Introduction

Developments since 2002 Workshop

Organised by Asst Prof Andrew Dawson, Nottingham

Mechanistic Design Workshop

Since the original Workshop at University of Canterbury in 2002, a series of subsequent workshops focusing on short presentations have been held to track advancements made in a calibrated mechanistic model for New Zealand unbound pavements, as well as associated research or informative case histories.

All historic presentations can be viewed here: https://www.pavementanalysis.com/research-menu/research-seminars-menu

For decades, pavement engineers have trailed other engineering disciplines in terms of the effectiveness of material characterization for prediction of performance.

In that context, the initiative taken by Andrew Dawson in 2002 and his papers produced then, have stood the test of time incredibly well, and provided the basis for very substantial improvements in performance prediction for unbound granular pavements.

The relevant considerations are given in both his Briefing Paper and his Outcomes which will be taken as read for the purposes of the current workshop.

Mechanistic Design Workshop (2002)

Relevant considerations for a ***calibrated mechanistic model*** for unbound pavements

Extract from Briefing Paper:

1	Failure
2	Design Criteria
3	Material Characterisation
4	External Influences
5	Computational Analysis

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Mechanistic Design Workshop (2022)

Relevant considerations progressively extended (now 10) -> (BCRRA22)

Dawson's 2002 basic concepts have been advanced towards the end goal, ie reliability in: Performance Prediction & Forward Work Programme

From 1952 (first use of Benkelman Beam) until 2010 (FWD and TSD), performance prediction that did not utilise in situ data, with regional precedent performance (RPP) as their basis for a calibrated mechanistic model, had a reliability of usually 10% or less, when predicting out several years.

Predictions can easily be made to 30 months on visual data and records. The challenge is 30 months to 30 years. (RPP 30-30)

In the last 5 years, by following Dawson's principles and progressively modelling more distress modes (more than 20 by 2017), NZ projects were able to achieve reliability of closer to 80%.

1	Distress Modes
2	Loading
3	Load Equivalency
4	Roading Database
5	Computational Analysis
6	Material Characterisation
7	Sampling
8	Treatment Lengths
9	Design Criteria
10	Reality Checks and Calibration

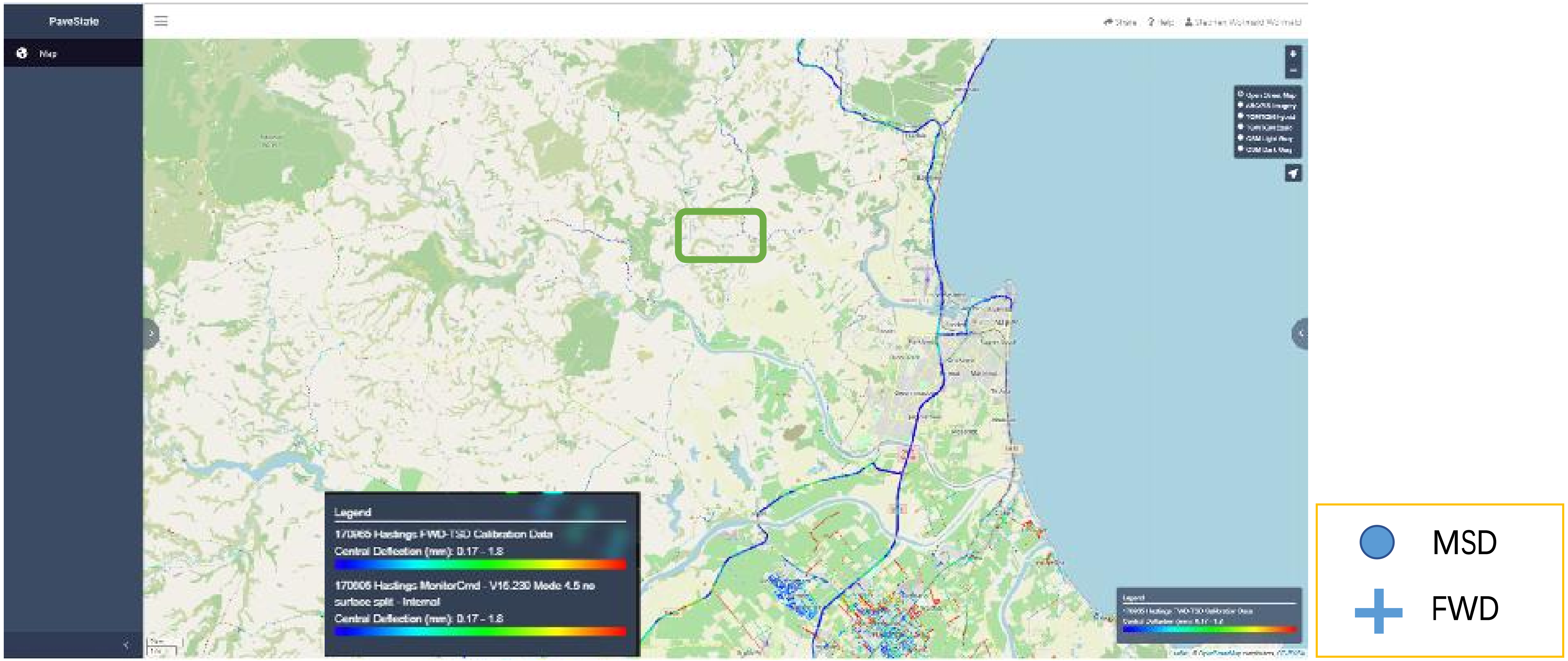
Recent advances that have provided reliability (Further details in BCRRA22)

