PAVEMENT CONDITION VISUALISATION INTEGRATED WITH IMAGES OF PAVEMENT SURFACE

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ABSTRACT

One of the solutions used by road administration in Germany to assess the results of road condition evaluation is presented in the paper. The solution, called ZEB-Visu or formerly TP3-Visu, consists in displaying highly aggregated decision-critical information about the road condition together with surface Makro pictures. Surface Makro pictures are digital images of the pavement acquired in order to evaluate its condition. This paper presents software which is needed to handle and visualize such information. The method of distresses evaluation used in measurement and evaluation campaigns in Germany is described for reference.

1 INTRODUCTION

Pavement condition evaluation is an essential part of road asset management. Large amounts of measurement data are acquired using high-end technology and then processed to obtain results which are tractable with pavement management systems, i.e. aggregated to large parts of road network (maintenance sections). These results are the basis on which decisions concerning the road maintenance are made. There is however a need to make the detailed, raw data also accessible to the decision maker. Satisfying this need gives the aggregated data much more credibility and acceptance, since it can be verified on the level of single distresses, short critical sections and elementary unprocessed data.

The procedure of pavement condition evaluation used in Germany follows this approach. The data collected during surveys using measurement systems moving at traffic speed is transformed to a standardised, XML-based form, where the standard is imposed by the state-wide Federal Institute for Roads (German: *Bundesanstalt für Straßenwesen*, BASt). Surveys are conveyed on a regular basis, organised in measurement campaigns which repeat every 4 years (for federal roads and motorways). The measurements include 4 subprojects: longitudinal evenness, transverse evenness, skid resistance and surface distresses.

The measurement of surface distresses (called *Teilprojekt* 3 or TP3) is unique since it applies human expertise as part of the measurement process. Occurrence of cracks, patches and other distresses is identified in the pavement surface images and coded with precision of one square meter. The pavement images allow a very detailed evaluation of the surface – cracks as thin as 1 mm should be visible and identifiable (BASt 2006).

After a series of transformation and aggregation procedures, the results of TP3 coding, together with measurement data from different subprojects, take a form of an integrated report on pavement condition, consisting of profiles and maps combining raw and aggregate information. Using ZEB-Visu software these results can be easily browsed, i.e. one can view the results of the condition evaluation for a requested piece of road network. Additional to these high-level and aggregate data, detailed coding of distresses coupled with the underlying Makro pictures is available for viewing (see Figure 1 and Figure 2).

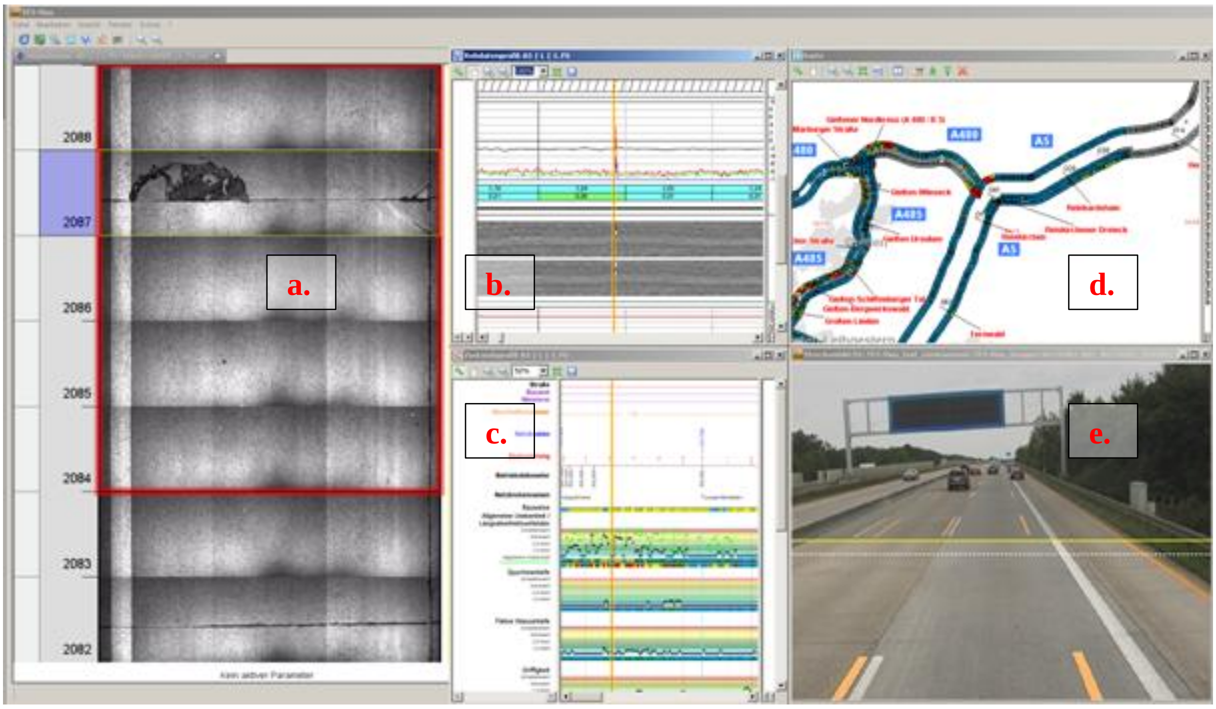


Figure 1: Example of navigating through evaluation results using ZEB-Visu. The following windows are shown: **a) Operations:** distresses coding laid over surface pictures **b) Raw profile:** detailed pavement condition profile including meter samples **c) Condition profile/strip:** overview pavement condition profiles (resolution 100m sections) **d) Condition map e) Right-of-Way picture**.

