METHODS OF ANALYZING SAFETY RISKS OF ROAD TRAFFIC USING PAVEMENT CONDITION INDICES

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ABSTRACT

The granting of traffic safety in accordance with accepted social standards is one of the main objectives of road maintenance. Road surface characteristics, such as skid resistance or unevenness combined with other road properties have high safety significance. For this reason, these safety-relevant road properties and systematic condition indicators have been detected during the nationwide, routinely realized condition monitoring and assessment (on motorways, highways and state roads) in Germany, and collected for more than 20 years at regular time intervals. Such properties include in particular skid resistance, fictive water depth, longitudinal evenness index and rut depth.

The determined condition indicators for skid resistance, fictive water depth (danger of aquaplaning) and rut depth are based on averaging. They serve as the basis for determining the road's serviceability value and are used for the purposes of medium and long-term maintenance planning.

However, the object-related statements about the actual or potential traffic safety risks of individual road sections based on these indicators, which have been determined by means of aggregation, mostly by averaging, are not allowed unlimited. Due to the variability of condition in the 100m assessment sections, and because of the fixed location of these sections, many dangerous points and road areas are not recognized by means of the 100m average values with regard to skid resistance and fictive water depth. For this reason, HELLER Ingenieurgesellschaft mbH has developed new condition indicators that are optimized specifically to describe safety aspects. These new condition indicators are based on the moving average value of the elementary condition data. The width of the evaluation window is variable and depends on the road class.

1 ELEMENTARY CONDITION DATA AS A BASIS OF STATE-OF-THE-ART CONDITION ANALYSIS

The correlation between pavement condition and traffic safety is ambiguous. Road accidents cannot be attributed to bad pavement condition only. In the majority of cases many factors are relevant. There is also no confirmed statistical relationship between pavement condition and road accidents. One of various reasons for this is that the specification of indicators of pavement condition is primarily geared to the goals of PMS and not to road safety aspects. For example, the length of the assessment sections (100 m) and the usage of average values are not suitable for road safety analysis.

Elementary pavement condition data can be used to develop alternative indicators, which are well adapted to traffic safety interests. They are not meant to replace existing indicators, but to complement them in such a way, that traffic safety can be better analyzed.

Over the last years, appropriate methods were developed in Germany and are currently used in operable projects.

The process of pavement condition monitoring and assessment (German abbreviation: ZEB) has been realized consequently on federal motorways and highways in Germany since 1992, divided into two sub-processes:

- Pavement condition monitoring
- Pavement condition assessment

During pavement condition monitoring, characteristics of road surface such as longitudinal evenness, transverse evenness, skid resistance and surface damages are explored with a very high information density and saved as so-called "elementary pavement condition data". In the course of the procedure, images of the surrounding road space as well as high resolution images of road surface are taken and saved.

During **pavement condition assessment**, these elementary pavement condition data is aggregated in assessment sections and pavement condition indicators are calculated.

As a direct result of the data monitoring process, files containing elementary pavement condition data with all information that is required for computing pavement condition indicators are obtained.. Transversal evenness, for example, is described by the transversal profiles of the unevenness, which are registered at a regular distance of maximum 1 m. Each of these transversal profiles consists of points at 10 cm distance and covers at least 3.2 m. Consequently, the transversal evenness of a 100 m lane section normally consists of at least 101 x 33 = 3,333 high points.

Longitudinal evenness is described by a so-called "real longitudinal profile" under the right wheel. The unevenness profile consists of the points at a distance of 10 cm, which are saved in the files containing elementary pavement condition data.

Skid resistance is determined as an SFC value (sideway-force coefficient) at a distance of 1 meter and saved together with several other variables such as speed, water temperature and air temperature in the files containing the elementary pavement condition data.