1	Distress Modes	It is necessary to identify the myriad ways (up to 23 or more) in which individual treatment lengths deteriorate to a terminal condition for the specific network. Multiple terminal conditions may be defined based on NPV and/or LOS but ideally both. Allocate any necessary adjustments according to each road classification or situation. Then identify a key mechanical measure for each, usually a vertical, horizontal or shear strain (or stress) at a specific depth and plan location relative to the contact patch of the design load, which will act as an indicator of the performance.
2	Loading	Reliable measurement and systematic classification of heavy traffic vertical loading spectra for each road. Speed of loading, longitudinal shear (braking and acceleration), geometrics and transverse shear (roundabouts) can be critical in specific cases.
3	Load Equivalency	Evaluation and assignment of load equivalency for the traffic spectrum for each individual distress mode/layer. Load damage exponents (LDEs) used to be considered to be constants. This came from short term studies of very dry pavements where strains were low (about half their critical fatigue limits). However, in recent years it has been widely acknowledged that is not the case: longer term in situ testing of in-service pavements demonstrates each distress mode has its own characteristic LDE and that each LDE increases exponentially over the life of the pavement (manifested by accelerated deterioration towards the terminal state). An alternative to LDE is to follow procedures for systematically calculating cumulative damage for each applicable axle group separately for each distress mode.
4	Roading Database	A comprehensive roading database is required for modelling reliability. Surface condition and distress severity may in some cases be adequate for short term trends, but relevant structural data subjected to detailed quality assurance (including correction for seasonal bias) are necessary for moderate term and long-term analysis.
5	Computational Analysis	A technique which reproduces all relevant deformation that develops in the in situ loaded state is needed and it should accommodate the properties of the range of materials encountered in each region.

Mechanistic Workshop (2022)

6	Material Characterisation	The validity of the computational technique rests, to a large extent, on the veracity of the constituent materials' stress-strain relationships. Modulus non-linearity with applied stress (or with ambient stress) needs to be addressed. The measurement techniques need to be accurate, and the correct parameters need to be evaluated.
7	Sampling	Given the inherent variation of both subgrades and imported materials, test spacing needs to be commensurate with spatial variability and the application: network level, project level and maintenance level evaluations benefit from successively smaller averaging intervals, and local experience is that test sampling at 20m or closer in each lane is essential for adequate reliability (80% target). Intervals of 20, 10 & 2m are feasible with TSD now that there is little difference in cost. Simultaneous testing of both wheelpaths is advantageous in mature networks where maintenance has been carried out.
8	Treatment Length Designation	Systematic sub-sectioning procedures for identification and delineation of homogeneous structural treatment lengths (STL's) are fundamental to an optimised, cost-efficient Forward Work Programme. Incremental recursive techniques are required, with re-assignment of STL's each year. This is essential where material properties such as layer moduli undergo loading or environmental changes and where spatial changes are induced by patching, dig-outs or other inevitable maintenance requirements, particularly for thin-surfaced or mature pavements.
9	Design Criteria	Each key mechanistic measure must be computable, and relevant terminal values (fatigue criteria) characterised. These need to be defined for each region or sub-region to accommodate what are now recognised as highly significant local effects, namely subgrade types, aggregate sources, construction practices, level of quality assurance, customary specifications, maintenance style/frequency and most importantly, climate (temperature, rainfall ingress, groundwater fluctuation and the impact of humidity on the equilibrium water content of unbound aggregates).
10	Reality Checks and Calibration	Site inspection is essential, to ensure adequate characterisation of the wide variety of distress modes exhibited by treatment lengths which have reached or are close to terminal condition (programmed for the rehabilitation in the current year). These provide the ideal candidates for calibration. The transitions from consistently distressed to consistently non-distressed treatment lengths provide ideal points for fine tuning of distress modes and their limiting fatigue criteria.