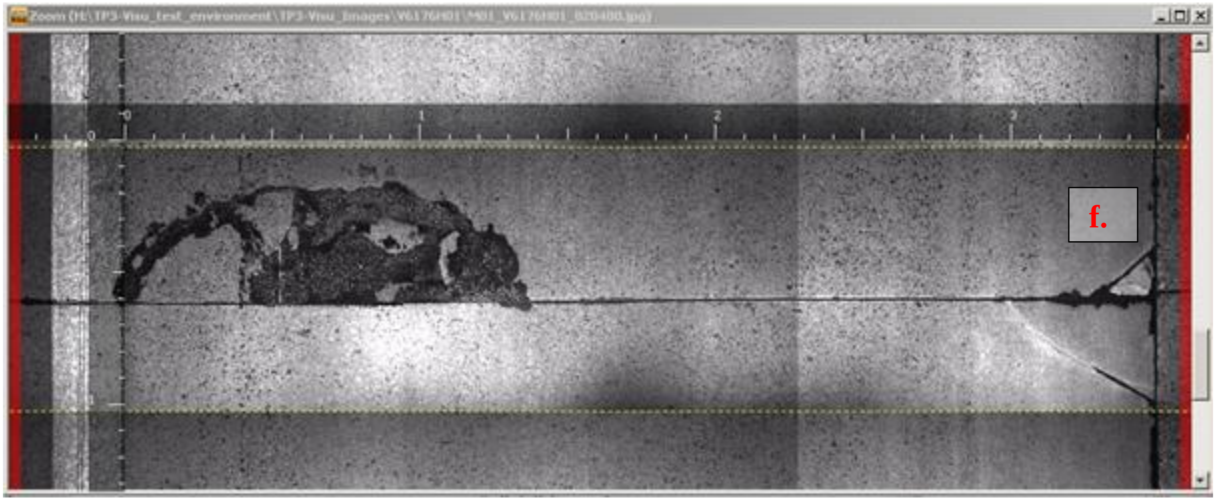


Figure 2: Close-up on the **f) Makro-picture window** of ZEB-Visu

To obtain such set of results, road administration authorities must implement certain processes of standardisation and quality control, so that companies and administration units deliver data of uniform and high quality.

This paper is organized as follows. The second section briefly summarizes the distresses evaluation procedure used in Germany is briefly presented. The third section describes organisational and practical issues concerning the process of identifying of distresses based on a set of Makro pictures. The fourth section consists of some examples of use of the ZEB-Visu solution.

2 SURFACE DISTRESSES IDENTIFICATION

The main reason why distresses identification is conducted is the importance of cracking. Cracking is the symptom of depletion of carriageway's load capacity. Appearance of cracks indicates that, assuming the same amount of traffic, the condition of the pavement will rapidly deteriorate. Keeping the extent of cracking under control allows us to prevent this from happening.

Other techniques of investigating load capacity are discussed, like following a full mechanistic approach by determining the layer structure of the carriageway or conducting deflection measurements (Janowski 2008).

Determining the layer structure, by means of core extraction and geo-radar analysis require considerable engineering knowledge to be carried out properly, which condition not always is possible to satisfy. What is more, it has significant costs and is used for detailed inspections of selected portions of roads rather than whole-network surveys, necessary for PMS.

Most deflection measurement techniques popular at the moment require the measurement system to stop or move at very low speed during the measurement. Until measurements using systems like Traffic Speed Deflectometer are accepted as an alternative, deflection is a parameter which is also quite hard to measure at a network scale.

The German road administration authorities are consequent in using cracking (and to some extent patching) as indicator of problems with low load capacity. This is reflected by the way the construction value (German: *Substanzwert*), which represents the condition of pavement's construction, is computed. Even though the formula for its value is more complex, one can assume that it is a weighted average of 3 components, one of which represents the extent of cracking (with weight 50%) and the other the extent of patching (with weight 25%). Thus 75% of the pavement construction condition evaluation is based on surface distresses.

3 SURFACE DISTRESSES IDENTIFICATION – PRACTICE

The process of distress identification is, especially in case of federation-wide measurements, a huge undertaking. It involves various organisations and requires cooperation between them and covers over 10 000 km of lanes.

It is a part of a bigger process namely the process of identification and evaluation of pavement condition as far as TP3 (subproject: surface distresses) is concerned. One can describe the steps of this process as (see Figure 3):

1) Acquisition of surface pictures, where the photographic material is collected, producing unstandarised raw data, dependent on the measurement system used.
2) Standarisation of surface pictures, where this data is transformed to meet the BASt standards. This data is independent of the measurement system used is subject to quality control processes to eliminate faulty measurements etc.
3) Identification of distresses itself. Results in standardised *Georohdaten* (German: raw geographical data) which consist of XML files with the coded distresses and pictures. This data is localised only by geographical coordinates.
4) Projection on network model, where geographically localised *Georohdaten* are bound to a network model.
5) Evaluation & analysis, where the aggregate parameters are calculated and pavement condition is evaluated. This stage involves other measurements like unevenness and skid resistance.

