



9th International Conference on **MANAGING PAVEMENT ASSETS (ICMPA9)**

Automated Pavement Condition Assessment Using Laser Crack Measurement System (LCMS) on Airfield Pavements in Ireland.

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QUESTIONS:

With airfield pavements subject to increased traffic levels;

- Would the use of an automated pavement data collection system such as an LCMS, be beneficial on airfield pavements?
- Could pavement condition index (PCI) surveys be completed within stringent time constraints and between flights using LCMS?

Presentation Structure

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1. INTRODUCTION

This case study details the use of Laser Crack Measurement System (LCMS) technology to establish and graphically report the pavement condition on two major runways at Dublin and Cork Airports, Ireland in 2013 & 2014.

The case study used the following 3 pavement distress identification methods used to derive a Pavement Condition Index (PCI):

- **Method 1: Manual surveys**
- **Method 2: Visual surveys using HD, pavement oriented video**
- **Method 3: Laser Crack Measurement System(LCMS)**

Pavement Distress Survey Methods

Dublin Airport

- HD Video
- LCMS

Cork Airport

- Manual
- HD Video
- LCMS

- The '*ground truth*' PCI was taken from the manual survey and both the Video PCI and the LCMS generated PCI was compared with the Manual PCI.
- The type, severity and extent of the pavement distress data were identified from the manual survey, the digital video, and using automated extraction from the LCMS 3D imagery to populate Micro-Paver to produce PCI results for both runways.

Airfield Pavement Evaluation

Traditionally, pavement distress data has been assessed and collected manually on foot and a Pavement Condition Index (PCI) determined where the:

- Pavement is examined by eye
- Distress data is measured by hand
- All distresses are logged for each sample unit
- The runway must close to air traffic

Disadvantages of Manual Airfield Pavement Surveys

- Surveys are labour intensive
- Surveys can be subjective
- Airfield PCI survey experience required
- Difficulties in making use of short time periods between flights
- Weather and light dependence
- Safety risks of having staff on airfield pavements
- Cost implications involved in airfield closure for these inspections

*Developments in automated data acquisition and image recognition techniques in recent years have allowed **automated pavement assessment using the Laser Crack Measurement System (LCMS)**.*

2. LASER CRACK MEASUREMENT SYSTEM (LCMS)



Laser Crack Measurement System (LCMS)

The automation of pavement condition surveys has developed significantly in recent years;

LCMS has been in extensive use in Ireland since 2012

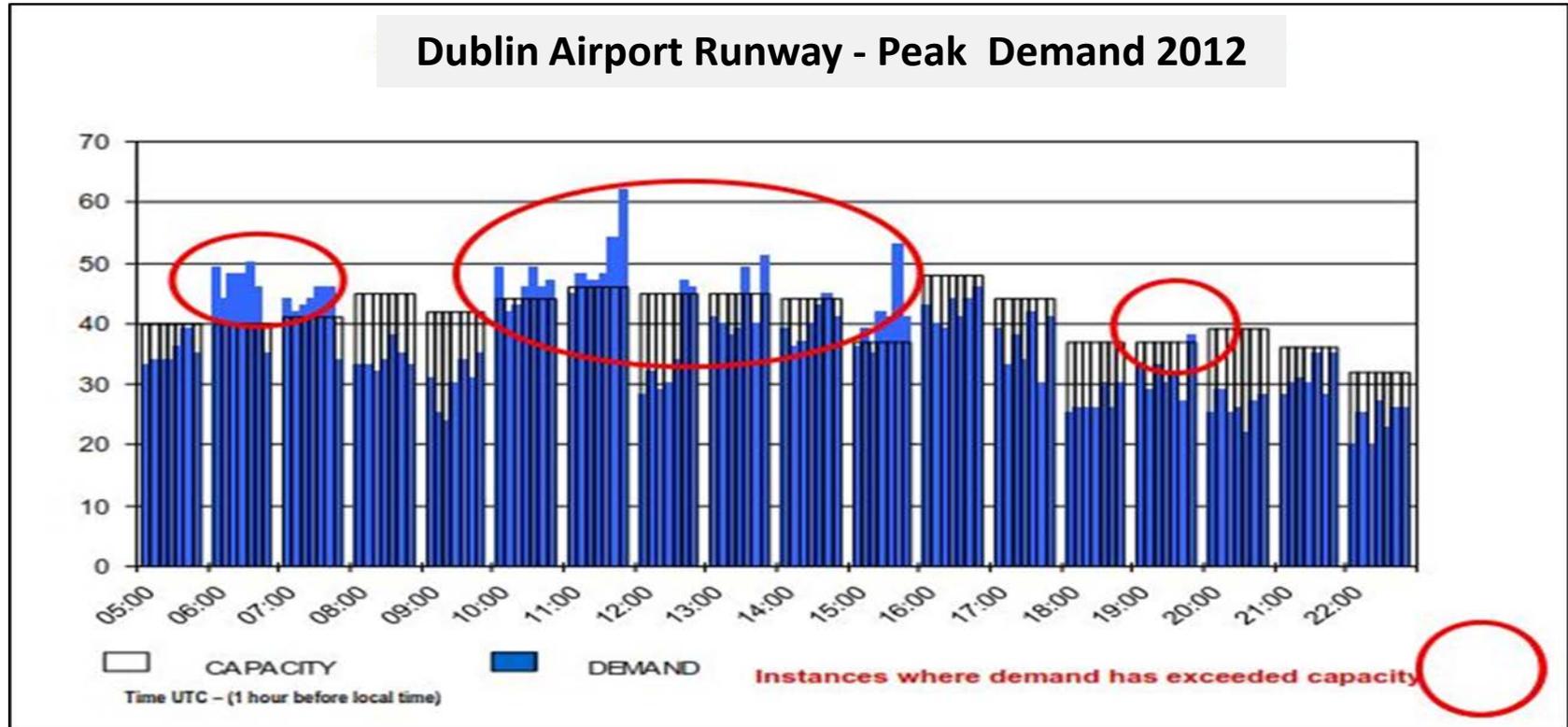
- Collection and processing of 3300 miles of Irelands National Road Network each year
- LCMS has been used by Airport authorities in Ireland to provide high speed pavement distress data and imagery for runways, taxiways and aprons since 2013/2014 on:
 - **Runway 16/34 Dublin Airport**
 - **Runway 17/35 Cork Airport**

Advantages of using LCMS to assess Airfield pavements

The use of Laser Crack Measurement Systems(LCMS) can:

- Lead to more objective identification of pavement distresses
- Hugely reduce the safety risks of having staff on the ground
- Reduces the amount of time staff must spend airside
- Collect data from the entire expanse of the runway, taxiway and apron pavements
- Reduce costly airside closures
- Allows user-friendly graphical displays of data

Capacity issues on Airfield Pavements



The use of LCMS technology allows pavement assessment to be carried out between flights and reduces airfield closure times.