Hastings DC
Puketitiri Road



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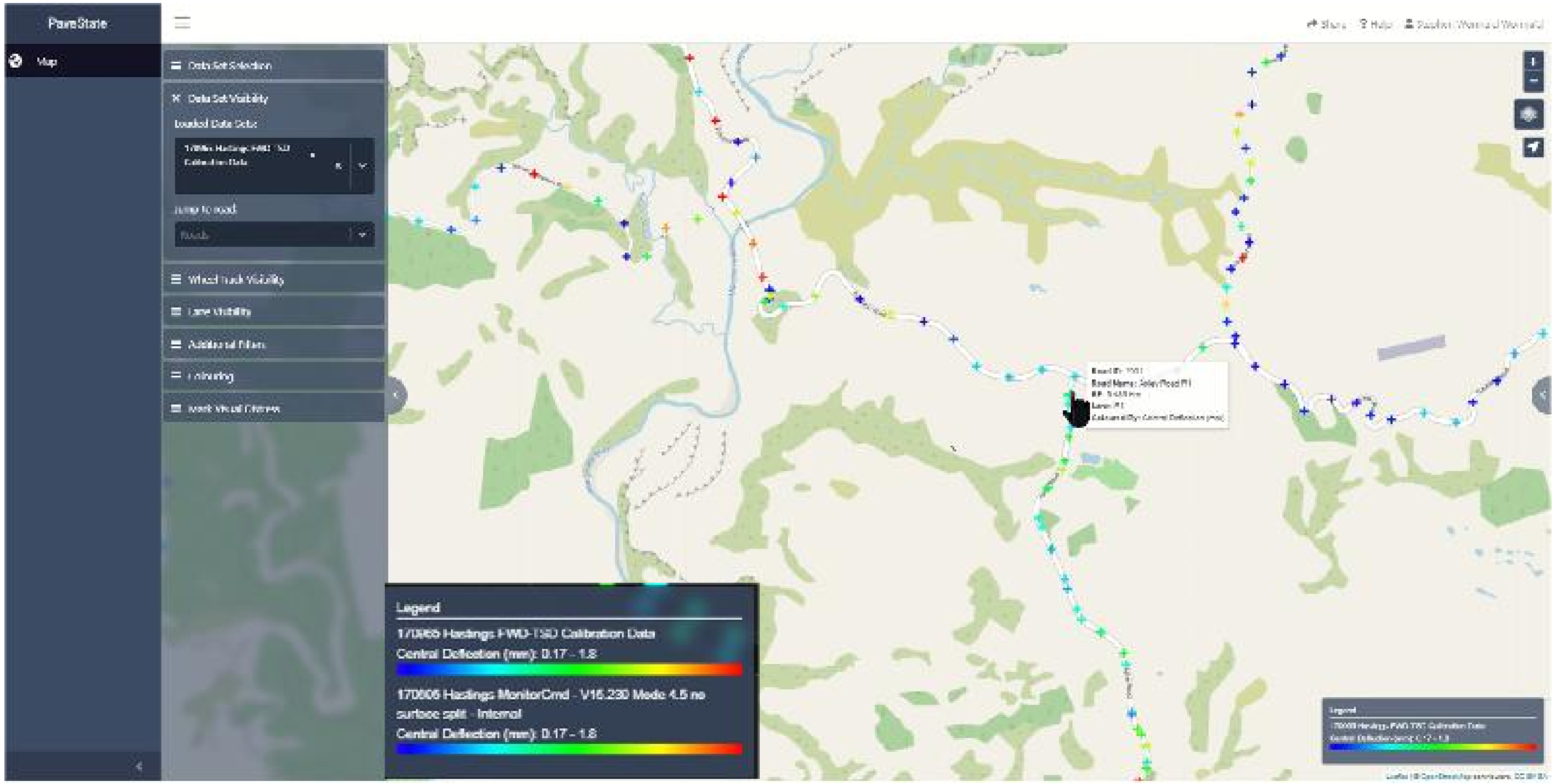
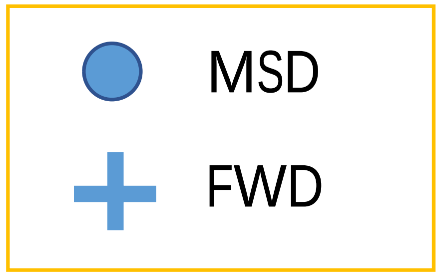
1st FWD (200m staggered) survey Oct 2014