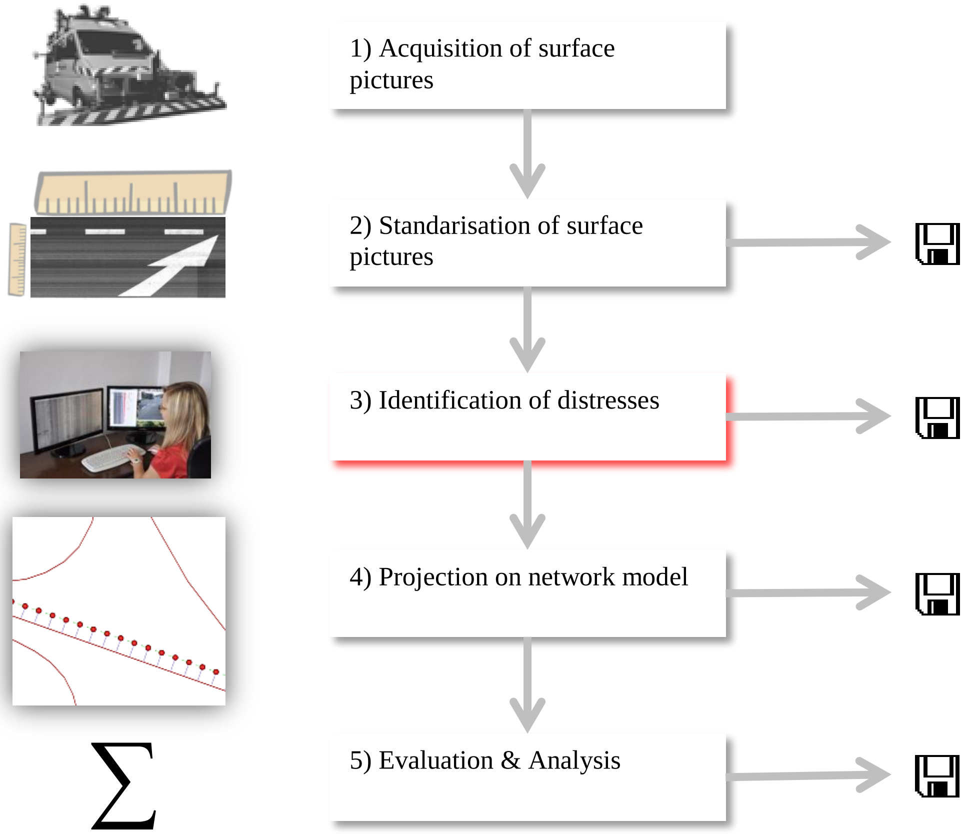


Figure 3: Outline of the procedure of surface distresses evaluation in Germany – part of ZEB procedure. Almost every step yields a result subject to rigorous quality control and available to the end user – road administration.

We will focus on the third stage “Identification of distresses”. The procedure of conducting federal-wide measurements in Germany, which are described here, is regulated by (BASt 2006).

The most important distress which is identified is cracking; however, occurrence of other features like patching, open seams, potholes and binder accumulation is also collected (see Figure 4). Patching is the second-most important, since it represents the distresses which it had repaired.

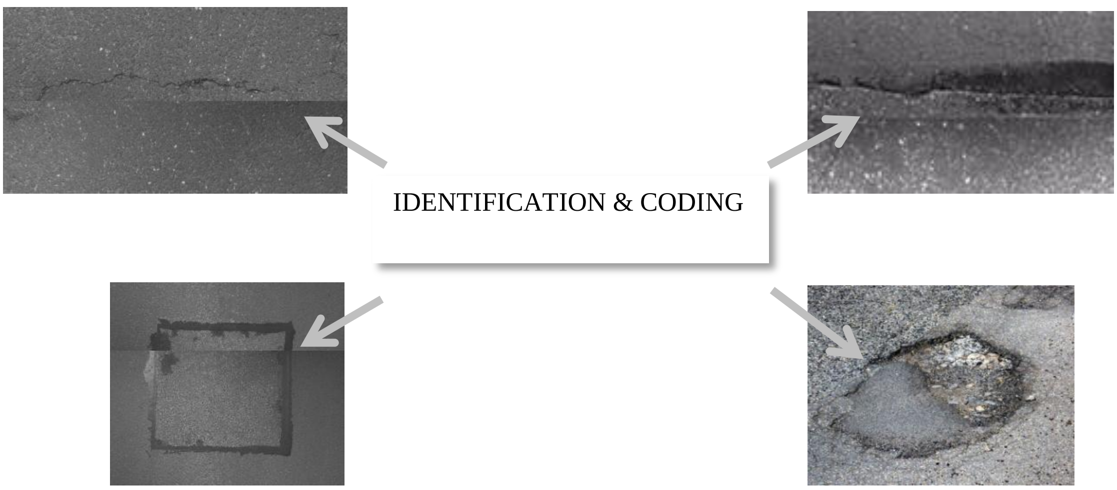


Figure 4: Cracking, patches, open seams and potholes being identified and coded.

On asphalt pavements (dominant in Germany) distresses are coded as binary (yes/no) variables on a grid laid over the pavement surface. The grid has 3 cells each having an area of approximately one square meter (1 meter times 1/3 of the lane width), see Figure 5.