A virtual grid is used for encoding **road surface damages** and other properties (e.g. cracking, patching). Each grid segment (approx. 1 m^2) contains information on the respective type of damage. On concrete slab roads, damages are registered for every slab and saved with the elementary pavement condition data. In addition, high resolution images of the road surface (10 m x 4.5 m) as well as of the surrounding road area are taken by the front camera. These images represent a basis for (automatically or manually) encoding road surface properties.

In addition, **geometrical data** such as transversal slope, longitudinal slope and curvature are collected and encoded.

A particularity of the German ZEB is the standardization of elementary pavement condition data. Format and content of the data to be saved are defined uniquely and separately for each sub-project of the ZEB, as XML files. All companies participating in pavement condition monitoring are obliged to deliver their analysis results in such files. Figure 1 features a file fragment with elementary pavement condition data on transversal evenness.

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Figure 1: Fragment of a XML file with elementary pavement condition data

There are two types of elementary pavement condition data: the GEO-oriented pavement condition data (short: GEO-data) and the RASTER-oriented elementary pavement condition data (short: RASTER-data). The direct results of data collection are represented by the GEO-data. All data (data streams) are localized via the measurement vehicle's geographical coordinates. GEO-data are subsequently "projected" onto the respective road network, in order to establish a relation with the road network system. The GEO-data are projected onto the road network by means of a standard software called GEO-ROH-RASTER, provided by the Federal Highway Research Institute (BASt) and available to all companies participating in the ZEB for free.

The GEO-data exists since 1997 for all federal motorways and highways and describes the condition of more than 500,000 lane km. All elementary pavement condition data, as well as GEO- and RASTER-data including the respective images are managed by the BASt in a central information system on the IT-ZEB-Server and are provided for all interested and authorized users [Wasser (2011)].

Elementary pavement condition data represent the basis of various evaluations. Depending on the defined objective, these data are aggregated differently and various indicators are calculated.

The understanding of the XML files' contents, i.e., of the elementary pavement condition data, is rather challenging for most users due to the files' complex structure and considerable file size (several megabytes). Therefore, visualizations of elementary pavement condition data are increasingly realized on data profiles. A section of such a profile is shown on figures 2 (left side) and 3 (right side).

