PUBLICATIONS

DATA QUALITY OBTAINED BY THE IPAVE DURING COMPREHENSIVE MEASUREMENTS OF ROAD INFRASTRUCTURE CONDITIONS.

Principal Engineer Bjarne Schmidt, ARRB Systems AB, Sweden

Director at Sloman Slovenko Henigman, Slovenia

Comprehensive measurements performed on a road network provide a strong and robust platform for identifying and prioritizing road sections that need routine or periodic maintenance, rehabilitation or even reconstruction. The ability to pinpoint these critical sections in the road network is vital in the provision of a sustainable and safe road infrastructure.

The iPAVe was introduced at the Conference Asphalt Pavements in 2021.

This presentation will show the quality of data that can be obtained from iPAVe measurements, using an example from a test section in Slovenia, where all the requirements from Slovenian standards were used. Additionally, an example of how the iPAVe can be used to investigate the consequences of seasonal variations on road infrastructure conditions will be shown.

The need for quality data to provide robust pavement assessments.

A well-maintained road infrastructure with correctly identified/prioritised intervention strategies to ensure an economically feasible use of resources, is a vital element in keeping society in motion and, ultimately, make roads safer globally.

As technologies for road infrastructure condition surveys continue to advance, most of this information can now be collected continuously, at traffic speed, and simultaneously integrated with other pertinent data. These advancements have brought about a greater awareness of the true resource needs for better managing road infrastructure networks, while significantly reducing life cycle costs and thereby producing a positive cost/benefit.

Comprehensive measurements of the complete road network provide a strong and robust platform for identifying and prioritizing road sections that need routine or periodic maintenance, rehabilitation or even reconstruction. The ability to pinpoint these critical sections in the road network is vital in the provision of a sustainable and safe road infrastructure.

Having a complete dataset, incorporating both surface and structural data (collected simultaneously), enables the road asset managers to better understand the true condition of their network and enables dramatically improved appropriate decision-making ability. Road agencies around the world are now using these tools to collect the desired pavement performance properties more efficiently.The ultimate goal is to ensure the data collected is verified and validated in providing value to the road authorities, and supportsthe decision makers to implement better informed, appropriate, and costeffective maintenance strategies, aligning with the challenges that influence road infrastructure condition, quality, and safety.

Modern road monitoring equipment operates within an in-service environment at traffic speed, with a major risk that traffic and traffic regulations can impact on the quality of the collected data, if the equipment's and their data collection ability is not tailored to accommodate for these potential interactions during measurements.

To investigate the actual performances in the field of the equipment used, it is common to test the measuring equipment's performance, both under a controlled environment and on in-service roads, testing the equipment's repeatability and occasionally the equipment's reproducibility. To accommodate for the investigation of the equipment's quality, the following are normally used:

- Tests are performed on special tracks and/or in-service roads.
- Testing is undertaken at different speeds.
- To determine repeatability, multiple runs (at least three), must be completed on the same section.
- Reproducibility can be investigated if a reference device is available, or a ground truth established.
- Reference or ground truth measurements are made with a view to study the accuracy of the device compared to a reference or a ground truth.

Alignments – is important when studying repeatability and reproducibility.

To obtain comparable data sets, being between runs using the same equipment or data from different equipment's, alignment of data is important. To secure alignment between data, several methods can be used, each of them providing different precisions, when aligning data.

Hand entered references are commonly used but are very dependent on the skills of the operator and can cause the alignment to be several meters out.

GPS alignments very much depend on the quality of the GPS used and are generally a few meters off.

An optical trigger, where an optical tape that the sensor records, is placed on the pavement. This method often provides an accuracy in the alignment of the data of 100 mm. The difficulty in using this method is the tape can move, if not glued sufficiently to the pavement. Also, there is a risk the tape is not detected on every run.

A physical block can be placed on the pavement to generate a spike in the data. The validity in using this method relies on post survey data manipulation to shift references to spike in the raw data. When using this method, the accuracy is determined by the size and shape of the used block and the sampling interval of the equipment.

Profile alignment is a commonly used method where statistical techniques are used to determine the optimum offset. The method shifts the profiles to compare until a best statistical match is determined. In theory, the accuracy is within the sampling interval of the equipment, however also the method used for obtaining the best fit, determines the accuracy.

Executing repeatability tests on in-service road in Slovenia.

In 2022, ARRB Systems was asked to perform a series of repeatability tests on an in-service road in Slovenia, using the companies iPAVe equipment, shown in figure 1.