The identification follows meter-by-meter, so every piece of the identified pavement is inspected. The operator decides whether a distress (i.e. cracking, pothole etc.) appears within the given cell or not. The borders of the lane need to be taken into account while determining the coding of distresses. For lanes lying between other lanes, the border reaches up to the center of the lane marking.

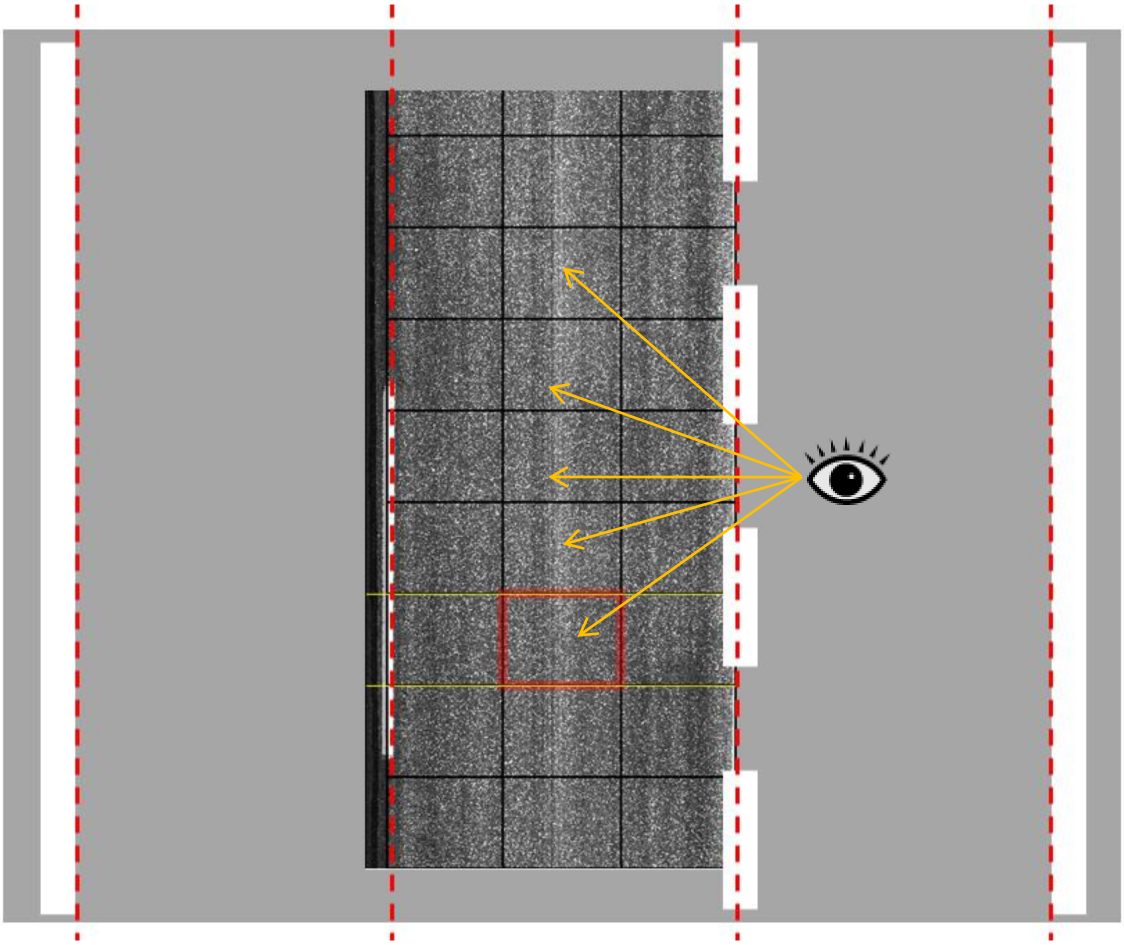


Figure 5: Coding of distresses on asphalt pavements. Red dashed lines represent borders of lanes designed for identification. One example Makro pictures is shown together with the corresponding division of the lane. Each cell is 1 meter long and approximately 1/3 of the lane width wide.

Thanks to the application of the standardised *Georohdaten*, the results of the coding are precisely localised and synchronised with the underlying images. Working with bare *Georohdaten* is unfeasible, therefore there are solutions (based on a concept similar to that of the ZEB-Visu) to display and browse the pictures and to code the distresses. The coding is done using various tools of the user interface (keyboard shortcuts, multiple cell selection), so the operator can concentrate on the features of the pavement. The key concept is for the operator to have all information he needs in every moment of his work.

The important part of the technology behind the results of the distress identification is the organisational and quality-assurance related side of the approach. The results of the coding (done by operators) are centrally stored and processed. The operator only has to press a “Save” button and his current results are committed to the central database, along with such information as time spent on a given road section, number of coded distresses etc. The results undergo detailed control procedures like:

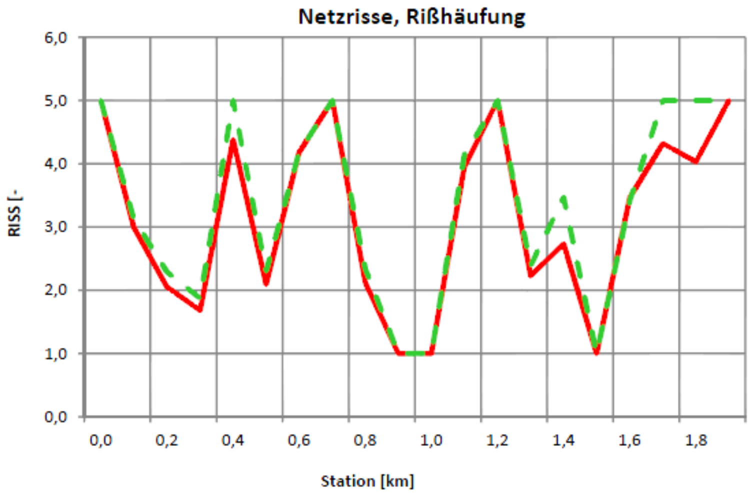
- examination of selected sections by an experienced professional,
- examination of sections done at exceptionally high speed or with no distresses present as well as
- regular repeatability tests called *Eigenüberwachung* (German: self-monitoring).

Repeatability tests are coding tasks done for the same portion of road network by distinct operators. Both results of such parallel coding are then compared, with respect to mean difference and standard deviation of the differences. Both should not exceed a specified threshold, so that it is certain, that the results acquired during the coding process are independent from whichever operator produces them. Example *Eigenüberwachung* protocol is presented on Figure 6.

Eigenüberwachung im Teilprojekt 3

Land: **Fahrstreifen:** 1 **Lage:** R
Strasse: **Bauweise:** Asphalt
amtl. Kennzeichen des Messfahrzeuges:

	Dateiname	Messdatum	Auswerter	Linienart		von NK:	nach NK:	Station:
Erstauswertung:		23.11.2011			Anfang:			
Zweitauswertung:		25.11.2011			Ende:			



Vergleichs-km von	bis	Auswertung 1.	2.
0,000	0,100	5	5
0,100	0,200	2,99	3,13
0,200	0,300	2,05	2,29
0,300	0,400	1,68	1,87
0,400	0,500	4,38	5
0,500	0,600	2,09	2,31
0,600	0,700	4,18	4,18
0,700	0,800	5	5
0,800	0,900	2,12	2,34
0,900	1,000	1	1
1,000	1,100	1	1
1,100	1,200	3,95	4,14
1,200	1,300	5	5
1,300	1,400	2,23	2,39
1,400	1,500	2,73	3,47
1,500	1,600	1	1
1,600	1,700	3,47	3,42
1,700	1,800	4,32	5
1,800	1,900	4,03	5
1,900	2,000	5	5
Mittelwert:		3,161	3,377

Mittelwert der Differenzen: -0,216 **Standardabweichung der Differenzen:** 0,290
zulässige Abweichung: 0,500 **zulässige Abweichung:** 0,500

Figure 6: Actual *Eigenüberwachung* protocol of TP3 (anonymised) . The graph represents an evaluation of cracking on a 2 kilometre section based on identification done by two distinct operators (red and green line). The result of the control is positive, although there are slight differences.

A similar procedure is used by the authority (BASt) to control the results externally – selected sections of the network are measured twice: first time by the company which delivers the results, second time by a controlling company. The two sets of results must not differ in terms of mean and standard deviation.

4 ZEB-VISU – EXAMPLES OF USE

In the following sections four examples of use of ZEB-Visu are presented. All images are screenshots of actual program use. All views in the program are navigable, e.g. the user can click on a profile and jump to a desired location to see the remaining features like surface and right-of-way pictures, map and distress coding details.

4.1 Verify bad condition area (cracking)

Simplest case of use of ZEB-Visu is to verify the coding (and thus the condition evaluation), where the pavement is, according to the evaluation results, in very bad condition.

Such example can be found in results of the measurement campaign 2009 done on federal motorways (Figures 7 and 8)

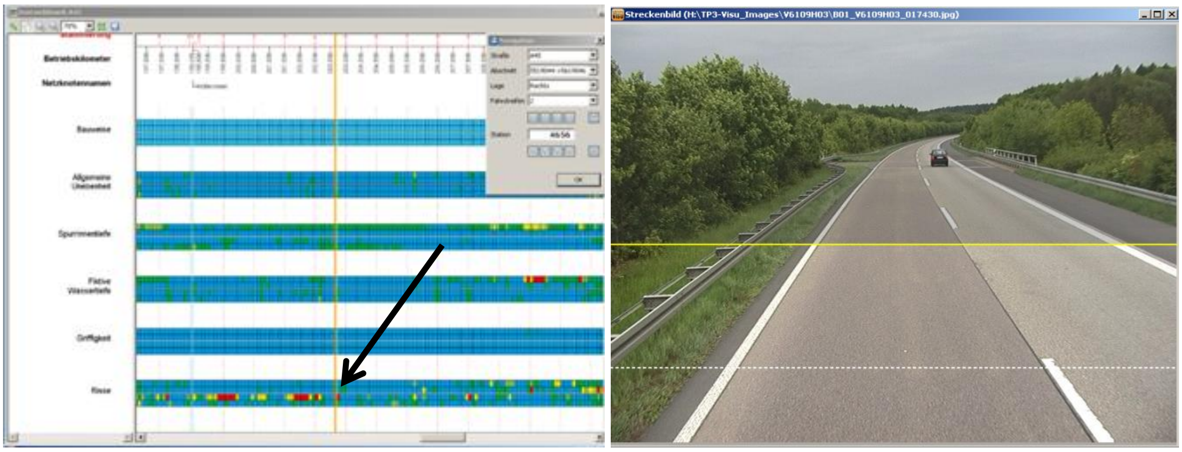


Figure 7: A single 100m section with a high amount of cracking is spotted on a condition strip. Right-of-way picture is not conclusive; the pavement seems to be in good condition.