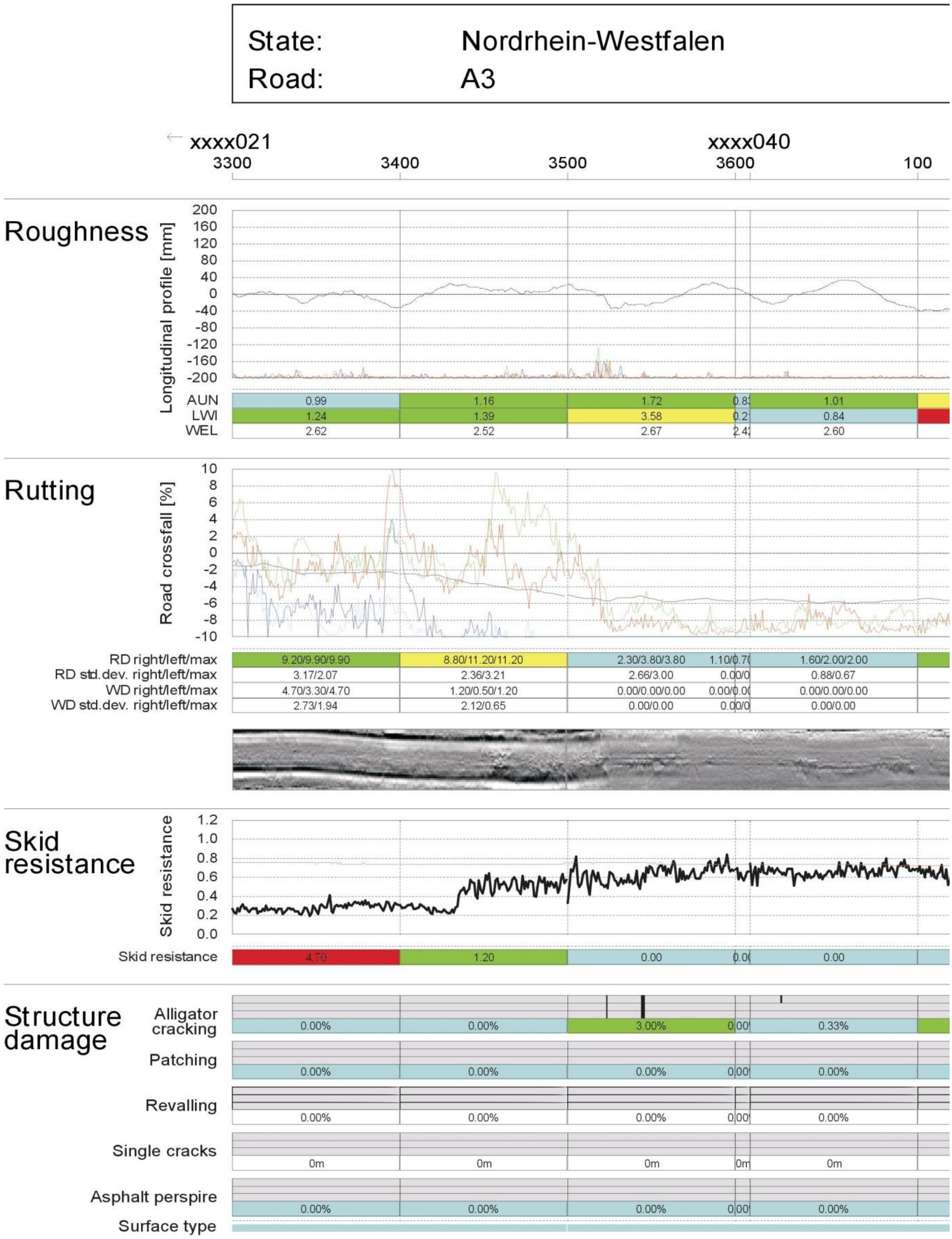

Figure 2: Visualization of elementary pavement condition data (left segment) [Heller (2004)]

