few years. Without establishing another full system, adding more modules can be easily achieved with ROMDAS' module philosophy.

Get even more with DataView

ROMDAS offers useful office software to assist with getting the most from of the LCMS module's data. Any visible defects not automatically extracted can be measured and recorded using DataView's video rating feature. This provides added flexibility and reduces the need for supplementary field surveys. DataView can also be used to create GIS layers for all datasets and assist with quality control thanks to it's synchronised viewing feature.



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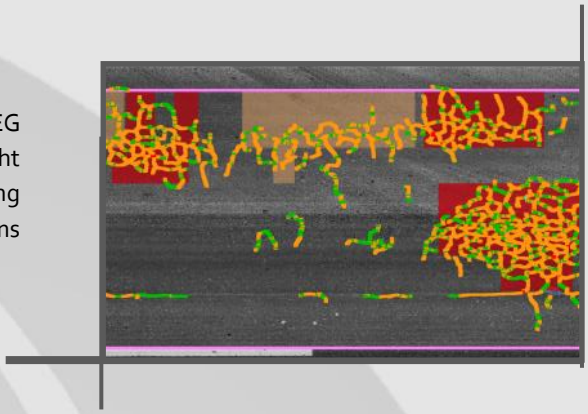
LCMS Special Features

The LCMS module sports several unique features that significantly enhances the data reliability and accuracy over other traditional laser profilers.

Laser Based Pavement Imaging

The ROMDAS software can display all LCMS detected defects on high quality JPEG images of the pavement surface. As these images are generated using laser light imagery, they are completely unaffected by ambient light conditions, ensuring perfect images even in complete darkness. While having the right lighting conditions can be quite problematic for traditional video-based systems.



Record Macrotexture across the entire lane

The high transverse resolution and scan rate means Macro texture can be calculated across the entire lane. Unlike single point lasers which only provide a thin line of texture data, the LCMS reports a variety of Macrotexture indices, including MPD, ETD and MTD, as well as other useful texture related properties like Bleeding and Road Porosity Index (RPI). Data is reported in 5 configurable bands compliant with AASHTO standards. The bands are: central band, two wheel path bands, and two outside bands.

If comparing to historical data from single point laser profilers the 2 wheel path bands can be reduced to a few mm in width and output results similar to traditional systems.

Lane Tracking: Minimising driver influence and vehicle wander

A key advantage of using LCMS is it's ability to identify lane markings due to its 4000+ laser points. This is particularly helpful for datasets that need to be referenced to the lane markings and kerb positions instead of the vehicle's transverse or longitudinal position travelled, which will vary from year to year.

Conventionally, for example, a front mounted rut bar unit is fixed at bumper height and uses only single point lasers. In theory, the driver is expected to always drive within the wheel-paths. But this is highly impractical as the driver will always wander away from the wheel-paths at some point (e.g. to avoid potholes or obstacles, or just going around a corner). The rut-bar system has no way of recognising whether the driver is driving in or outside the wheel-paths. This can influence the quality of transverse profiles and greatly affect the quality of the Longitudinal profile (Roughness). The LCMS' 'lane tracking' capabilities will eliminate this data variability, which would otherwise be practically impossible to mitigate.

The LCMS with it's Roughness Upgrade, in combination of using this unique feature, will collect highly accurate longitudinal profiles to calculate wheel-path and lane roughness (IR). The lane tracking feature can be used for macrotexture measurements and rutting scan width as well.

Classic system: Results depend on the trajectory of the vehicle (subject to variation based on driver's ability)

LCMS-IRI system: Erratic trajectory of the vehicle will still result in straight elevation profiles

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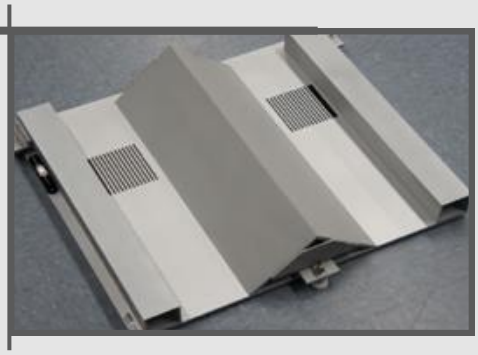
LCMS Special Features

Roof Mounted Equipment

As the LCMS sensors are mounted 2.2m above ground and only extend marginally beyond the edge of the vehicle, it is less vulnerable to accident and damage. Traditional multipoint Laser rut bars which are usually mounted around 300mm high, are exposed to potential damage from other traffic and obstacles. Our mounting system can be installed on almost any van for 4WD and its designed to be exceptionally rugged.