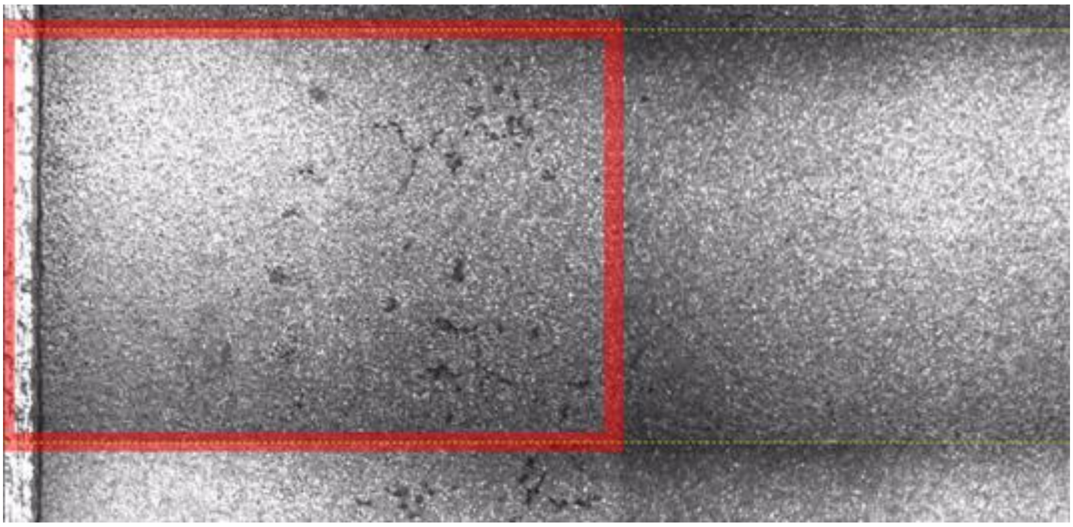


Figure 8: Makro picture reveals cracking near left hand edge of the lane

4.2 Verify unexpected condition values (longitudinal unevenness)

Sometimes the result of a survey may be strongly biased by a single feature of the pavement which gives very high values of evaluation parameters. Obviously unevenness parameters are sensitive to all sorts of bumps and sinks in the pavement. One of parameters, calculated according to guidelines and algorithm in (BASt 2006) and (Löcherer 2009) is the LWI

(German: *Längsebenheitswirkindex* – longitudinal evenness action index), that monitors the influence of unevenness on the vehicle components and the driver.

A section where LWI reaches high levels is presented below on Figures 9 and 10.

