INTEGRATED EVALUATION OF RURAL ROAD NETWORKS

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Abstract: To ensure road safety and performance is of particular importance for the road network. This requires the compliance with minimum standards for the design of roads outside of urban areas resulting of technical and economical requirements. Procedures for verifying and evaluating road safety and road conditions are already available. Methods dealing with the evaluation of the road geometry of complete road networks do not exist yet.

Within a pilot study an investigation method for the geometrical evaluation of road networks has been developed. The geometrical evaluation is based on the “Guidelines for design and alignment of rural highways” (RAL, draft 08/2012). By using a predefined scheme deviations of road sections concerning alignment and cross section are determined and recommendations for expansions are derived. Due to economic restraints the recommended measures are not realizable immediately. Therefore an order of priority is necessary basing on the analysis of the road safety and the road conditions. The results can then be represented and visualized on maps, tables and road portraits.

Keywords: Road Safety, Evaluation of Alignment, Maintenance Management

1. INTRODUCTION

Roads need to suit the requirements concerning performance and road safety according to their importance within the road network. To fulfill these requirements the analysis and evaluation of roadway networks considering the current guidelines and research results is necessary. The evaluation can be carried out according to different aspects. The ESN (2003) and the ZTV ZEB-StB (2006) describe methods for the verification and evaluation of road safety and road conditions. By the use of “Pavement Management Systems” (PMS) road condition data can be managed and possible maintenance measures can be determined. However a method for an evaluation of the geometrical design of roads throughout a network does not exist. Therefore maintenance measures are intended (including the use of PMS-Systems) without considering deficits in the alignment.
Therefore it is the aim of this investigation to develop a (automated) method which enables an analysis and evaluation of an existing geometry of a road traffic facility. On this basis recommendations for reconstruction and expansion are given.

Considering economic restraints and conditions that have to be met a prioritization of methods dealing with maintenance, reconstruction and expansion is required. Therefore results of road safety analysis and road condition evaluations are used. By that it is possible to combine the current separately performed evaluations of road safety and road conditions and the geometrical evaluation to one integrated evaluation approach.

2. DATA BASIS

Road data usually is collected and managed within road information databases. These include information on alignment elements (type, dimension and sequence of the site plan elements) and the cross section (carriageway width). This information can serve as an evaluation basis. At this point, however, the quality and the completeness of the data should be proved. Studies by LIPPOLD ET AL. (2011) and HEINE (2012) revealed that information of road data bases may be incomplete and can further contain partially faulty or implausible values.

For a completion or validation of the existing geometrical data kinematically measuring systems can be used (see Fig. 1). To display the existing road exactly these systems need to be equipped with high-precision, satellite-based positioning systems. Subsequently the geometrical data (site plan elements) can be calculated by the use of road design software (e. g. CARD/1).

Fig. 1. Measurement vehicle „UNO“; TU Dresden

The possible visualization of the data is an additional benefit of collecting road data by the use of such measurement systems. The measurement vehicle is equipped with front or scenery cameras. The taken pictures enable a subsequent “drive” on the road sections (see Fig. 2). Furthermore the calculated geometry as well as accident and condition data can be
featured. The photogrammetrically calibration of the front cameras enables furthermore the measuring of distances within pictures.

![Fig. 2. Viewing tool RoadView (TU Dresden)](image)

### 3. METHOD OF EVALUATION

The analysis and evaluation of a road network within this investigation can be separated into three parts:
- analysis of the geometry,
- analysis of the accident occurrence,
- analysis of the road condition.

Afterwards all individual results are combined in one total evaluation. Based on these results recommendations for maintenance measures can be derived and priority rankings can be set up.
3.1. ANALYSIS OF THE GEOMETRY

The evaluation of the geometry is based on the „Guidelines for the design and alignment of rural highways“(RAL, draft 08/2012). First all elements of the site plan are being evaluated. Therefore the single arc radii are being reviewed whether the parameters according to the RAL are met with regard to relations and minimum values. Furthermore the existing carriageway widths of the network sections are being compared to the intended cross section. By combing site plan and cross section evaluations recommendations concerning suitable expansion can be made.

3.1.1. Sections of the network

Main through-routes are based on different design principles than rural roads (driving geometry vs. driving dynamics). Therefore only sections of the “Open Road” are being evaluated. A road section can be defined as a (Fig. 3):
- section between road network nodes,
- section between road network nodes and main through-routes and
- section between main through-routes.