MSD survey Oct 2021





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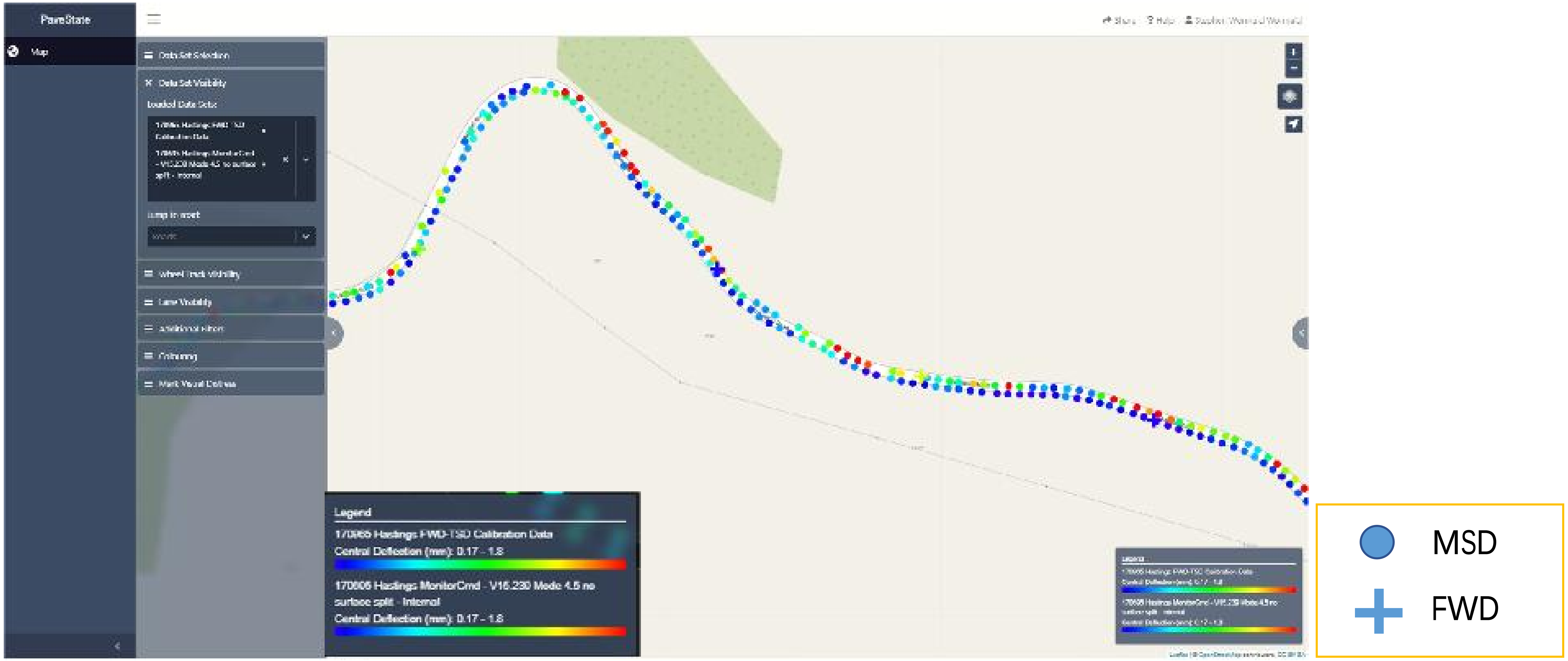