3. AIRPORTS USED IN CASE STUDY

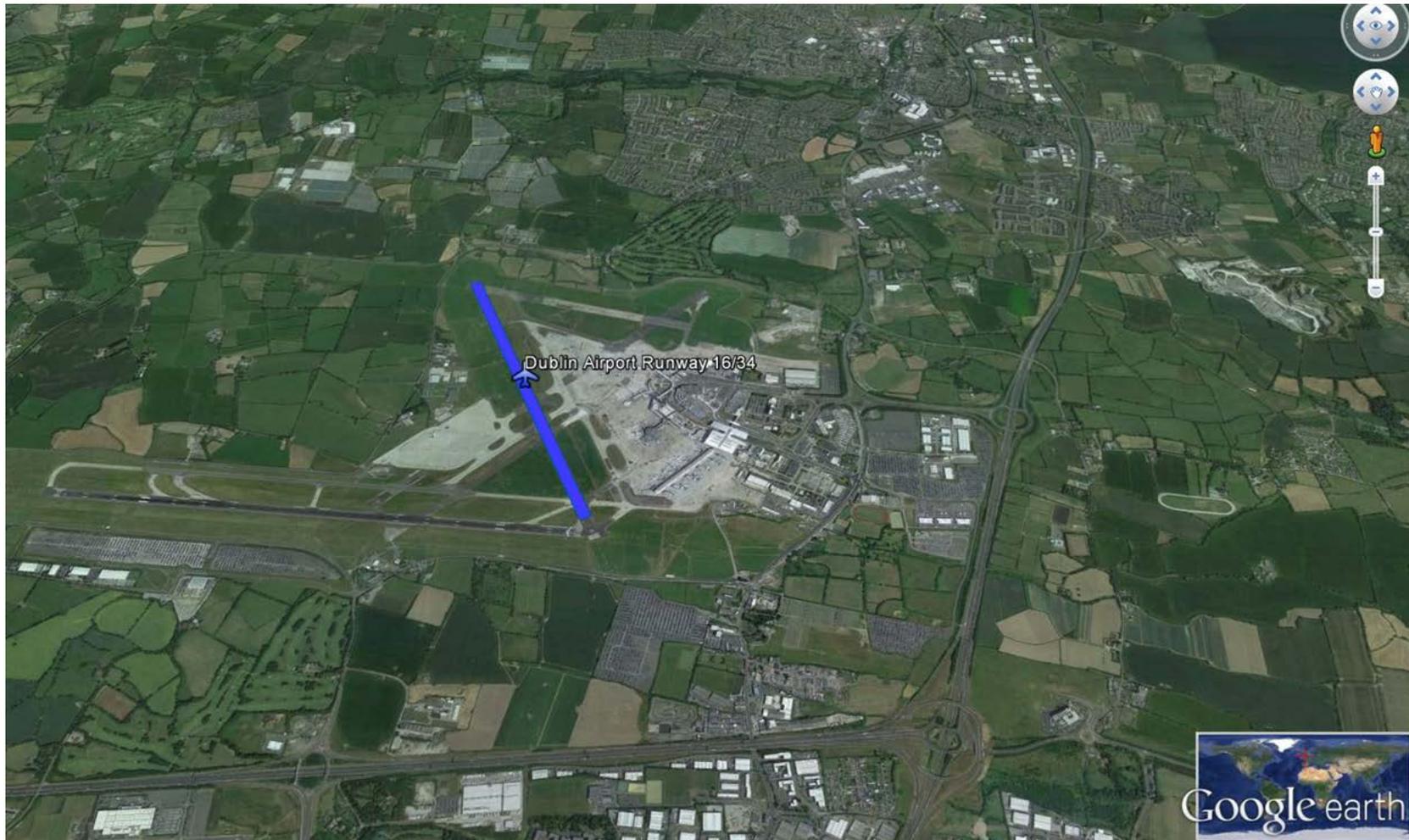
Dublin Airport

- Largest Airport in Ireland
- Handles on average 20 million passengers per annum
- Has two runways-main Runway 10/28 and
- Runway 16/34 which was surveyed using the HD Video and LCMS methods