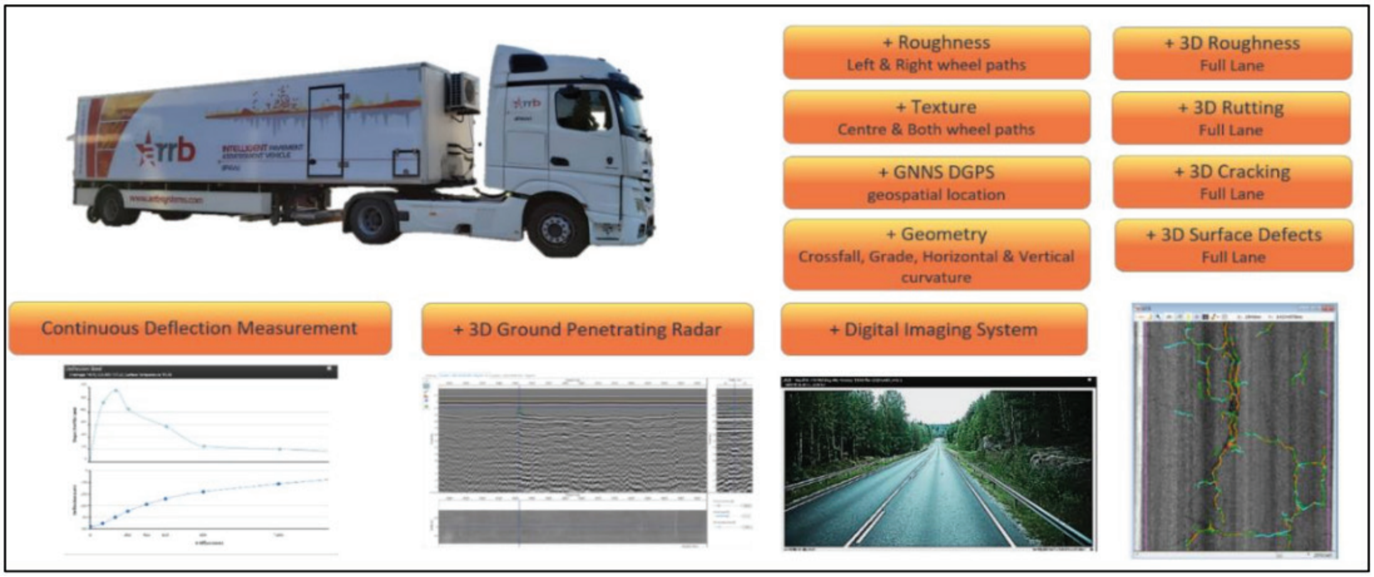

Figure 1: The intelligent Pavement Assessment Vehicle (iPAVe)

Tests were performed at traffic speed on a 9 km in-service road section, measuring in both lanes. In total five repeated runs were performed in each direction.

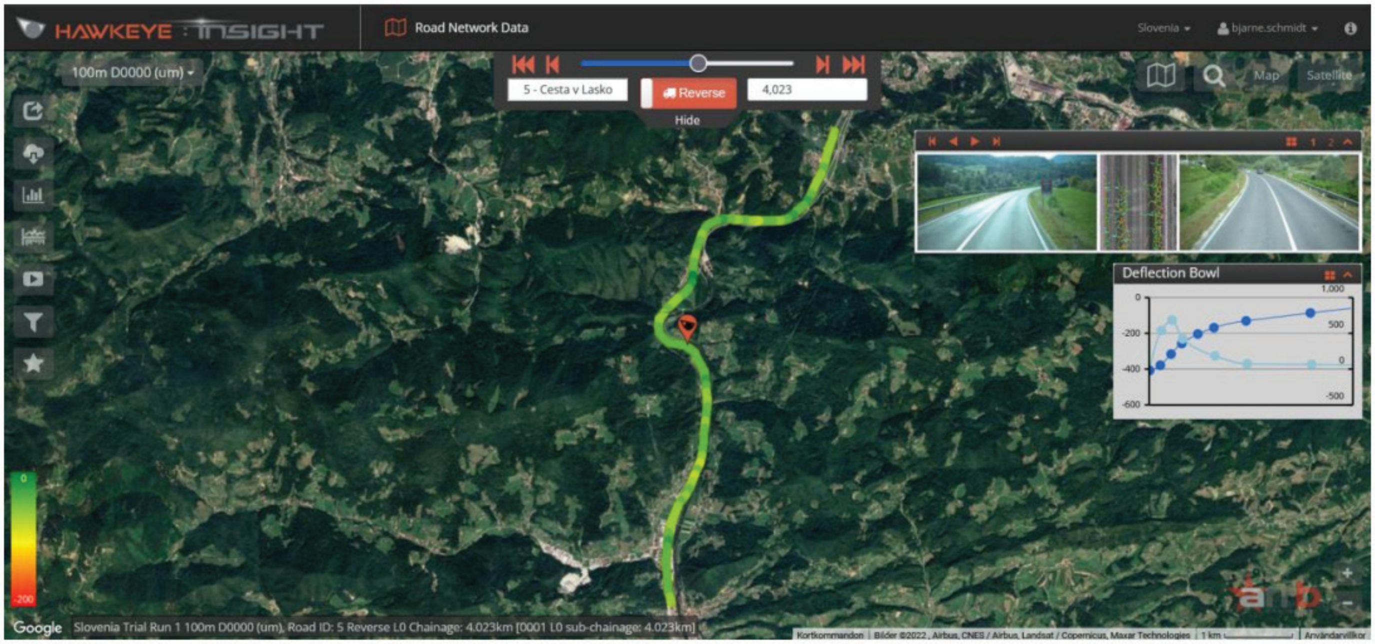

Figure 2: Road sections measured in Slovenia.