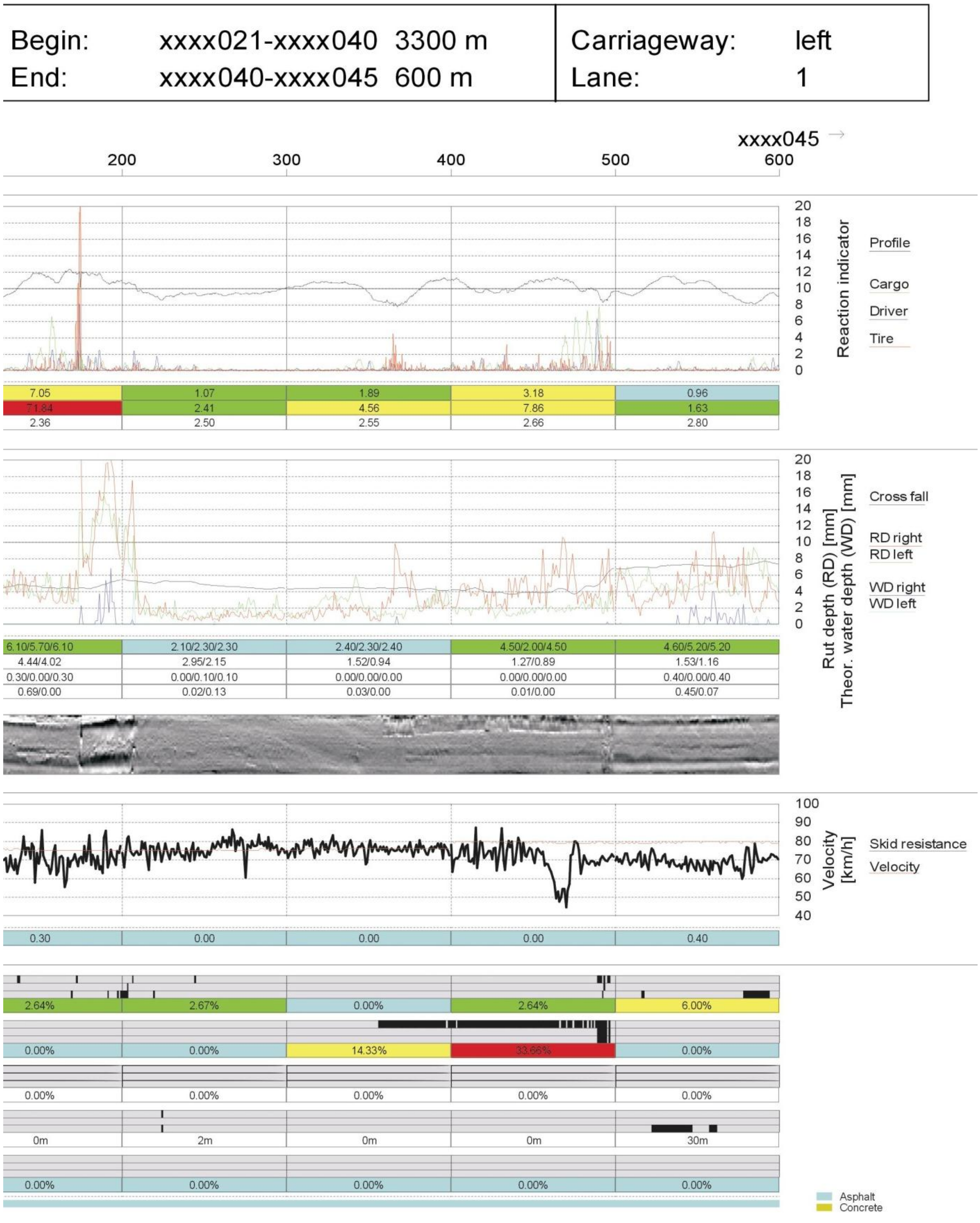

Figure 3: Visualization of elementary pavement condition data (right segment) [Heller (2004)]

2 TASK-RELATED PAVEMENT CONDITION ASSESSMENT

The elementary pavement condition data constitute the "real" and task-independent representation of the road surface. Thus, they serve as a uniform, standardized basis of further assessment and undergo various transformations, depending on the respective task. For "classical" ZEB assessments, a subdivision into a fixed grid of 100 m, while at cross-town roads, of 20 meters is made.

Pavement condition data are mostly used in maintenance management. Elementary pavement condition data are first aggregated in the assessment sections (100 m) and pavement condition indicators are identified for each section, such as average rut depth, average fictive water depth and average skid resistance. For maintenance management, data are further aggregated in longer, so-called "homogeneous" sections, taking other information, such as construction and traffic data, into account.

Condition indicators determined on the basis of elementary pavement condition data are adjusted for the respective applications. Similarly, condition values obtained from the condition variables during assessment are adjusted as well, see Figure 4.