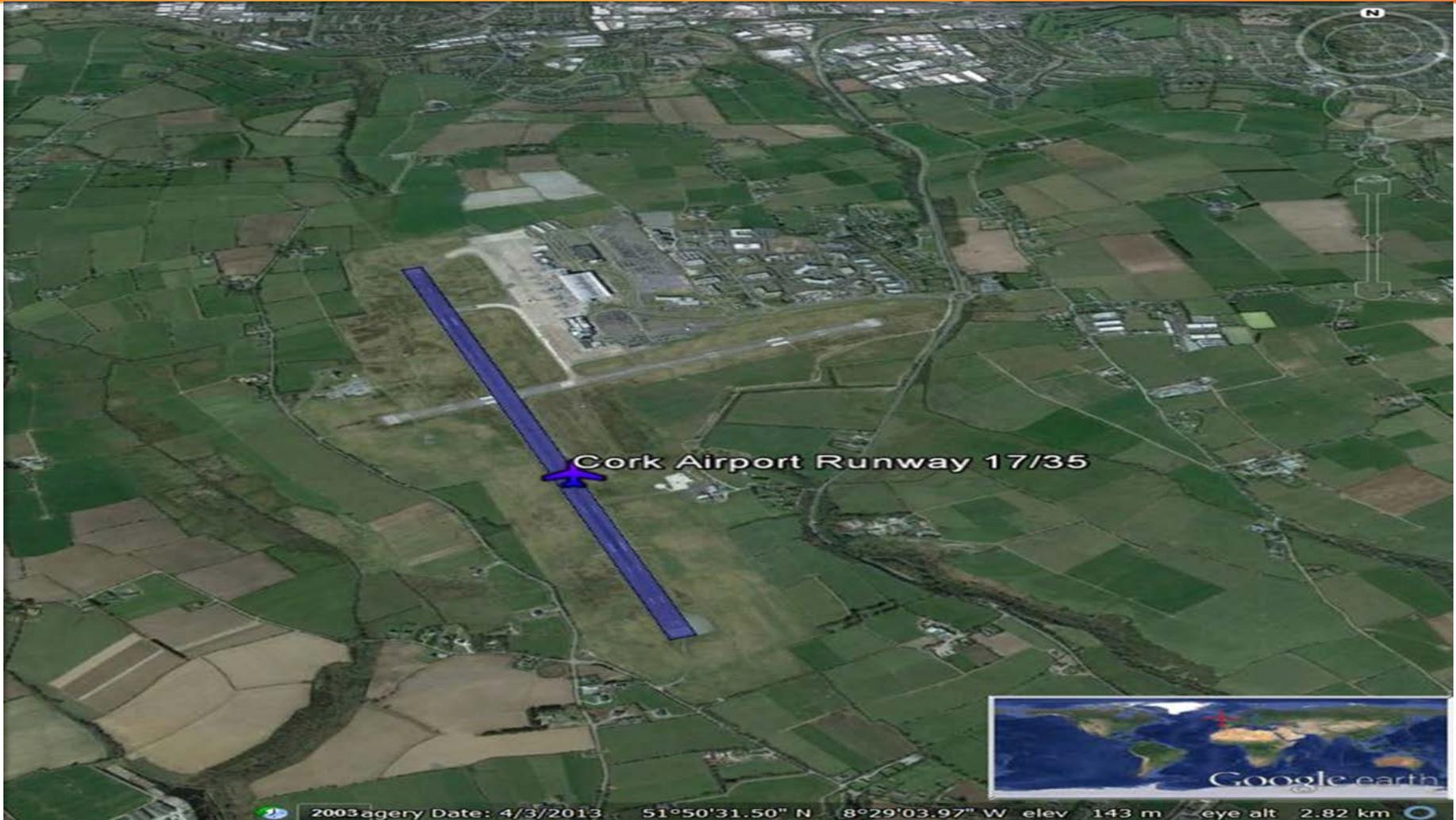
Cork Airport

- Irelands second largest airport
- Handles on average 2.4 million passengers annually
- Cork Airports main Runway 17/35 was surveyed using Manual, Video and LCMS methods

Dublin Airport, Ireland



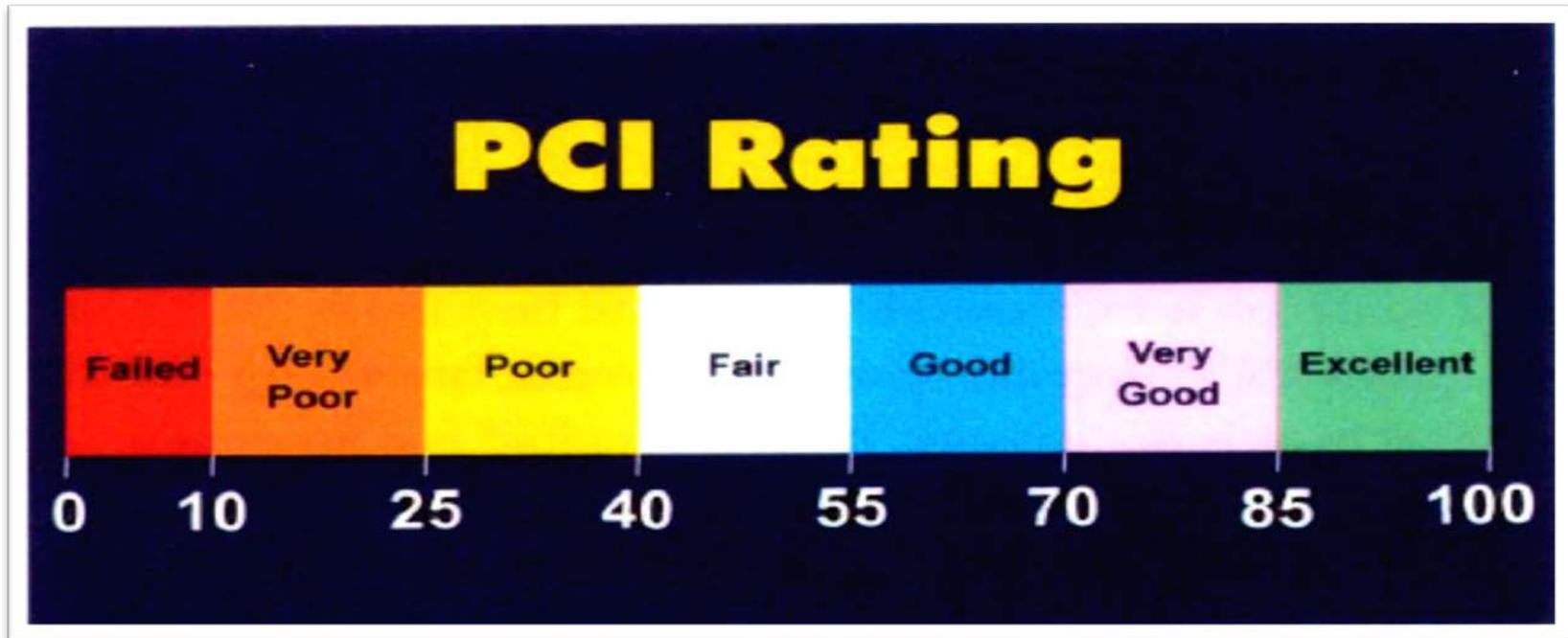
Cork Airport, Ireland



The Micro Paver System and PCI

The Micro PAVER system, developed by the U.S. Army Corps of Engineers, uses the Pavement Condition Index (PCI) to establish pavement condition