As the tests were performed on an in-service road, it was obvious several factors influenced the collection of data and the ability to operate the iPAVe in an optimal way. Although facing the obstacles, illustrated in figure 3, which is not ideal for testing repeatability and hence the quality of data, this is the reality when performing data collection on in-service roads. Therefore, the test performed, does provide information on what data quality can be obtained by the iPAVe, during in-service testing.

Figure 3: Challenges of testing on in-service roads

Repeatability tests of the most commonly used condition parameters for roads

As the iPAVe performs a comprehensive measurement of all pavement characteristics, only repeatability of the most commonly used indices is reported in this paper, being:

- Pavement longitudinal evenness represented by International Roughness Index (IRI m/km)
- Pavement transverse evenness represented by pavement rutting (RUT mm)
- Pavement macro texture represented by Mean Profile depth (MPD mm)
- Pavement deflection represented by structural curvature index (SCI 300 μm)

Pavement longitudinal evenness IRI represented by International Roughness Index (IRI m/km)

Figure 4 shows the IRI for the complete set of IRI values measured on the 9 km test sections for the five repeated runs. From figure 5 shows that there is a very high degree of consistency between the five repeated runs.

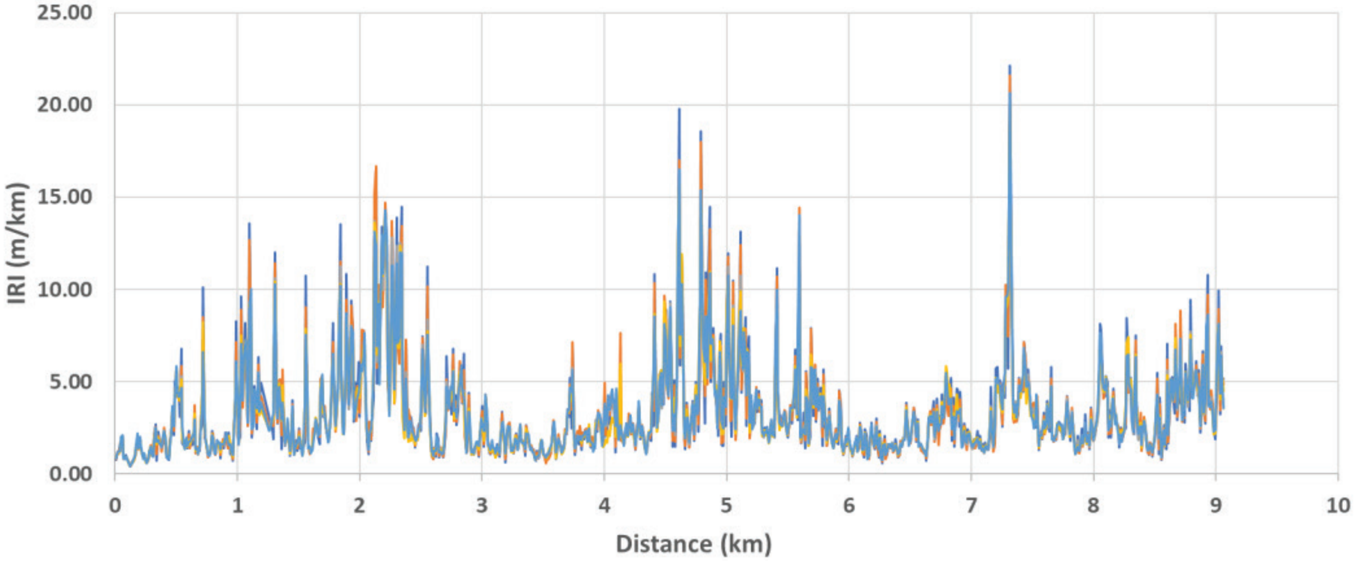

Figure 4: Five repeated evenness measurements

To do a repeatability analysis of the measurements a scatter plot and regression between data must be done. In figure 5 the scatter plot for the IRI is shown.