Validation Tool & Calibrations



The *LCMS Validation Tool* uses a calibrated pyramidal object along with a test software to validate the calibration of the Sensors. The validation includes:

- Range validation: Verifies the sensor alignment in order to make sure that calibration tables (.ltx and .ltz files) are still valid.
- Focus Validation: Assesses the sensors optical quality

These tests will be carried out on a regular basis and will alert the operator to any anomalies well before they start to affect the accuracy of the data. This ability to verify the system calibration to such accuracy in the field is a huge step forward in terms of ensuring the quality of the data.

Optional Upgrades

Roughness (IRI)

The LCMS Roughness upgrade uses a full 6 degrees of freedom IMU with 3 axis accelerometers and3 axis gyroscopes accurately measuring the tilt, roll and cornering. With this you receive a much accurate longitudinal profile and IRI values. Using the Lane tracking capability, the LCMS is able to position roughness profiles and improve repeatability. Lane tracking also allows you to adjust the position of the roughness profile post survey and then reprocess it.

Curvature, Grade and Cross fall Option

With this option, the Inertial Measurement Units (IMUs) allow for the calculation of Longitudinal Grade, Horizontal Cross Fall (cross slope), Super Elevation and Radius of Curvature.

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Optional Upgrades

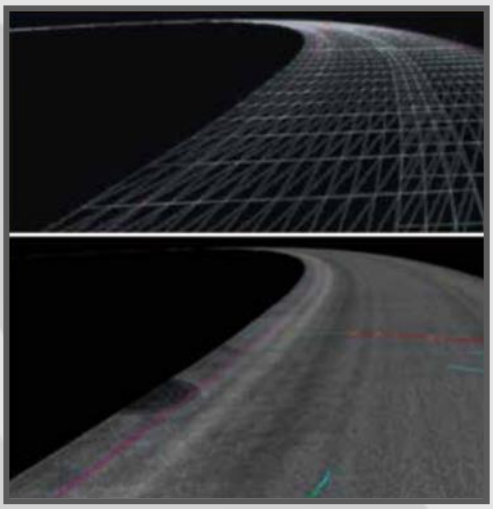
LCMS' unmatched resolution means it can collect data which can't be obtained by many other so-called 3D profilers. The LCMS technology can be expanded for 3D mapping of road surfaces and collect data for object detection for airports .

Laser Digital Terrain Mapping System (LDTM)

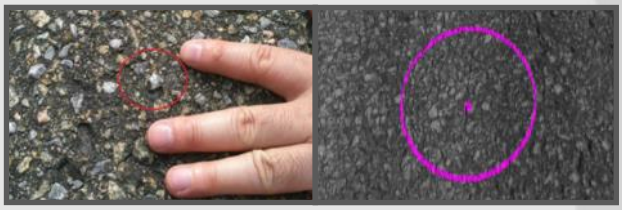
The Laser Digital Terrain Mapping (LDTM) module upgrade leverages the prolific LCMS technology to acquire high resolution and high accuracy 3D profiles of the road surfaces in real-time.

With this upgrade, the LCMS system is capable of automatically generating break lines and detect lane markings, road edges, curbs, measure drop-off of unpaved shoulders, road profile, curvature, slope and cross-fall. Both 2D image and 3D data are simultaneously acquired at a rate of up to 45 million points per second. These images and data are seamlessly merged together into a high accuracy digital terrain map.

The LDTM data of 1 mm resolution can be imported as .LAS and Bentley MicroStation formatted files for easy use and analysis.



Laser Foreign Object Detection (LFOD)



Loose aggregate, normally invisible to other systems, detected by LFOD at

Unaffected by FOD colours or material type

The Laser Foreign Object Debris (LFOD) detection module upgrade uses the dynamic LCMS technology to acquire high resolution 3D profiles of airport runways, taxiways and aprons to detect even the smallest objects at highway speeds.

With this upgrade, the LCMS module is capable of automatically detect objects as small as 2mm and trigger pre-set alarms upon detection of specific FOD sizes or volumes. It can also accurately geo-reference detected debris within a scanning width of 12 to 18m per pass. The system can be used with a GPS display to offer a visual guidance for the detected FOD.