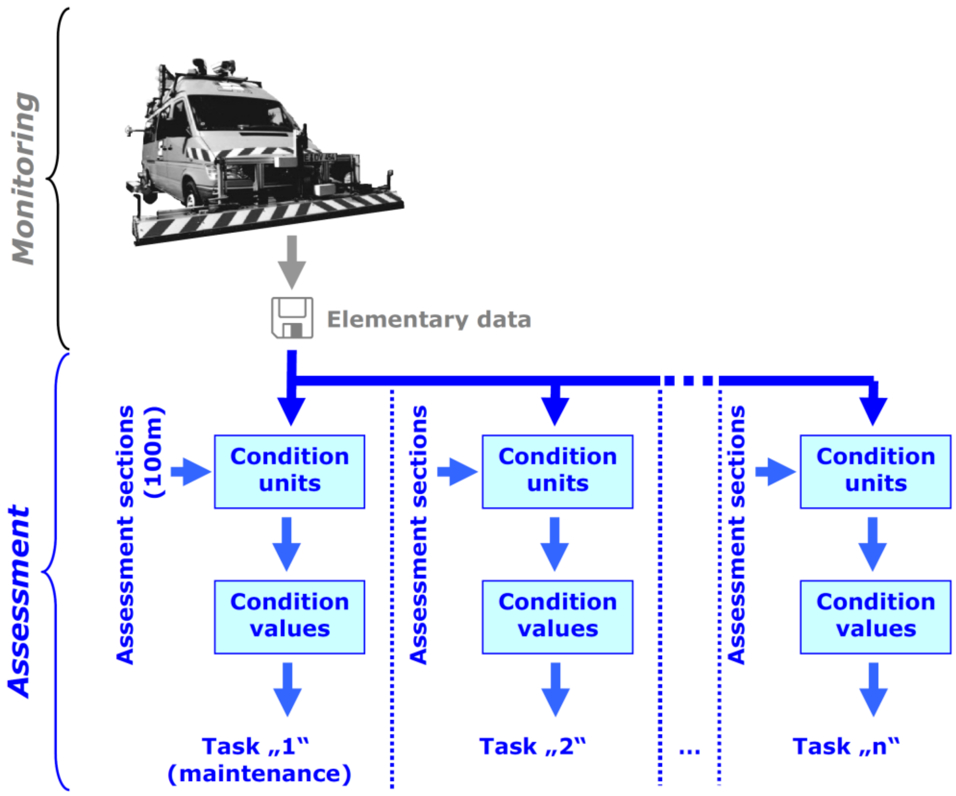

Figure 4: Task-neutral monitoring and task-oriented assessment of pavement condition data [Heller (2011)]

3 USE OF PAVEMENT CONDITION DATA IN THE ANALYSIS OF TRAFFIC SAFETY

Besides structural maintenance, traffic safety is one of the most important concerns of middle- and long-term maintenance management in road engineering. Within the frame of the ZEB-projects, pavement condition indicators oriented exclusively or predominantly towards safety concerns are regularly identified. These indicators include, e.g. skid resistance, fictive water depth and longitudinal evenness [Heller (2006)].

The 100 m section aggregation of elementary pavement condition data, which is reasonable for maintenance management and is mostly based on averaging, is not suitable for analyzing traffic safety. Averaging skid resistance or fictive water depth often leaves critical lane areas undetected. Figure 5 features profile with elementary pavement condition data for skid resistance. It can be clearly observed that there are sub-sections within the area of a 100-m-assessment section, which show rather low skid resistance. The length of these sub-sections exceeds 60 meters considerably, which justifies the need for observing such areas in more detail.