A breakdown of pavement classification by PCI scale is:



4. AIRFIELD PAVEMENT DISTRESS-SURVEY METHODS

1. **Manual PCI** methodology in accordance with the ASTM Standard D5340 “Standard Test Method for Airport Pavement Condition Index Surveys”
2. **HD Video PCI**-Pavement oriented, broadcast quality camera allied to a high-accuracy Distance Measurement Instrumentation (DMI) and GPS is used to record video.
3. **Laser Crack Measurement System (LCMS)** derived PCI-use of the automated identification of pavement distress to derive PCI on identical sample units

Airfield Pavement Distress Survey Methods

Laser Crack Measurement System (LCMS)

- A laser-based, high-speed and high-resolution transverse profiling system-comprising of:
 - two downward facing, high-speed line scan cameras
 - high power laser line projectors which acquire both 2D images and high-resolution 3D profiles of the pavement surface.
- LCMS range and intensity data is processed using automated image/data algorithms to identify pavement distress
- Dynatest Explorer software used to classify and output the type, severity and quantity of pavement distress data for input into the Micro PAVER database

LCMS at Dublin Airport



Dynatest Explorer- Processing software

The screenshot displays the Dynatest Explorer software interface. The main window shows a road profile with a vertical axis on the left indicating distance in kilometers (km) from 0.695km to 0.702km. The profile is divided into two sections: the top section is labeled "Frame: from 0.702km to 0.708km PID: 1" and the bottom section is labeled "Frame: from 0.696km to 0.702km PID: 1". A green line is visible on the profile, likely representing a specific data series. The interface includes a menu bar (File, Options, Help) and a toolbar with various icons. A secondary window titled "ROW Image Viewer" displays a photograph of a road surface. Below the image is a "Summary Tables" window with a table of data. The table has columns for Station, Pavement, Row, IRI, Latitude, Longitude, Altitude, Unit, RSPDF, and ROW. The data row shows values for Station (0.699), Pavement (69), Row (139), IRI (0), and other fields marked as N/A. A "Map (Google)" window is also visible, showing a map of the area with a red line indicating the location of the road profile.

Station	Paveme...	Row Im...	Rutting...	IRI (m/k...	Latitude	Longitude	Altitude	Unit	RSPDF...	ROW/Of...
0.699	69	139	0	0	N/A	N/A	N/A	km	N/A	N/A

5. DATA COLLECTION-DUBLIN & CORK AIRPORTS

Surveys conducted on Runway 16/34 at Dublin Airport and Runway 17/35 at Cork Airport.

- The runways were divided into 3 metre (about 10ft) wide sections which were sub-divided into 100 metre (about 328 ft) long sample units.
- The pavement condition data was collected on both runways during daylight hours in between flights.
- LCMS vehicle mobilised to start points using high-sensitivity GPS/SBAS Trimble GPS receiver and antenna enabled tablet
- The runways at both airports were constructed with asphalt-surfaced pavements

Data Collection

Runway 16/34 at Dublin Airport

June 2013

- Runway 16/34 at Dublin Airport was 2072 metres long and 60 metres wide.
- Divided into 20 no. 3m wide rips(lanes) with 19 sample units in each rip and totalling 380 sample units in the whole runway.
- LCMS was carried out and processed on all test rips and an LCMS PCI was completed
- Video PCI was completed and processed on full length of rips D, H, I, J, K, L, M, P and S (180 sample units in total)