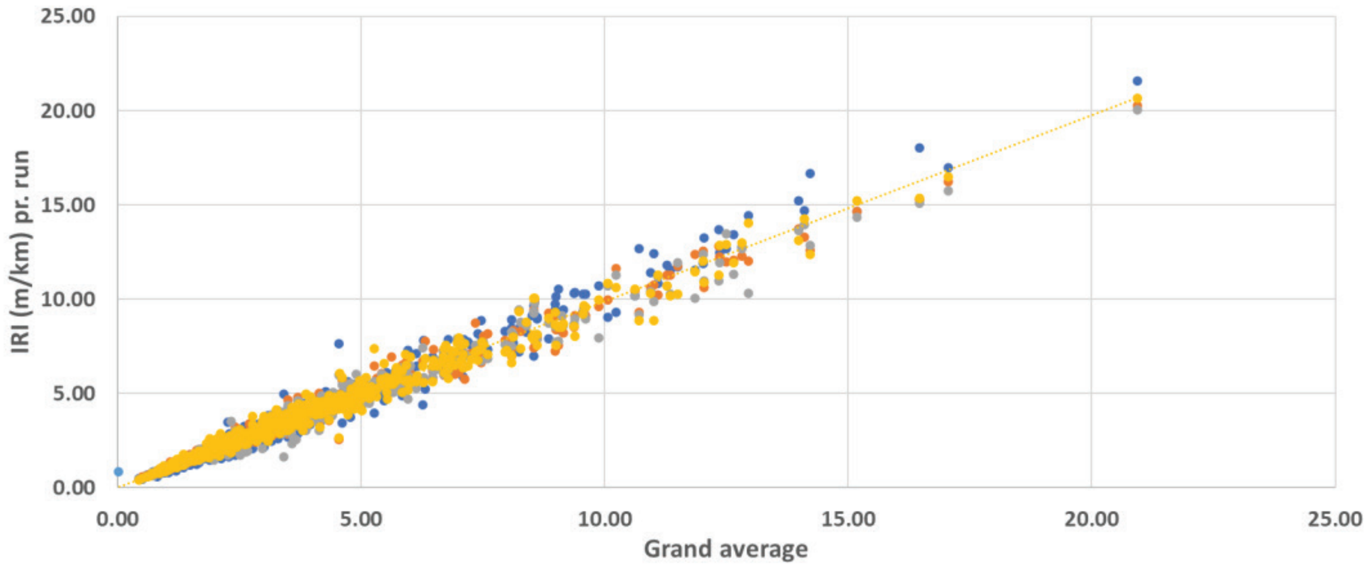

Figure 5: Scatter plot of repeated evenness measurements

So not only does the data show there is a degree of correlation between the data, but also the scatter around the regression line is very low. This shows a high degree of repeatability for the longitudinal evenness. Calculating the regression and the R2 value shows a goodness of fit between the runs of y = 0.99x with an R2 of 0,99. The standard deviation of the residuals are calculated to 0,37 m/km, and the accuracy is 88%.

Pavement transverse evenness represented by pavement rutting (RUT mm)

The evaluation of the transverse evenness of road pavements are often represented by calculating the amount of rutting in each wheel path. Recording the actual rutting on pavements is important in relation to traffic safety and thereof the risk of aqua planning. To highlight the iPAVe's ability to repeat measured pavement rutting, the calculated rut in the outer wheel is used in the analysis. The rutting is calculated from the transverse profile measured by the LCMS sensors, located on the back of the iPAVe. The measured rutting is shown in figure 6.