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Manual Condition Inspections Vs LCMS

Network level surveys are significant projects, often covering thousands of lane km. This is part of the reason why manual inspections, especially for pavement defects like cracking, are only performed on small samples sections across a network. While manual site inspections were the only option for many to record surface defects, there is no dispute they are extremely time-consuming, costly and often subjective, which makes timely and informed decisions about road maintenance difficult. Manual inspections are also difficult to quality-control, usually requiring additional site visits.

The LCMS addresses these problems by;

- Collecting condition data at high-speed across the entire network. This promotes an accurate understanding of the true network condition.
- It's objective and repeatable, removing the subjective influence between inspectors,
- Pavement images and DataView's Synchronised Viewing allow for quick office-based quality control,

With these limitations overcome, cracking and other defects can now be surveyed across an entire network, leading to quantifiable and more informed decision-making about maintenance and budgeting.

Auckland University's Dr Henning and Mia compared automatic crack detection from the LCMS against manual visual inspections (called RAMM inspections in NZ), and below summarises the results.

DID WE GET WHAT WE WANTED? – GETTING RID OF MANUAL CONDITION SURVEYS

Theunis F.P. Henning and Mohammad N.U. Mia

"*CONCLUSIONS AND RECOMMENDATIONS :*

This research has compared the survey accuracy of the [ROMDAS] laser scanning automated crack detection (LCMS) to accurate LTPP survey data and to RAMM survey data on a network length. These comparisons were ultimately assessed on the basis of earlier findings of inaccuracies identified with the RAMM surveys (Tapper et. al., 2013) The outcome of the research suggested the following:

- *There was a strong correlation between the LCMS and the LTPP cracking data;*
- *The comparison with RAMM network survey data suggested that more than 60% of crack lengths are missed according to the 10% sampling length used for the RAMM surveys.*

On the basis of this research, it is recommended that authorities in New Zealand should give strong consideration of using the automated crack detection. It also illustrated that the accuracy of the RAMM survey data nullifies its value for any trend monitoring and or performance specifications. It is simply not accurate enough. "

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LCMS vs Traditional Rut Bar Units

Principle of Calculating Rutting Data from Transverse Profiles

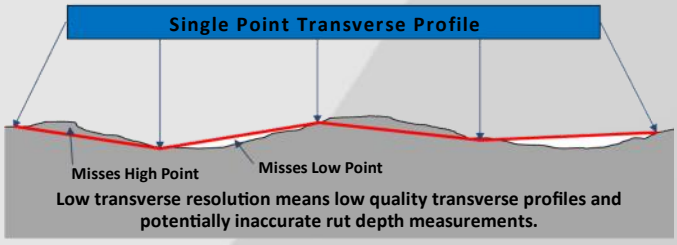
When collecting transverse profiles (i.e. profiles across the lane width), it is important to note that the number of data points per transverse profile has a significant affect on the calculation of rut depths. If the number of points (i.e. resolution) are low, it can potentially miss peaks and troughs in the transverse profile, causing rutting to be underestimated. Essentially, more data points mean more accurate profiles, which means more accurate rutting data.

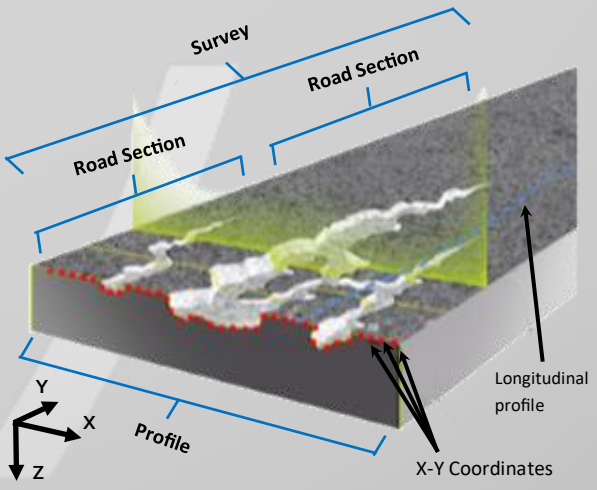
Traditional Rut Bar

- Rut Bar units use "single point" lasers mounted in a large unit on the front of the vehicle.
- It is based on the principle of collecting multiple 'longitudinal' profiles referencing them to high accuracy distance data.
- The software then estimates the 'transverse' profile across the lane width.
- The disadvantage of rut bars is that the distance between each laser is around 200mm and the accuracy of the lasers can be low.
- The larger the gap between the contact points, easier to miss the peaks and lows of pavement.