Data Collection

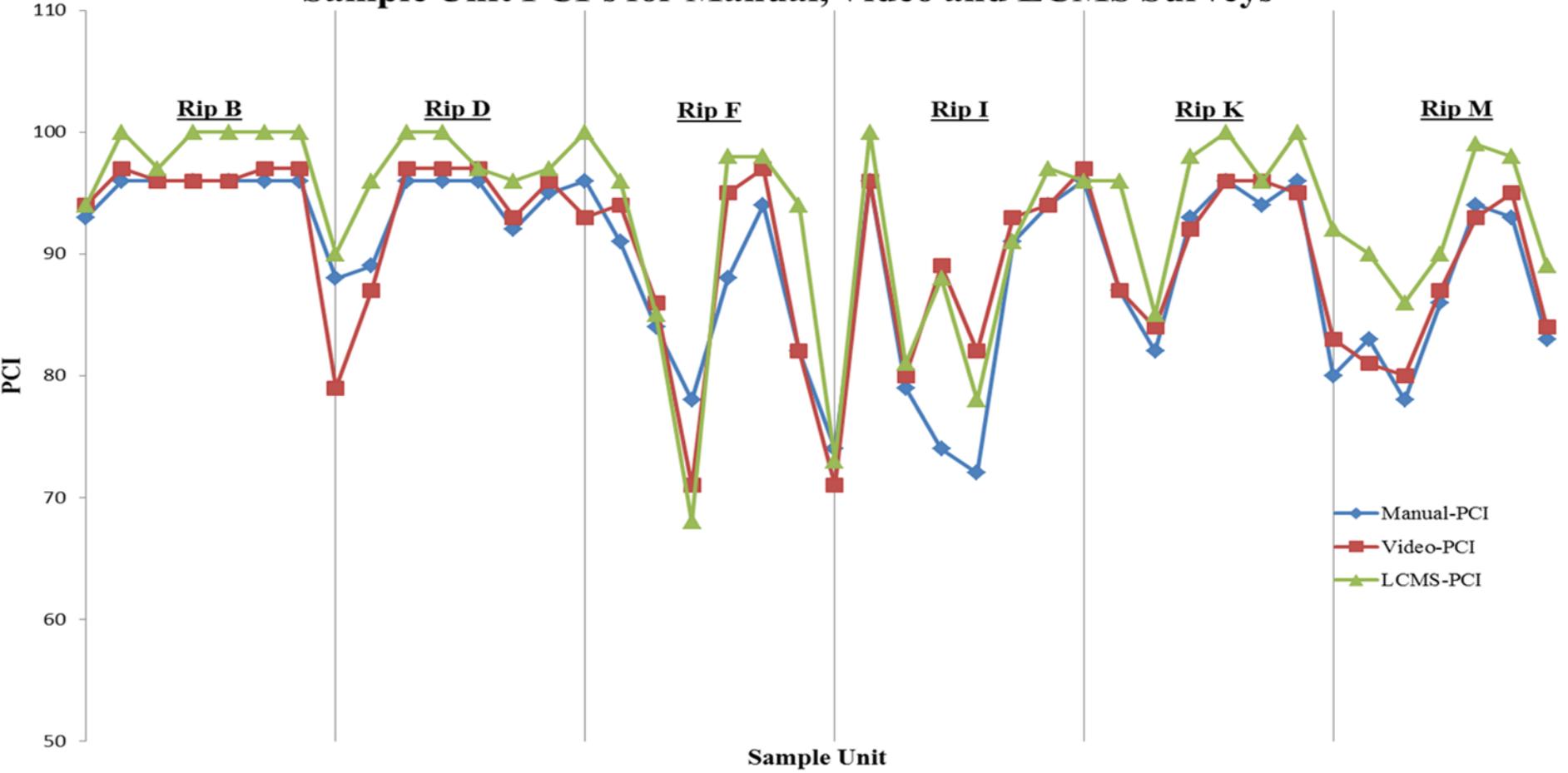
Runway 17/35 at Cork Airport

March 2014

- Runway 17/35 at Cork Airport was 2130 metres long and 45 metres wide.
- Divided into 15, 3m wide rips(lanes) with 21 sample units in each rip and totalling 315 sample units in the whole runway.
- A manual PCI survey was also carried out to establish ground truth.
 - In total, 42 sample units (13% coverage) were manually surveyed comprising 7 sample units randomly selected in rips B, D, F, I, K and M.

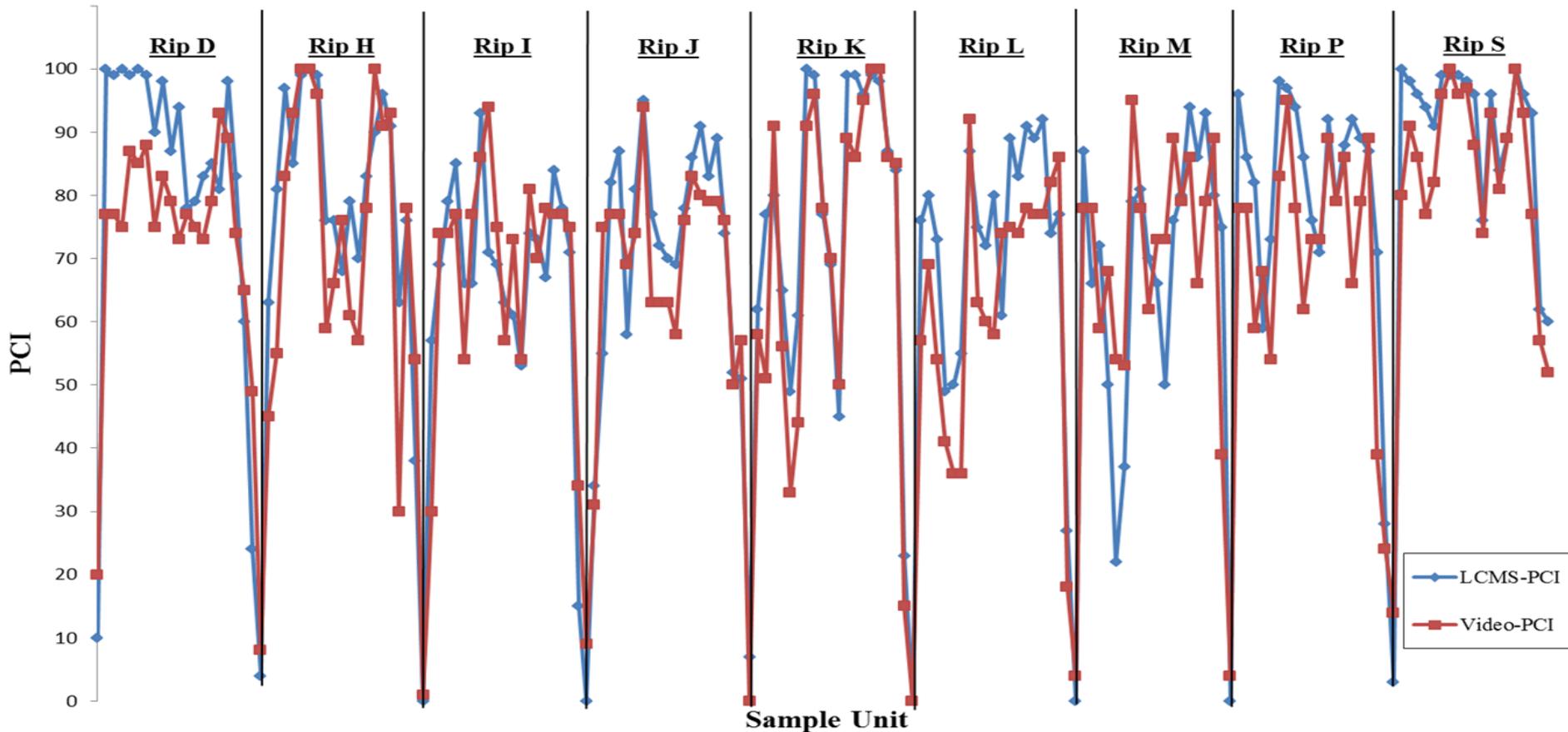
6.SURVEY RESULTS AND ANALYSES

Cork Airport Runway 17/35
Sample Unit PCI's for Manual, Video and LCMS Surveys



Survey Results and Analyses

**Dublin Airport Runway 16/34
Video-PCI Vs LCMS-PCI**



Survey Results & Analysis

PCI Averages

Cork Airport Runway 17/35 PCI

- Average Manual PCI of 89
- Average Video PCI of 90
- Average LCMS PCI of 94

All of the above indicated a runway condition of '*Excellent*'