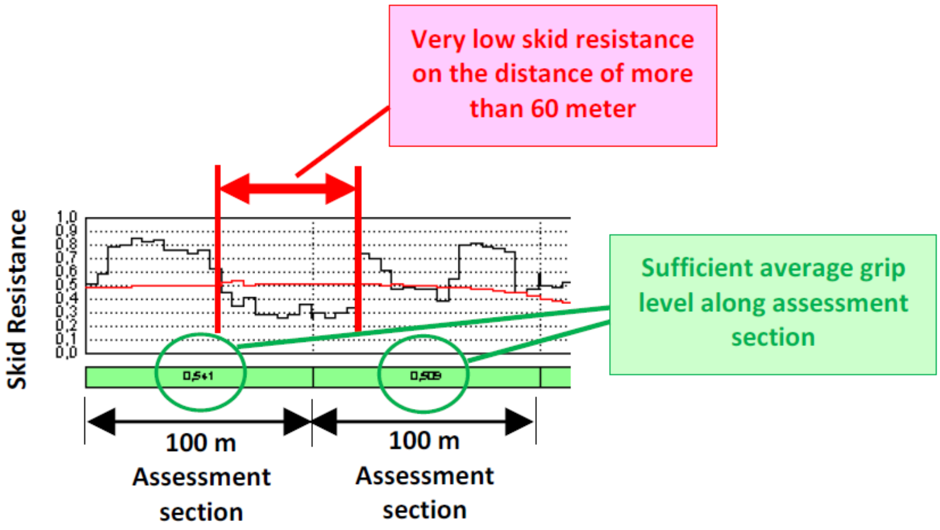

Figure 5: Variations of skid resistance in assessment sections

For this reason, an alternative procedure is used besides the "classical", average-based procedures for the assessment of such safety-relevant characteristics of road surface as for example skid resistance and fictive water depth. The alternative procedure helps detect further traffic safety-oriented pavement condition indicators, namely the worst moving average from all 30 m-sub-sections in the area of the respective assessment section. Accordingly modified limit values (critical values and warning values) are also defined for the new pavement condition indicators. These new limit values allow for the automatic determination of places with safety risks, see results in Figure 6.

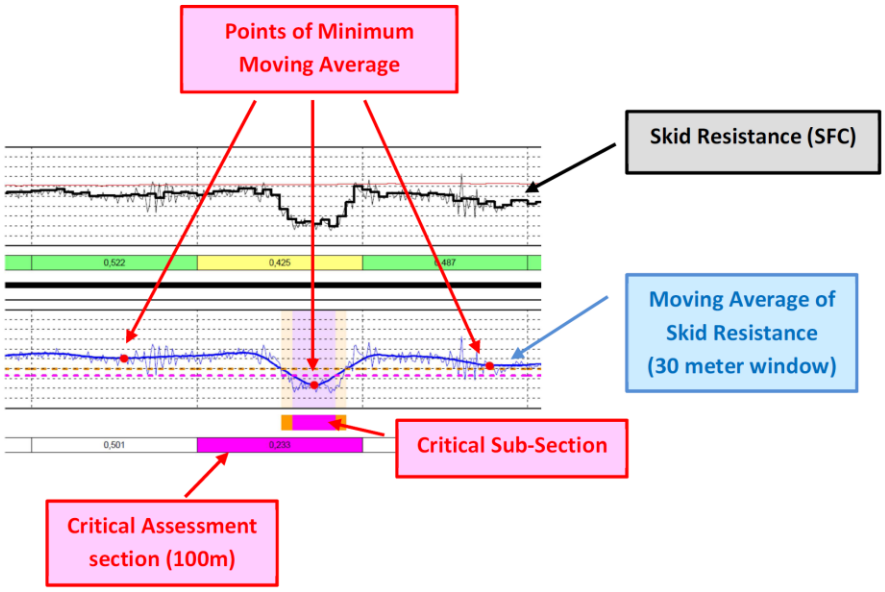

Figure 6: Profiles with elementary data and the places with safety risks defined by means of the moving average The elementary pavement condition data-based analyzes of places with safety risks are realized independently from the "classic" ZEB assessment. Federal states such as Hesse and Lower Saxony are already using the procedure in the entire road network (federal highways, motorways and state roads).

Experience has shown that more and more influential factors have to be considered when analyzing safety risks. Therefore, sections determined automatically on the basis of elementary pavement condition data are indications of possible risks. For a thorough safety analysis, further data must be included as well. This is reached by an information system, which provides many of these data as well as the strip maps in graphic form, for analyze of actual safety risks to be assessed in the most comprehensive and objective manner, see Figure 7.