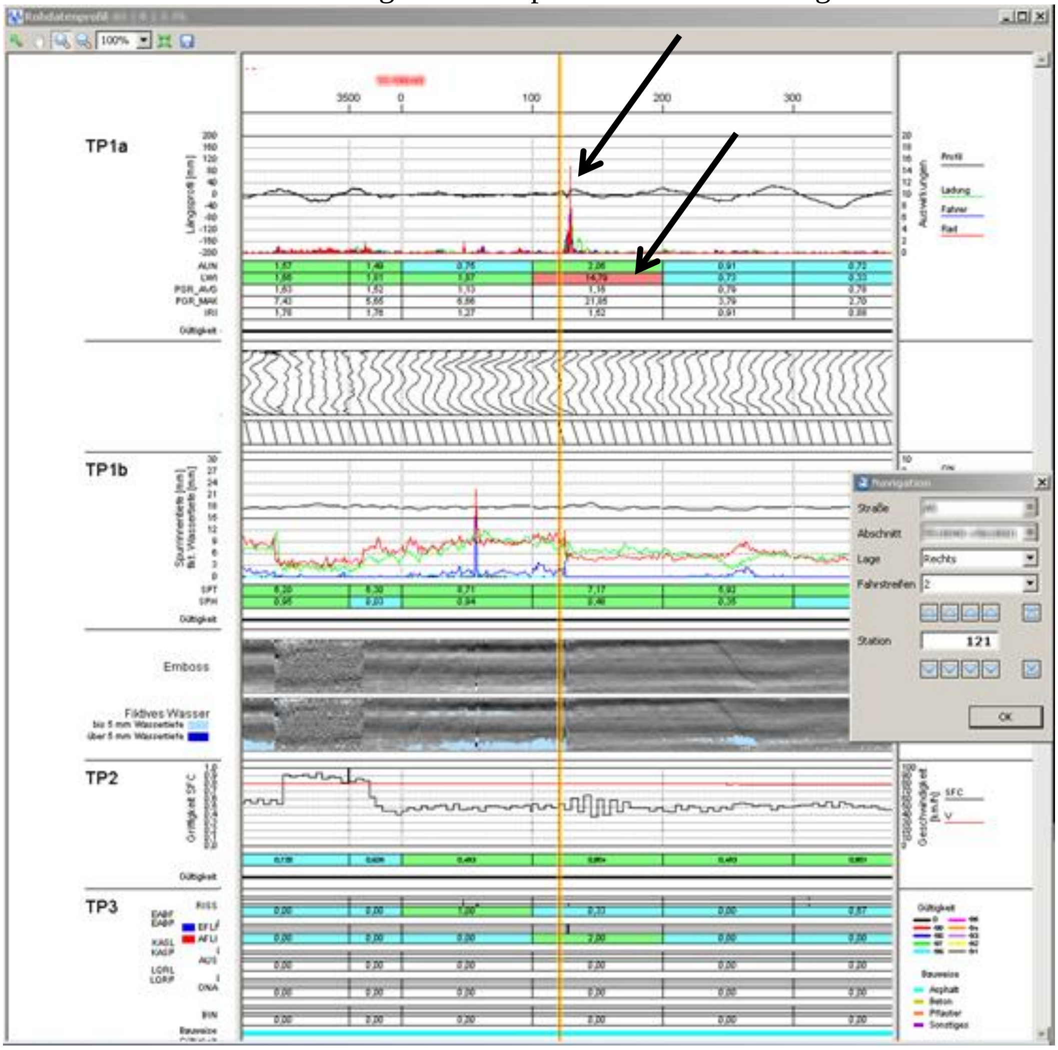


Figure 9: A 100 meter-long section where LWI has high value (red rectangle and peaking graphs within its range). No other parameter indicates bad pavement condition in this area – there are only green and light blue boxes.

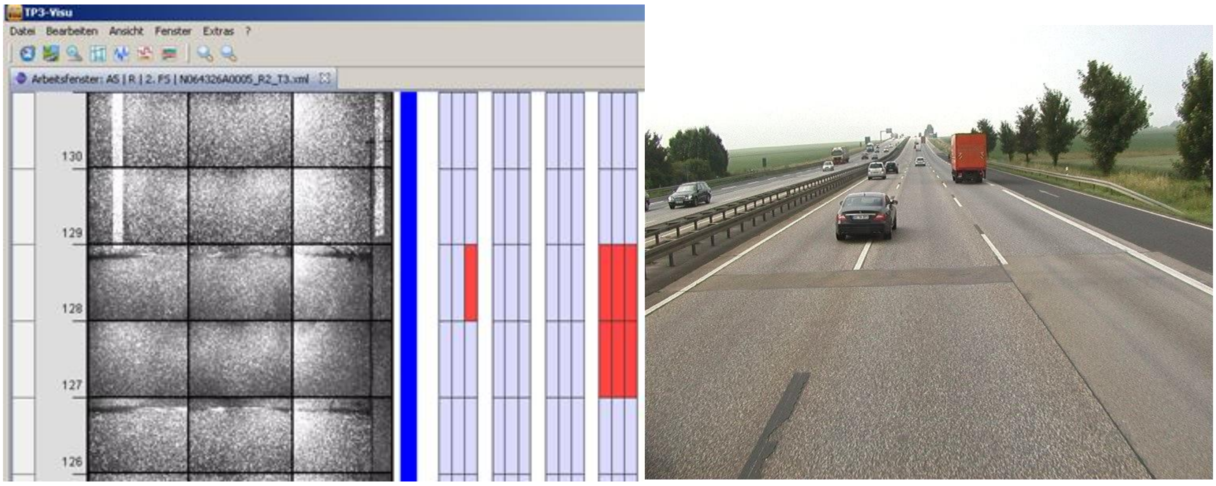


Figure 10: Makro picture (Operations window) and right-of-way picture reveal a patch causing the high values of LWI. The coding of the patch can be seen – red cells.

4.3 Verify condition transition spots

Sometimes a spot of transition in pavement condition (i.e. good to bad or bad to good) can be observed. This may be due to a pavement treatment which took place in the past, faulty construction of a given section or any other reasons. Someone responsible for efficient pavement management should be able to investigate it.

A section where rutting evaluation changes rapidly is seen on one of the roads in Poland (see Figures 11 and 12).