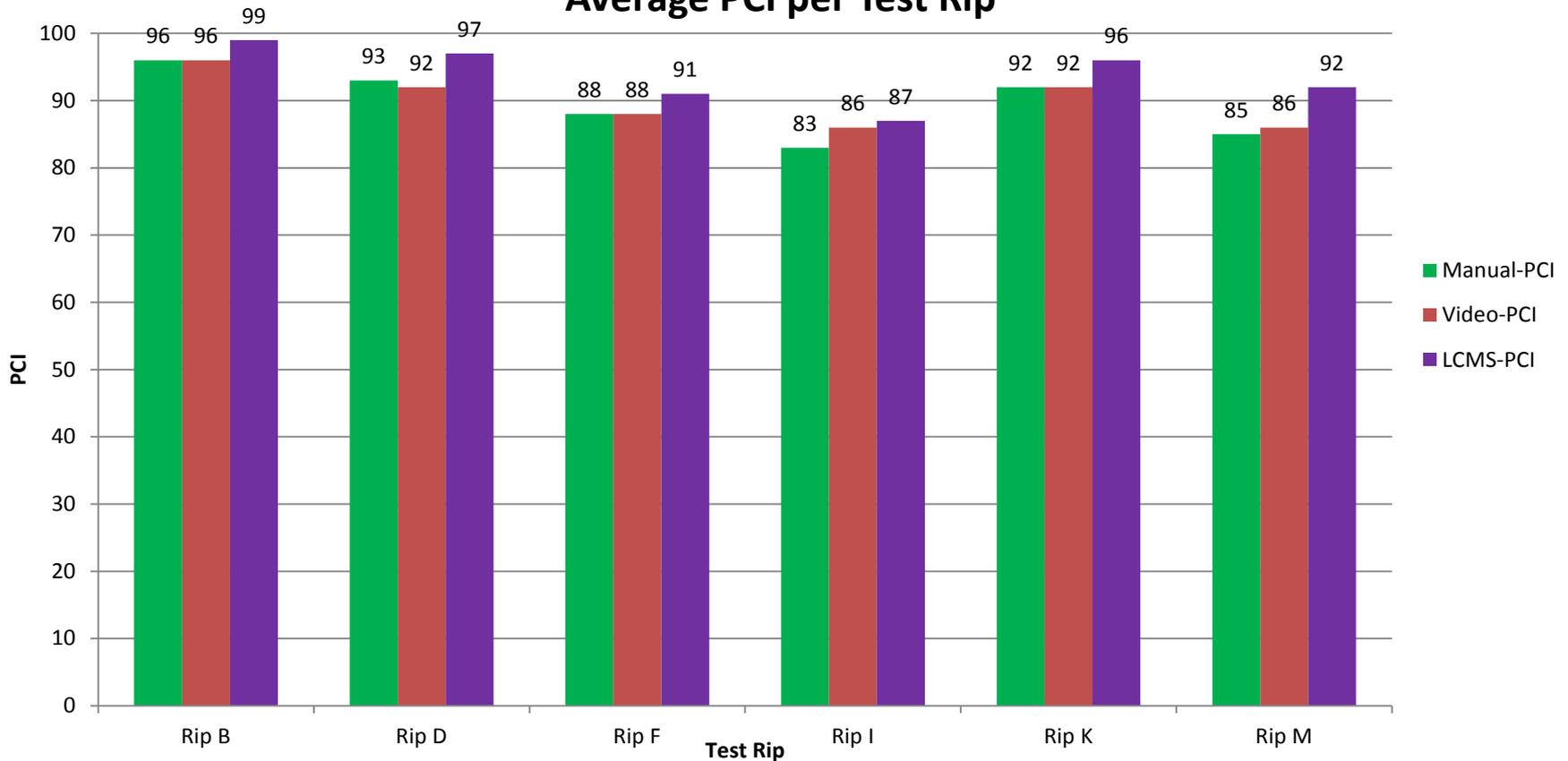
Dublin Airport Runway 16/34 PCI

- Average Video PCI of 69
- Average LCMS PCI of 74

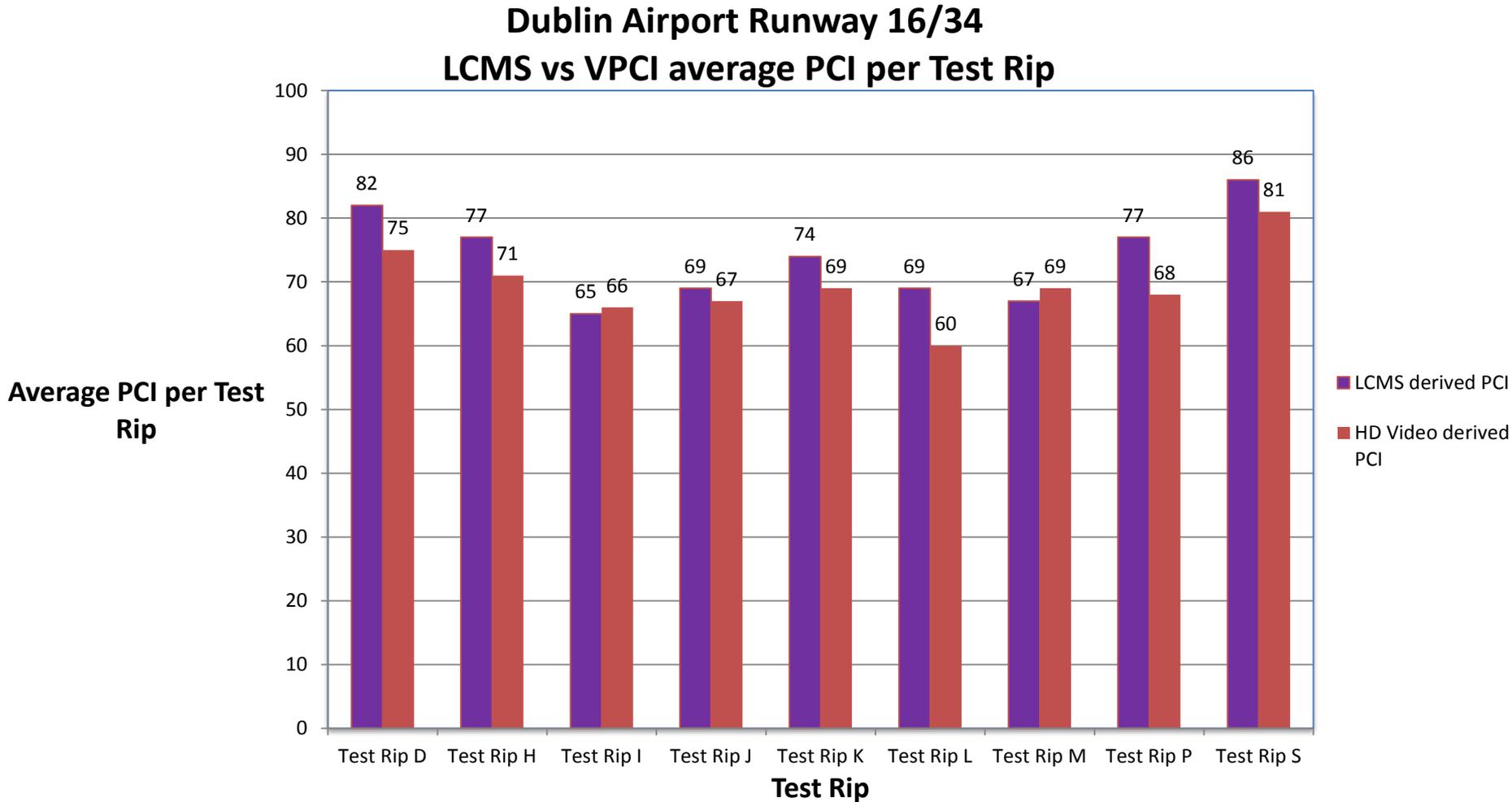
All of the above indicated a runway condition of '*Very Good*'

Survey Results & Analysis

Cork Airport Runway 17/35
Manual-PCI Vs LCMS-PCI Vs Video-PCI
Average PCI per Test Rip



Survey Results & Analysis



Survey Results & Analysis

Using linear regression analysis the levels of agreement between the PCI results obtained from the following methods were established:

- Manual survey
- Video survey
- LCMS survey

Statistical regression models were run to test the consistency of the patterns between the three survey methods:

- LCMS PCI versus Manual PCI
- Video PCI versus Manual PCI
- LCMS PCI versus Video PCI

Coefficient of determination- R^2

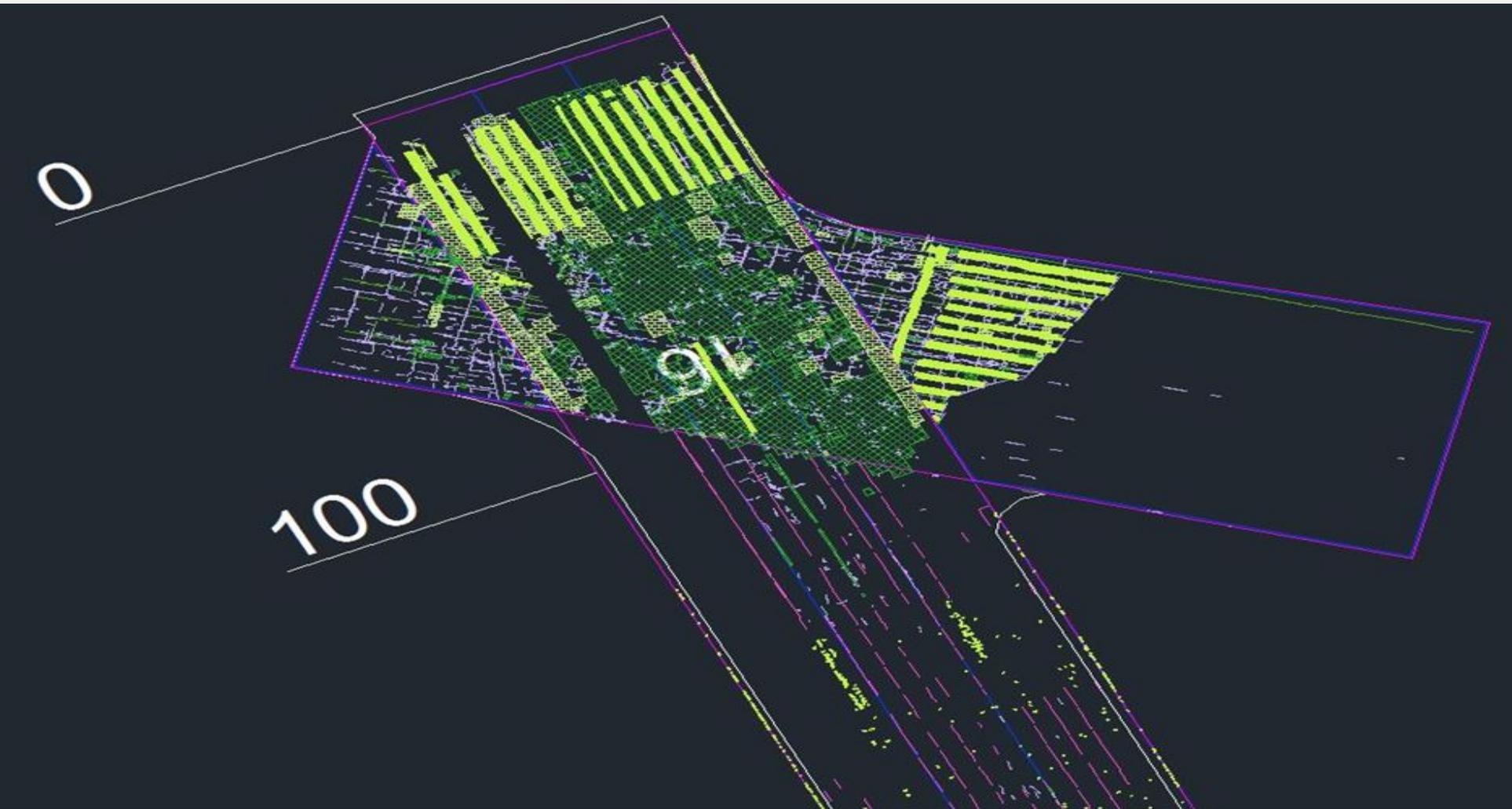
R^2 of LCMS derived PCI

- R^2 of 0.746 vs Manual PCI in sample units
- R^2 of 0.940 when considering Section Manual PCI values.