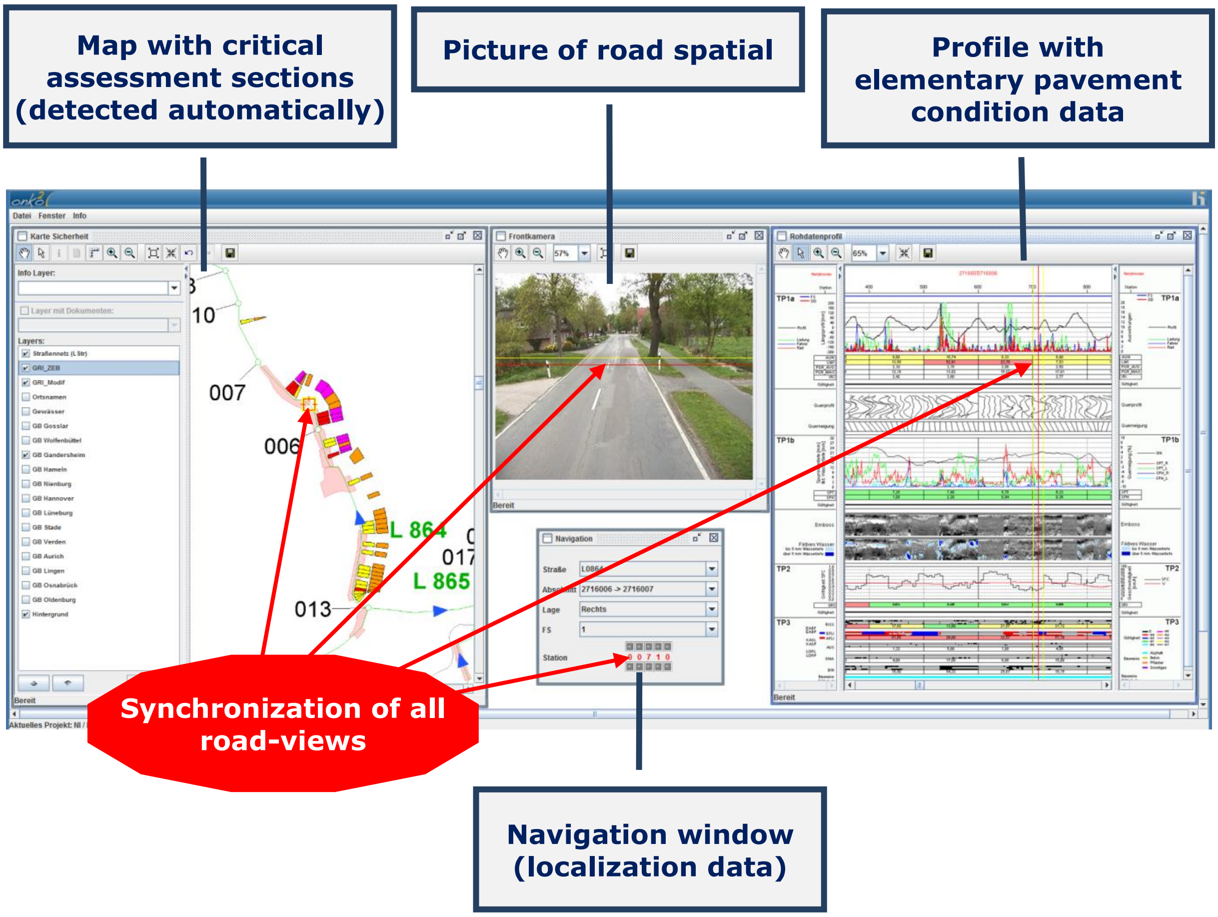

Figure 7: Application of information system OnKo2 for the analysis of safety risks

4 CONLCUSION

Experience has shown that elementary pavement condition data collected and archived within the frame of the ZEB-projects can be used even beyond maintenance management. However, this requires that further condition parameters adjusted for the respective task, be defined.

For the purpose of analyzing the safety risks of road traffic due to the poor condition of road surface based on average values measured at 100 m-assessment sections are not suitable. Instead, shorter sections should be used by means of the procedure based on moving averages. The procedure has been delivering plausible results for several years and it is being used in Warsaw (Poland) [Heller at al. (2010)], in federal states of Hesse and Lower Saxony on approximately 50,000 lane kilometers.

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