Fig. 3. Differentiation of road network sections (HEINE 2012)

3.1.2. Determination of design classes

The design class is used as an input value for determining decisive design parameters. It is derived from the linkage function of the road within the network, the road category (link function level). Whether a different classification of the design class to the road category is useful can be reviewed with the traffic load. Link function levels are determined by the concept of central places and are included in federal transport plans.
3.1.3. Evaluation of curve radii

The dimensions and sequences of circular curve radii are supposed to enable a consistent driving at a speed according to the design class. Therefore the existing site plan geometry is reviewed whether the parameters according to the RAL (Draft 08/2012) are met. The evaluation of the circular curves focuses on the relation of sequenced circular curves, permitted radii subsequent to straights and minimum radii. Therefore the amount of deviation is assessed.

The amount of deviation is divided into four categories:
- no deviation,
- minor deviation,
- mean deviation and
- high deviation

from the RAL. Therefore the compliance of the relations has a higher weighting (cf. Tab. 1).

### Classification of the deviation from the guidelines

<table>
<thead>
<tr>
<th>relation of elements</th>
<th>deviation from the guidelines</th>
<th>no dev.</th>
<th>minor dev.</th>
<th>mean dev.</th>
<th>high dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>relation of radii</td>
<td>Dev. = 0</td>
<td>0 % &lt; Dev. ≤ 10 %</td>
<td>10 % &lt; Dev. ≤ 20 %</td>
<td>Dev. &gt; 20 %</td>
<td></td>
</tr>
<tr>
<td>straight-circular curve</td>
<td>Dev. = 0</td>
<td>0 % &lt; Dev. ≤ 10 %</td>
<td>10 % &lt; Dev. ≤ 20 %</td>
<td>Dev. &gt; 20 %</td>
<td></td>
</tr>
<tr>
<td>minimum radius</td>
<td>Dev. = 0</td>
<td>0 % &lt; Dev. ≤ 25 %</td>
<td>25 % &lt; Dev. ≤ 35 %</td>
<td>Dev. &gt; 35 %</td>
<td></td>
</tr>
</tbody>
</table>

The RAL (draft 08/2012) set focus on a steady and flowing alignment. To avoid undesired differences in speed the given relations concerning the transition of subsequent radii and straight-circular curve need to be observed (cf. Fig. 4).

The transition from mean to high deviation is near the line between the usable and the non-applicable range. Safety-critical speed differences greater than 15 km/h (\(\Delta V\)) should not occur within element relations that are assigned to high deviation (LIPPOLD 1997).

The RAL (draft 08/2012) further defines radii ranges according to the design classes. The upper range limit supports the securing of the intended overall effect of the road type. A straight alignment within the design class EKL 3 and EKL 4 is undesired as this can suggest overtaking possibilities where safe overtaking maneuvers are not possible.

The review of the circular curves, however, concentrates on the lower radii range limit. This is due to the fact that for “too large” radii no reconstructions or expansions should be recommended.
A higher priority was assigned to the compliance of the relations than to the compliance of the minimum radius. This is due to the fact that according to the RAL (draft 08/2012) a lower deviation of the lower range limit is permissible (up to 15% in justifiable exceptional cases) if at the same time the relations of the elements are met. Moreover, roads with a sequence of smaller circular curves, where the radii relations are met, are not necessarily questionable concerning road safety.

Finally the highest deviation out of the individual evaluations (relation of radii, transition straight – circular curve and minimum radius) is assigned to the corresponding circular curve radius.

### 3.1.4. Evaluation of the alignment

The evaluation of the alignment is based on the percentage of the deviation (high, mean, minor, no deviation) of the element relations (relation R-R, Relation S-R, minimum radius) with regard to the total length of the road section.

According to the classification of the individual element evaluation the evaluation of the alignment is also divided into four aspects:

- alignment of the entire route without any deviation,
- alignment of the entire route with minor deviation,
- alignment of the entire route with mean deviation and
- alignment of the entire route high deviation.
3.1.5. Evaluation of the cross section

According to the RAL (draft 08/2012) standardized, recognizable road types shall be created. The appearance of a road is mainly influenced by the cross section. Therefore one cross section for each design class is intended. For the assessment of the cross section the width of the existing carriageway is being compared to the demands of the RAL (draft 08/2012). Therefore the amount of deviation from the RAL is differentiated into four ranges:

- no deviation,
- minor deviation  $0 \text{ m} < \text{Dev.} \leq 0,50 \text{ m}$,
- mean deviation  $0,50 \text{ m} < \text{Dev.} \leq 1,00 \text{ m}$,
- high deviation  $\text{Dev.} > 1,00 \text{ m}$.