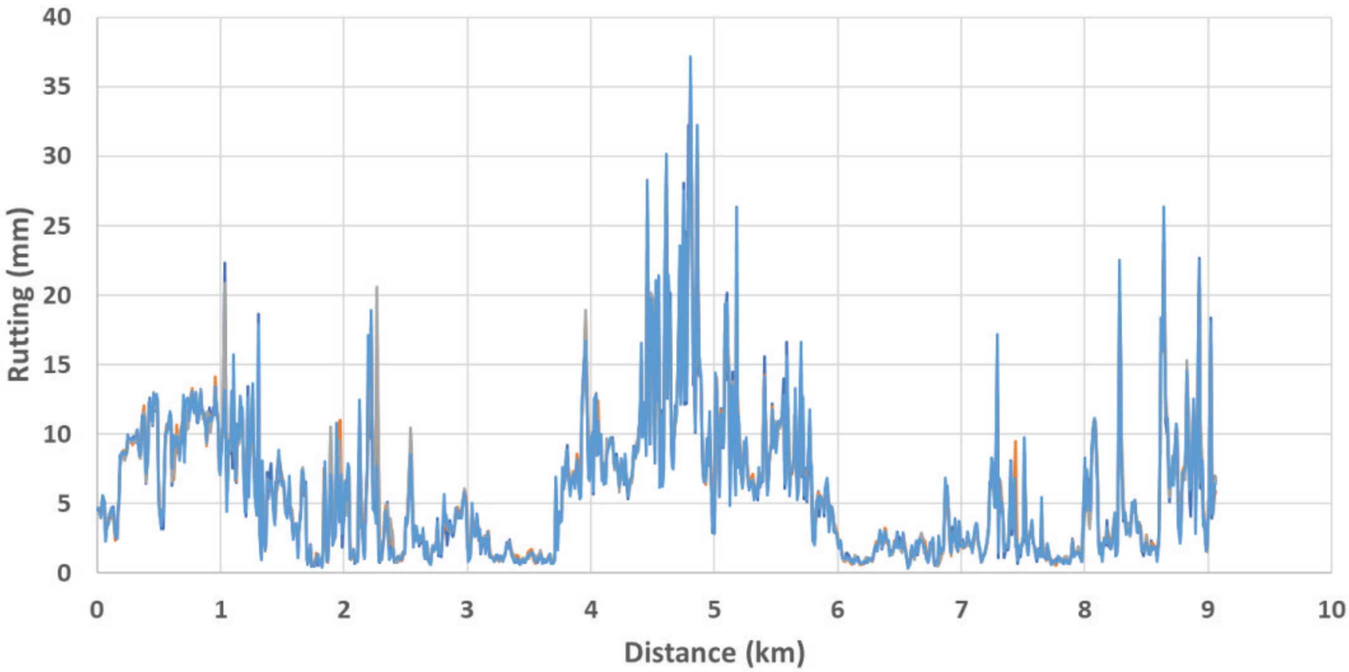

Figure 6: Five repeated rutting measurements

Figure 7 shows the scatter plot of the repeated rut measurements including the calculated regression line.

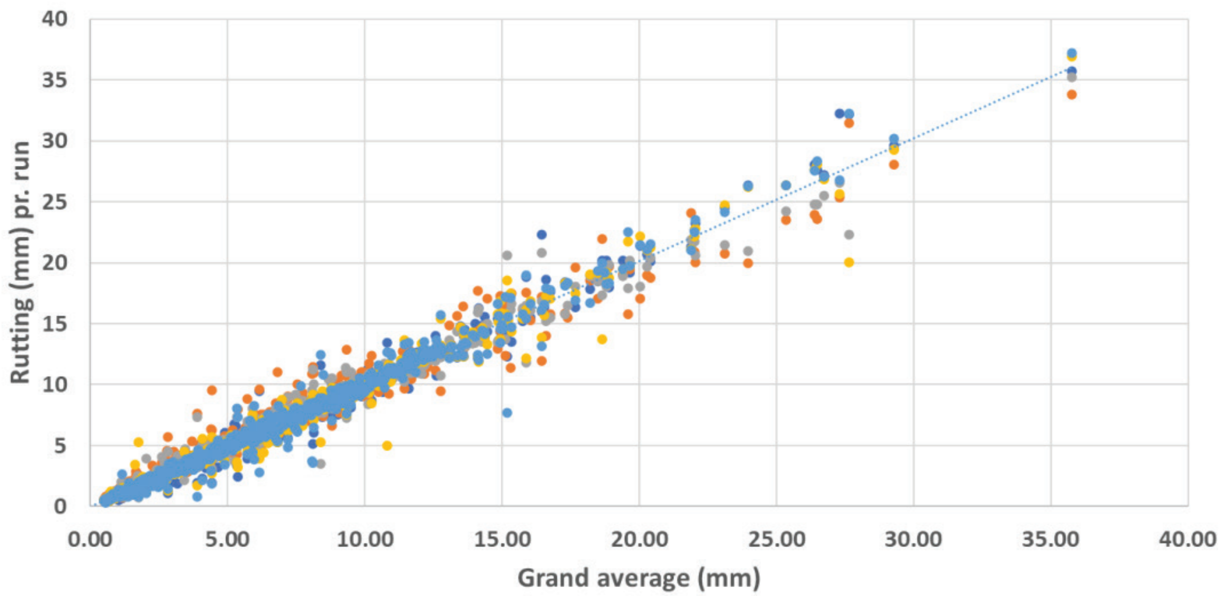

Figure 7: Scatter plot of repeated rut measurements

Calculating the correlation and the R2 value shows a goodness of fit between the runs of y = 1.00x with an R2 of 0.99. The standard deviation of the residuals is calculated to 0,67 mm. For the determination of rutting, an excellent repeatability is obtained, and it can be concluded that rutting measured by the iPAVe can be determined with an accuracy of 91%, when measuring on in-service roads.

Pavement macro texture

The evaluation of the pavement macro texture is normally represented by calculating the Mean Profile Depth (MPD) and is usually calculated in both wheel paths and in-between wheel path. To determine pavements macro texture is important in relation to traffic safety, thereof to map the risk of low tyre/pavement skid resistance and the pavements' ability to minimise splash and spray, when the pavement is wet. For the investigation of the iPAVe's ability to measure pavement texture, the calculated MPD in the outer wheel is used in the analysis. Figure 8 shows the MPD from the five runs on the road section.