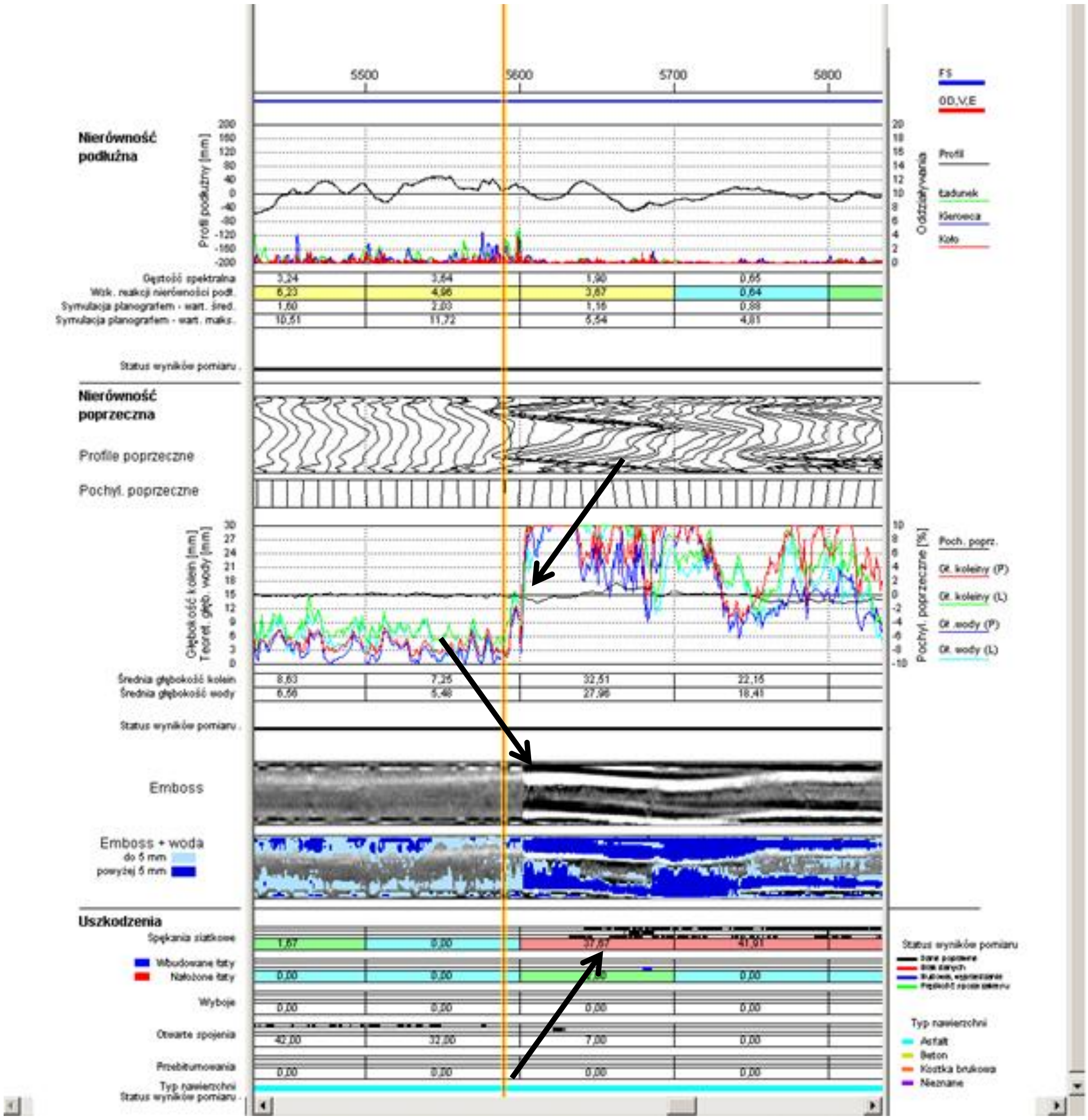


Figure 11: Transition of rutting condition evaluation. The high values of the graphs indicate extreme rut depths. The 3D-image of the ruts reveals transition point. One can also compare this with results of crack identification – the section after the transition point has much more cracking (red coloured rectangles).

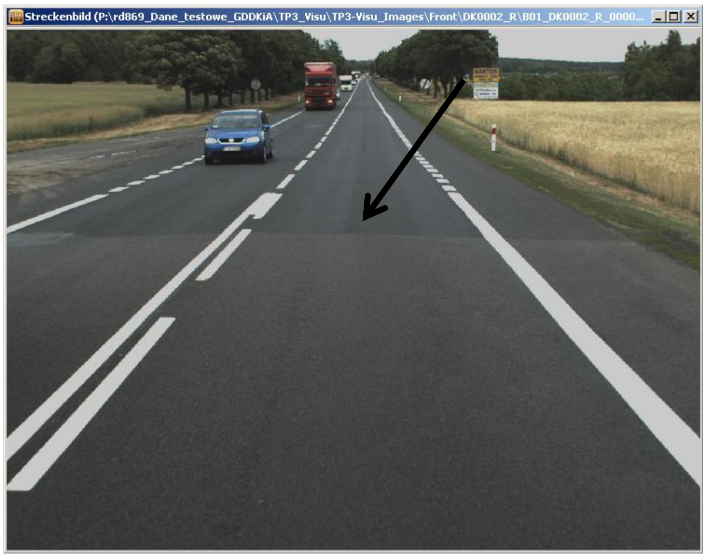


Figure 12: Rutting depth transition point as seen on the right-of-way picture. The border between the section before treatment and the section after treatment is visible.

4.4 Determine cause of cracking

When the pavement condition evaluation provides information only on the appearance and extent of cracking, one might wish to investigate the cause of the cracking for a given section. The pavement condition evaluation procedure applied in Germany (BASt 2006) allows for such investigation, since the underlying pavement pictures are available to the road administration. Using ZEB-Visu one can determine that cracks as seen in Figure 13 have been caused by the alkali-silica reaction (ASR) in the concrete slabs. This may qualify the affected section for special treatment procedures (Anger 2009).

Figure 13: Cracks qualified as caused by alkali-silica reaction (ASR) during detailed analysis using ZEB-Visu

5 CONCLUSION

The presence and availability of surface pictures makes the pavement evaluation verifiable without the need of doing site inspections. Other road condition patterns, like local shifts of surface roughness or skid resistance due to patching, can be easily observed. The pavement condition evaluation process is no longer a “black box” which gives only final results in form of charts and tables.

Exposing the highly detailed and raw data gives insight into the nature of the pavement condition. It also provides better understanding of the algorithms and rules used during the evaluation. Allowing for this in an efficient, user-friendly and intuitive graphical interface has made advanced and specialised knowledge available.

Introduction of ZEB-Visu to the German road administration has led to an increase of acceptance and trustworthiness of pavement condition evaluation. This results in an increase of acceptance of decision support provided by PMS-Systems.

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