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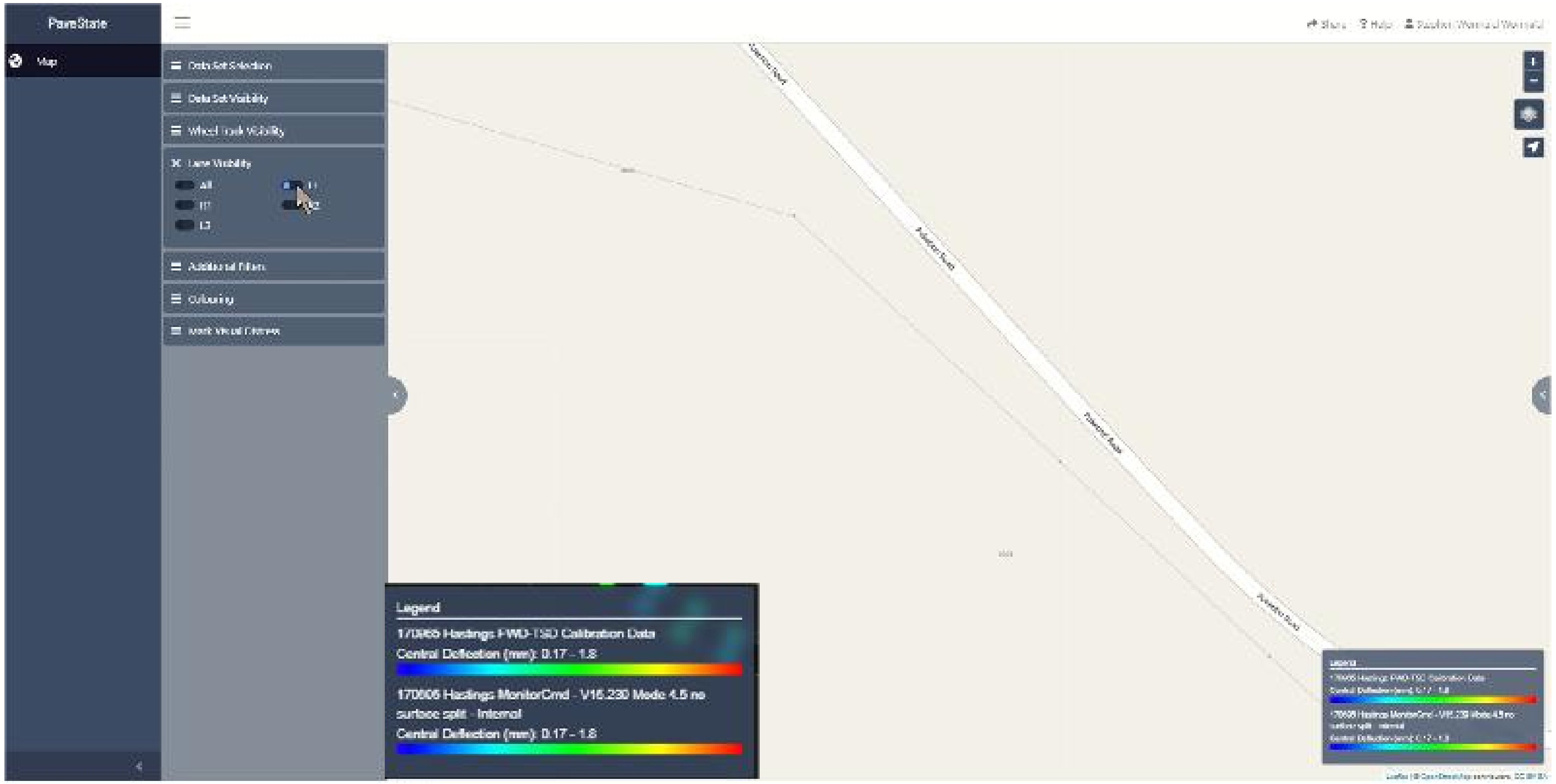

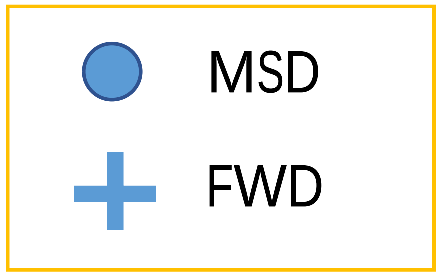

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MSD

FWD

Current Status

To summarise, the most substantial advances in performance prediction which have come into effect in the last 5 years are:

- Dawson's focus on the "myriad" of distress modes. These are a feature of unbound granular pavements and the calibrated mechanistic procedure for dealing with them now addresses many of the former unknowns.

- Load damage exponents are now known to range substantially with distress mode and which layer is critical. They also increase progressively with loading repetitions (exponentially towards the end of life) and can now be measured and characterised much more routinely in each network, facilitating rational deterioration models

- Sampling for networks surveys used to be sparse (often 100 or 200m centres) but much greater speed and reduced cost can now generate 300,000 test points per day and this can be at 10m or 1m centres and in both wheelpaths, a major advance in view of the known wide ranging spatial variance of most pavement layer properties.

These three advances in particular, contribute to the increase in reliability of longer-term pavement performance prediction from a Hit Rate which was less than 10% only a decade ago, (using overseas criteria) to a much more useful value of closer to 80% today using all of the 10 relevant considerations. Traditional simplistic approaches have not been demonstrated to address the 30 month to 30 year objective.

Thank you