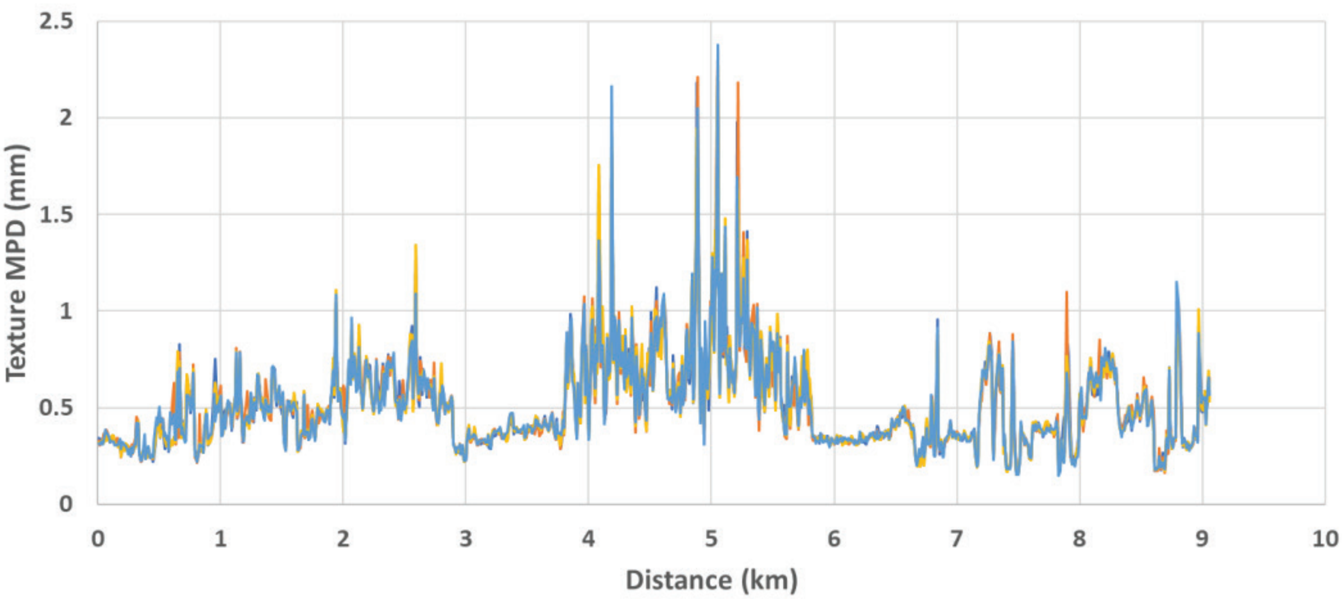

Figure 8: Five repeated MPD measurements

Figure 9 shows the scatter plot of the repeated rut measurements including the calculated regression line.

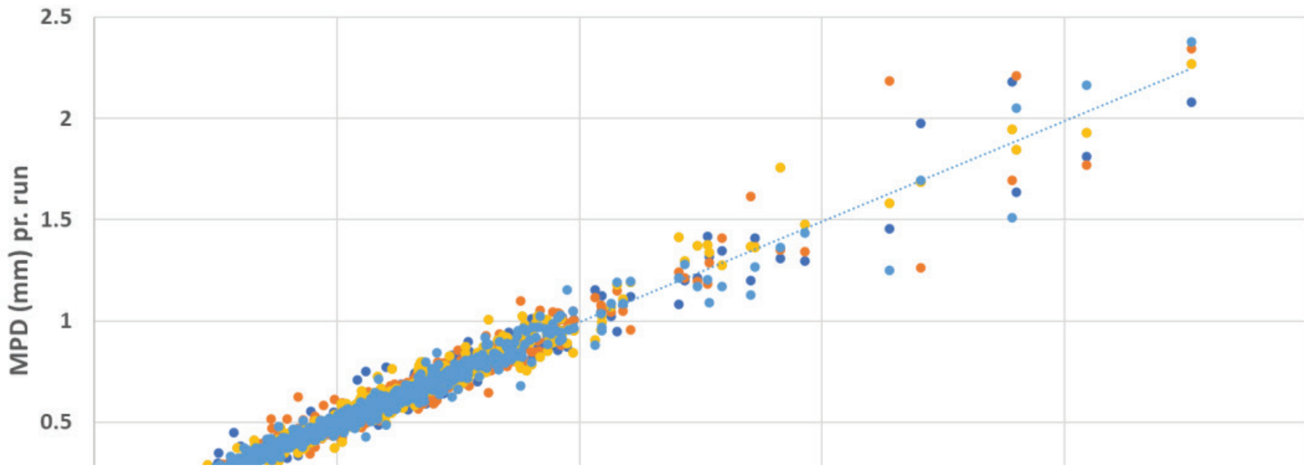

Figure 9: Scatter plot of repeated MPD measurements

Calculating the regression and the R2 value shows a goodness of fit between the runs of y = 0.99x with an R2 of 0.99. The standard deviation of the residuals is calculated to 0.037 mm. For the determination of MPD, an excellent repeatability is obtained, and it can be concluded that MPD measure by the iPAVe can be determined with an accuracy of 96%, when measuring on in-service roads.

Pavement deflection represented by structural curvature index (SCI 300 µm)

The iPAVe measures the full deflection curve as shown in figure 10 during measurements, by using the integrated Traffic Speed Deflectometer.