R^2 of HD Video derived PCI

- R^2 of 0.941 Vs. Section Manual PCI values
- R^2 of 0.825 Vs. Section LCMS derived PCI values

7. GRAPHICAL REPORTING OF THE LCMS DATA



Dublin Airport-Runway 16/34

Pavement Distresses-Google Earth Display

Legend

Area Distress (sq)

- 0
- <=2.5
- 2.5 - 10
- >10

Linear Distress (r)

- <= 5
- 5 - 10
- 10 - 15
- >15

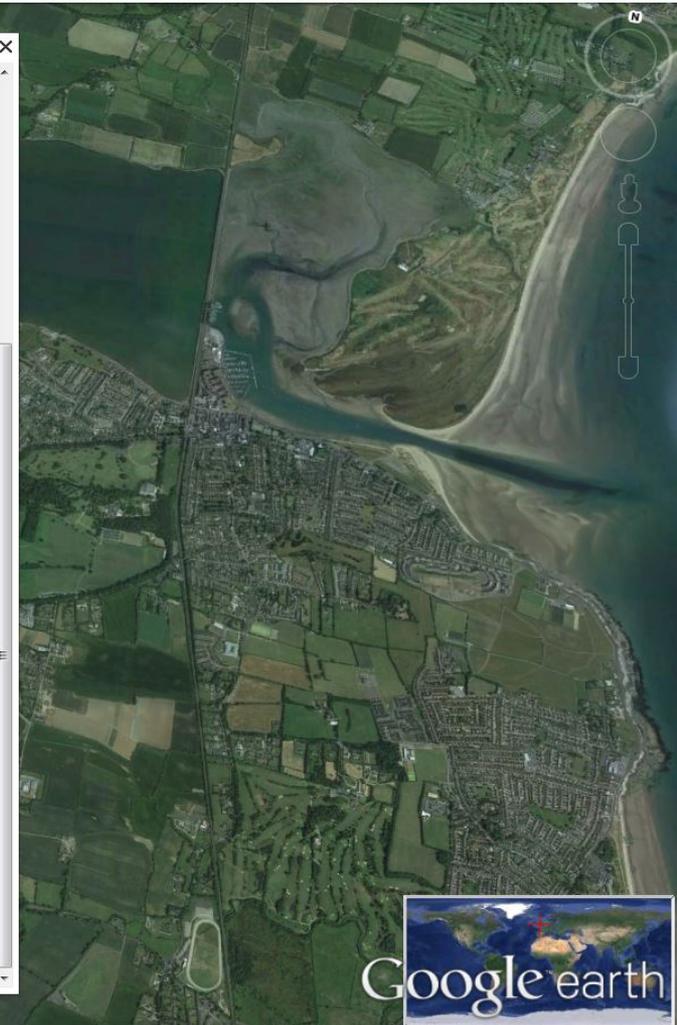
Ravelling (sqm)

- <=1
- 1 - 5
- 5 - 10
- >10

Images

Forward/view 0to5m

Forward/view 5to10m



Cork Airport-Runway 17/35

Pavement Distresses-Google Earth Display



Dublin Airport-Runway 16/34

Airfield Pavement Distress Viewer

Airport Viewer Beta

The software interface displays the following components:

- Top Row:** Three images showing different views of the runway pavement. The left image is a close-up of a textured surface. The middle image shows a wide view of a runway with a small vehicle in the distance. The right image is another close-up of a textured surface.
- Middle Row:** An aerial map on the left shows a color-coded distress area on a runway. A red pin is placed on the map. The right side of the middle row features a 'Crossfall Plot' graph with 'Depth' on the y-axis (ranging from 1500 to 1900) and 'Sensor Position' on the x-axis (ranging from -1500 to 1500). The graph shows a red line representing the crossfall profile.
- Bottom Row:** A 'Controls' panel with the following elements:
 - Buttons: Add RSP Files, Play, Add Sample PCI, Clear Routes, Pause, Reverse.
 - Legend: A color scale for distress levels: >70 (green), 50-70 (yellow), 20-50 (orange), 0-20 (red).
 - Playback Speed: A slider control with 'fast' and 'slow' labels.
 - RSP File: AC13RA121E
 - Chainage (km): 0.035
 - Map Zoom Level: A slider control with 'out' and 'in' labels.
 - Map Provider: Radio buttons for Open Street, Google, and Sat (selected).
 - Graph Type: Radio buttons for IRI, Crossfall (selected), and MPD. An 'Exit' button is also present.
- Logo:** The PMS logo is located in the bottom right corner.

Summary and Conclusions

- **Very good consistency** found between the type, quantity and severity of distress data identified from the Manual, Video and LCMS techniques.
- Hypotheses testing using the F-Test showed there was no significant difference between the variances of the three samples for a 95% confidence level.
- The R^2 values indicate that the regression models for the automated LCMS is a good model for predicting the manual/ground truth PCI and video PCI.

ANSWER:

With airfield pavements subject to increased traffic levels; Would the use of an automated pavement data collection system such as an LCMS, be beneficial on airfield pavements?

Could pavement condition index (PCI) surveys be completed within stringent time constraints and between flights using LCMS?

In our view the Laser Crack Measurement System (LCMS) can successfully automate pavement condition index surveys and allows rapid pavement assessment overcoming air traffic constraints on airfield pavements.

Thank you for your attention



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