The evaluation is based on the „Information Sheet concerning the transfer of the design class principles of the RAL to existing roads“ (M EKLBEST, draft 09/2009).

3.1.6. Recommendations for expansion based on the geometrical evaluation

The recommended measures resulted from the combination of different deviations in the alignment and cross section. Therefore the following recommendations for expansion are given:

- no constructional measures,
- adjustment of the alignment for individual elements,
- adjustment of the alignment,
- widening of the cross section,
- widening of the cross section with adjustment of the alignment for individual elements and
- widening of the cross section with adjustment of the alignment.

Tab. 2 shows expansion recommendations according to the combination of the evaluations of alignment and cross section.
### Matrix for derivation of expansion recommendations

<table>
<thead>
<tr>
<th></th>
<th>alignment deviation</th>
<th>cross section deviation</th>
<th>recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no deviation</td>
<td>no deviation</td>
<td>no constructional measures</td>
</tr>
<tr>
<td></td>
<td>no deviation</td>
<td>minor deviation</td>
<td>no constructional measures</td>
</tr>
<tr>
<td></td>
<td>no deviation</td>
<td>mean deviation</td>
<td>widening of the cross section</td>
</tr>
<tr>
<td></td>
<td>no deviation</td>
<td>high deviation</td>
<td>widening of the cross section</td>
</tr>
<tr>
<td></td>
<td>minor deviation</td>
<td>no deviation</td>
<td>no constructional measures</td>
</tr>
<tr>
<td></td>
<td>minor deviation</td>
<td>minor deviation</td>
<td>no constructional measures</td>
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<td></td>
<td>minor deviation</td>
<td>high deviation</td>
<td>widening of the cross section</td>
</tr>
<tr>
<td></td>
<td>mean deviation</td>
<td>no deviation</td>
<td>adjustment of the alignment for individual elements</td>
</tr>
<tr>
<td></td>
<td>mean deviation</td>
<td>minor deviation</td>
<td>adjustment of the alignment for individual elements</td>
</tr>
<tr>
<td></td>
<td>mean deviation</td>
<td>mean deviation</td>
<td>widening of the cross section with adjustment of the alignment for individual elements</td>
</tr>
<tr>
<td></td>
<td>mean deviation</td>
<td>high deviation</td>
<td>widening of the cross section with adjustment of the alignment for individual elements</td>
</tr>
<tr>
<td></td>
<td>high deviation</td>
<td>no deviation</td>
<td>adjustment of the alignment</td>
</tr>
<tr>
<td></td>
<td>high deviation</td>
<td>minor deviation</td>
<td>adjustment of the alignment</td>
</tr>
<tr>
<td></td>
<td>high deviation</td>
<td>mean deviation</td>
<td>widening of the cross section with adjustment of the alignment</td>
</tr>
<tr>
<td></td>
<td>high deviation</td>
<td>high deviation</td>
<td>widening of the cross section with adjustment of the alignment</td>
</tr>
</tbody>
</table>

The RAL include safety reserves for design parameters. By that road sections with only minor deviation in alignment and cross section are still within the relatively safe range. For that reasons no constructional measures are recommended.

The recommendation „adjustment of the alignment for individual elements“ includes mainly the straightening of particular „critical“ circular curve radii. This is recommended for roads with mean deviation in the alignment. In case of road sections with high deviation in the alignment the „critical“ circular curve radii are distributed in a way that individual reconstruction is not possible. Due to that an improvement of the alignment for the entire road section is recommended.

The widening of the cross section is recommended on roads with mean or high deviation.

The measures for improving the alignment and the cross section can also occur in combination.

Besides these recommendations additional detailed information concerning number, lengths and proportion of critical elements within the alignment are given. The distribution of critical elements over the road network section can be displayed for example in a road portrait (see Fig. 5).
3.2. ANALYSIS OF ACCIDENT OCCURRENCE

Investigations on the road safety of road networks should be based on the real accident occurrence (HEINE 2012). The „Recommendations for safety analysis of road networks” (ESN 2003) describe such a method. The safety potential is the most important parameter within the ESN (2003). It describes with regard to the lengths the avoidable accident costs for an expansion of the road section in accordance with the guidelines. Therefore the determined actual accident costs are compared to the federal mean costs per accident for roads built in accordance with the guidelines.

Furthermore the results of the safety analysis enable an order of priority concerning the improvement potential for traffic safety. These priorities can serve as the basis for decisions on investments, especially for maintenance, restructuring and expansion measures.

Dividing the road into sections on the basis of the network is an essential part. Basically, there are two possible ways of dividing the road into sections given by the ESN.
- dividing the road into sections on the basis of the network and
- dividing the road into sections on the basis of the accident occurrence.