LCMS

- The scanning lasers in the LCMS module records over 4,000 points per transverse profile (compared with the 5-17 points of Rut Bar units). This contributes to very high accuracy rut depth information.
- The high-resolution profiles also enable the calculation for Rut Width, Type and Cross-sectional Area.
- The LCMS has the capability to exclude curbs which presents higher accuracy rut measurements compared to traditional and other laser based rutting equipment.
- Provides datasets not achievable with traditional Rut Bar units.





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LCMS vs Defect detection from 2D Cameras

Principle of Detecting Cracking from Shadows

Low resolution scanners often use 2D cameras and are supplemented with software algorithms. The algorithm detects pavement markings and takes that as a reference line to detect cracks within that travel lane. The software is programmed to consider 'dark pixels' as cracks; these are basically shadows casted by the light sensors. These dark pixels, however, can also 'appear' due to shading from overhead power lines, or as stains on pavement surface. In contrast, the algorithm may not detect some cracks as they are too narrow or toowide to cast shadows to calculate cracks. Or the shadows are not aligned to the light sensors of the scanners missing the cracks altogether. This can create false negatives and positives, and cannot achieve accurate depth measurements.

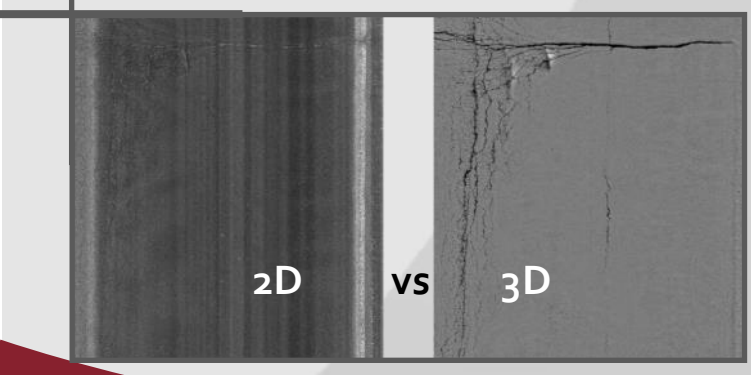
LCMS' high resolution and scanning frequency along with it's 3D algorithm creates accurate pavement models with the ability to detect and isolate cracking and other surface defects to improve reporting.

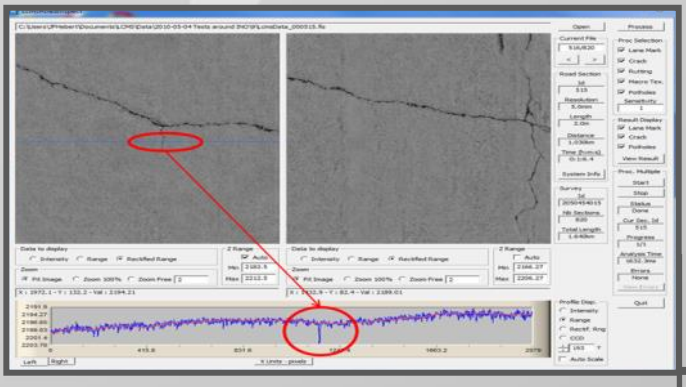
Low resolution and frequency of 2D scanners

- Most scanning laser systems on the market use lower transverse resolution (e.g. 1000 points per profile), and scan frequency (e.g. 800 profiles per second).
- Due to the large gap between two points and the use of 'dark pixels' principle, it can incorrectly identify to detect normal cracks and unsealed cracks.
- Some systems will supplement their 3D scanners with 2D cameras and software to identify visible defects.
- The lower resolution and scan frequency make most systems to be able to calculate rutting data from these 3D profile. But this can also be achieved by a bumper-mounted Transverse Profile Logger (TPL).

LCMS detects depths and sealed cracking accurately

- LCMS' 3D algorithms create accurate pavement models and you can see the appearance of a suspected crack.
- The LCMS module can also report the crack's true length, width and depth using this 3D data.
- LCMS uses crack depth as one of the parameters and allows to create separate reports for sealed and unsealed cracks.
- The 3D profile data makes a significant and practical difference in crack detection results with less missed cracks and less false positives included. This brings high accuracy to reporting and analysis.





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