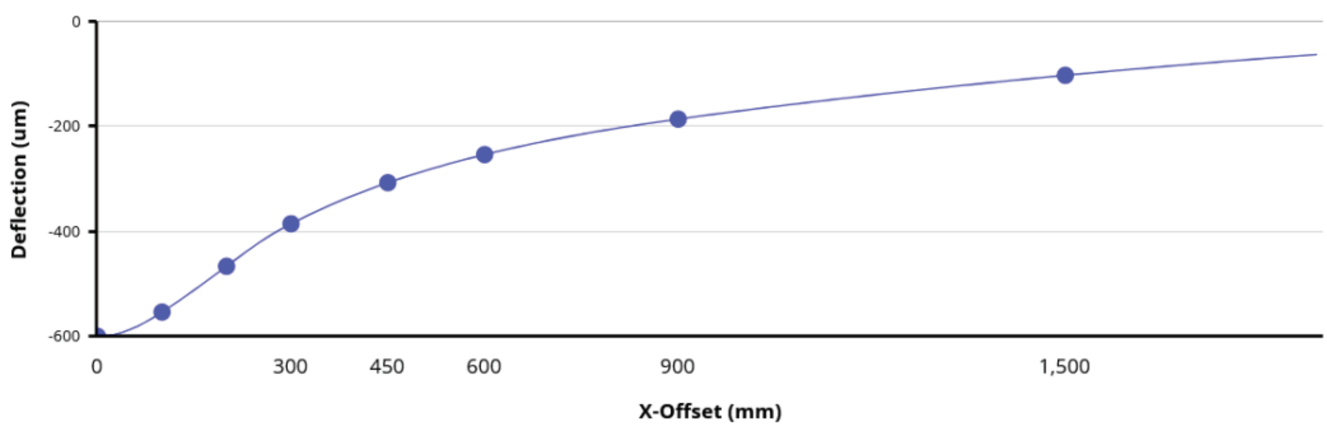

Figure 10: Typical deflection bowl obtained by the iPAVe

To analyze the structural capacity of the pavement. several indices can be used which represent the stiffness of the different layers in the road construction. To illustrate the capacity of the iPAVe, in relation to detecting the structural capacity of the road pavements, the Surface Curvature Index (SCI) 300 mm is used. The SCI300 is the difference in measured deflection under the centre of the loading plate and 300 mm from its centre. SCI300 is the characterizing factor representing the stiffness of the upper part of the pavement structure

Figure 11 shows SCI300 from the five repeated runs, and figure 11 clearly shows there is a good correlation between the different runs.

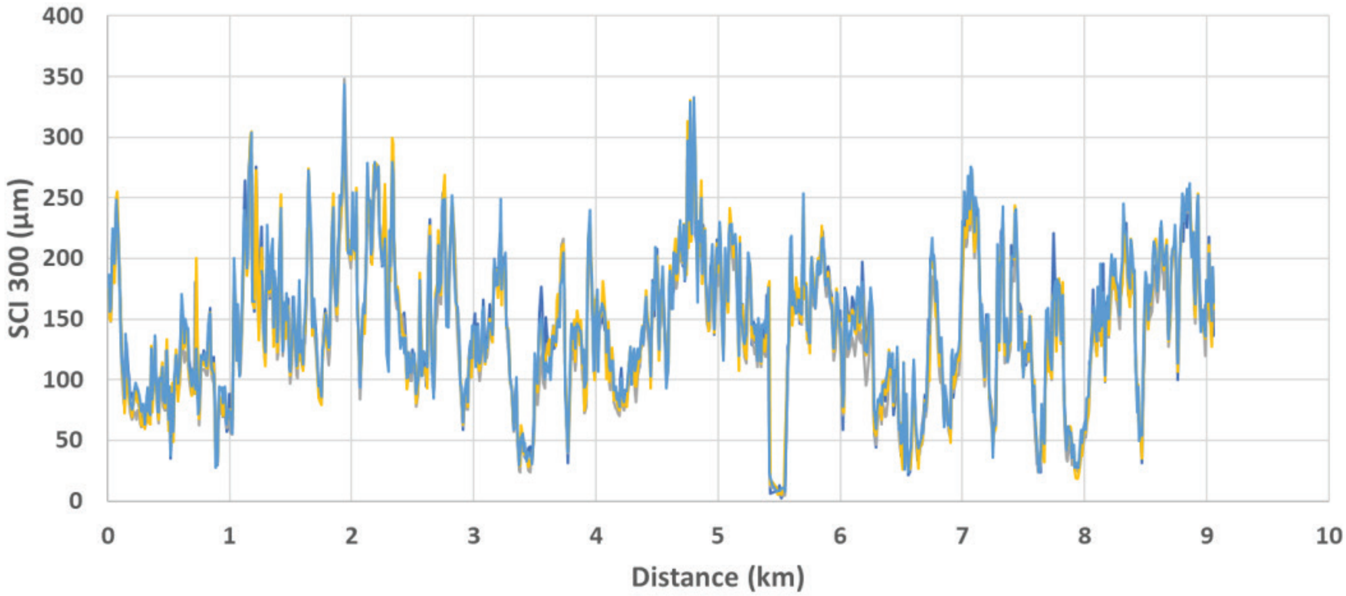

Figure 11: Five repeated SCI 300 measurements

The scatter plot in figure 12 supports the visual interpretation of the correlation between the SCI300 values obtained through the five runs on the road section.