An investigation from EBERSBACH/SCHÜLLER (2007) on the practical application of the ESN revealed that both methods are suitable for the identification of roads with safety deficits. Dividing the road into sections on the basis of the accident occurrence (visual accident density) is very work-intensive. Therefore dividing the road into sections on the basis of the network is recommended as this can be done (partly) automated.

Avoidable accident costs are used as criterion of demarcation. By that over evaluated safety potentials of existing short road sections, less than 1.000 m, can be compensated. With regards to recommendations from EBERSBACH/SCHÜLLER (2007) ordering the road sections according their priority is differentiated into four aspects:
- road section with a high priority (< 20 % of avoidable accident costs),
- road section with a mean priority (20 - 60 % of avoidable accident costs),
- road section with a minor priority (60 - 100 % of avoidable accident costs),
- road section without any safety potential.

3.3. ANALYSIS OF ROAD CONDITIONS

Analysing constructive road conditions can be separated into two parts of investigation. Within investigation part I a first network wide pre-investigation regarding the conditions of the road network based on ZTV ZEB-StB is carried out. By that sections that are worth to be maintained can be identified and differentiated.

Investigation part II includes a targeted analysis of structural material characteristics (drillcore) by means of laboratory tests. On this basis the possible point of time for an instant of failure is predicted. Subsequently dimensions of the superstructures for maintenance measure are calculated. These consider local conditions as well as material characteristics of remaining layers within the road surface. With regards to dimensioning
calculations and in consideration of financial aspects different constructional versions can be opposed and weight against each other.

3.4. TOTAL EVALUATION

Within the total evaluation previous results of the described investigation parts are being overlaid to rank priorities. Therefore a differentiation according to the linkage function is made.

Within the second step the results are used for a ZEB-evaluation. Therefore the lengths of sections which evaluations are above the threshold value (GW ≥ 4.5) are added up. The result is then compared to the total lengths of the network section. The next division of the network is then based on this resulting ratio. In case that at least 50% of a section have a GW ≥ 4.5 extensive maintenance measures for the greater part of the network section are promptly necessary. Due to this the recommendations resulting from the geometrical analysis should be fully considered.

Network sections with better conditions according ZTV ZEB-StB are considered separately concerning the maintenance management. Focus is here set on medium-term maintenance strategies to achieve an economic and sustainable planning of measures. Subsequent to the order of priority and in advance of any planning of measures an investigation of the structural substances of the adjacent sections should be made. By that the remaining useful life of the construction and which constructional measures may contribute to the aspirated time horizon can be proofed. For changes within the alignment and therefore a ground-extension such considerations are not required.

Furthermore rankings of priority are developed. Avoidable accident costs are used as objective criteria. By that a ranking according to amount of avoidable accident costs is possible.
4. RESULTS

The results can be prepared and displayed in different forms (e.g. tables and maps). Road portraits are one possibility to summarize and visualize results (cf. Fig. 5).

![Fig. 5. Example of a road portrait (HEINE 2012)](image)

Especially deficits in the alignment for road sections can easily be detected. Road portraits can also be used to determine useful maintenance sections.

5. SUMMARY AND CONCLUSION

Ensuring road safety and capacity is of particular importance for road networks. This requires the compliance with future minimum standards for the design of roads outside of urban areas (rural roads). For the evaluation of design standards the new RAL (Draft 08/2012) are used as benchmark. Based on the geometrical evaluation (alignment / cross section) recommendations for expansion are derived. The method of the geometrical evaluation can be algorithmized and can therefore be applied to various sizes of road networks.

The investigation further reveals a possibility to transfer the different evaluations of geometry, road safety and road conditions into one integrated evaluation. On this basis
prioritizations of road sections can be made and recommendations for maintenance measures considering the geometrical design of the traffic facility can be given.

Literature


ZINTEGROWANA OCENA WIEJSKICH SIECI DRÓG

Streszczenie: Zapewnianie bezpieczeństwa na drodze i jej użyteczności jest priorytetem każdej sieci dróg. Aby to osiągnąć, podstawowe standardy płynące z technicznych i ekonomicznych wymagań wykonywania dróg poza miejskich muszą zostać spełnione. Procedury dla oceny i ewaluacji bezpieczeństwa i warunków na drodze są powszechnie dostępne. Nie istnieją jednak, żadne metody analizowania geometrii dróg będących częścią sieci drogowych.


Słowa kluczowe: bezpieczeństwo na drodze, ewaluacja dostosowania, zarządzanie utrzymaniem