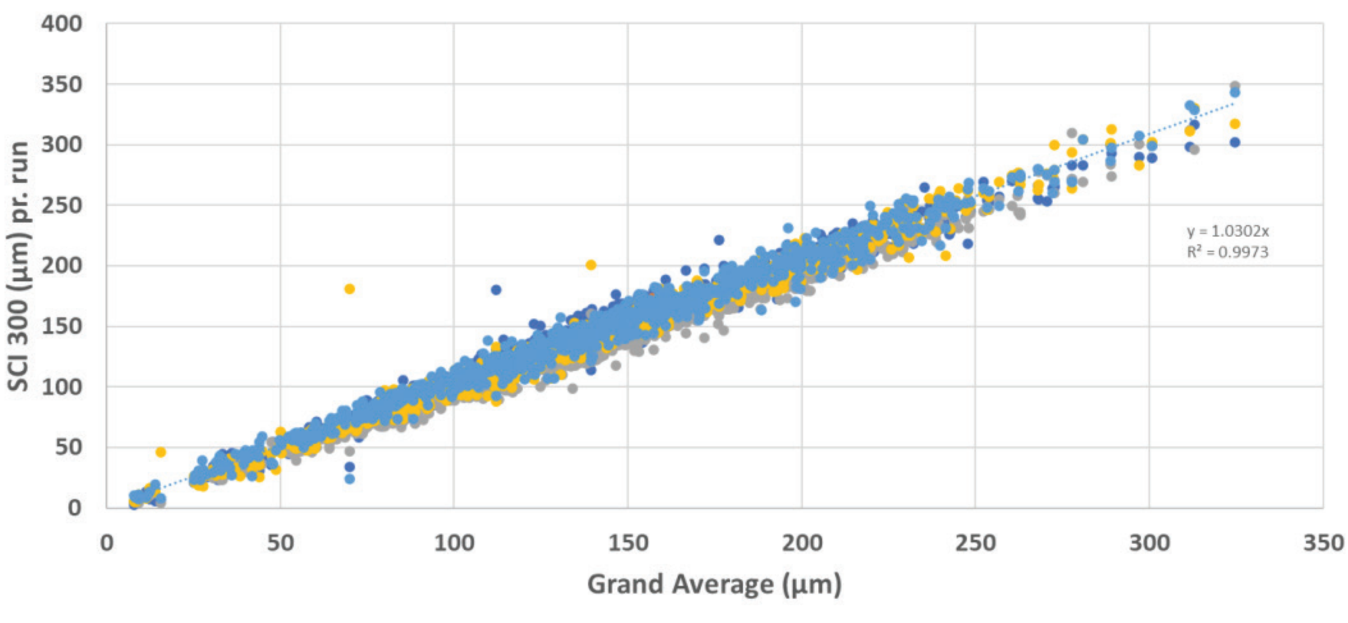

Figure 12: Scatter plot of repeated SCI300 measurements

Calculating the regression and the R2 value shows a goodness of fit between the runs of y = 1.03x with an R2 of 0.99. The standard deviation of the residuals is calculated to 8.3 µm. For the determination of SCI300, an excellent repeatability is obtained, and it can be concluded that SCI300 measured by the iPAVe can be determined with an accuracy of 95%, when measuring on in-service roads.

Test of alignment when performing repeatability tests.

The key to a successful repeatability test is that the data between the different runs are aligned and hence provides for a point-to-point correlation, between the measurements. The iPAVe positions the measured data by using five GPS positioning systems. This provides an accurate identification of the position of the data on the road. To test the alignment of the data and thereof the iPAVe's ability to correctly position the data point, the longitudinal profile of each run was aligned and the shift in the profile that gave the best fit of the data was calculated. This exercise gave a value for the accuracy ofthe data position of approximately 1 meter in average. This is considered acceptable, taking into consideration that the measurements were done during traffic speed and on an in-service road.

Conclusion

The measurements conducted in Slovenia, to test the validity of the data provided by the iPAVe, clearly shows a high degree of correlation and repeatability. The average accuracy of the test parameters is93%. The tests clearly showed measurements undertaken on in-service roads, during normal traffic, will produce reliable data to be used in connection with strategic maintenance planning of present rehabilitation needs. Also, the credibility of the data provides a solid background for forecasting maintenance needs, when used in connection with road infrastructure asset management.