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Road quality service levels
and innovations to meet user expectations

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Summary:

Even small disruptions in the network caused by traffic restraints or through the failure of parts of the network lead inevitably to large traffic obstructions and in consequence considerable costs for the user and the national economy. It is therefore of far-reaching importance that the maintenance measures are managed using a system which, taking the available funds into account, guarantees that the measures can be taken at an optimal time with regard to both construction and traffic.

In order to provide a more objective basis for decisions that were previously made on a subjective basis, a system to rate and evaluate the condition of federal trunk roads in Germany (ZEB) was introduced in 1992. Factors measured include longitudinal evenness, transverse evenness, skid resistance and surface damages. The road network is evaluated every four years. Through a standardised evaluation of condition indicators and the establishment of alert values and threshold values, a sort of requirement level is defined. It is practically impossible to use the mass of data appropriately if it is only stored on a computer or available as a print-out. Therefore tools have been developed which are able to represent the data on plans and maps. The possibilities for depicting the data have met with considerable interest on the part of the road planning administration.

On the basis of the ZEB, a national standardised Pavement Management System (PMS) is being developed that can be applied routinely by the Federal States (Länder) in order to reach an optimisation of road maintenance through standardised, economic assessment of maintenance measures. The PMS developed was tested in all of the 13 larger States during the initial application. The users consider the PMS a significant aid to systematic maintenance planning. The PMS results for both sections of network and the overall road network are evaluated as plausible and practical. The initial application of PMS has in some places undergone a smooth transition into regular application, and in initial stages, is even being used routinely. The user now has a tool available that provides assistance for maintenance management and planning through

- establishment and rating of the technically possible alternatives for rehabilitation / restoration measures on the project level,
- creation of a maintenance programme for the respective road network based on the optimised alternatives,
- rapid implementation of strategic objectives in quality or financial scenarios for parts or the whole of the network.

The present methods for measuring longitudinal unevenness are reaching their limits. For example, step-like, mostly periodic uneven areas, which primarily appear on older cement road surfaces of the Federal motorways that are often in need of repair, are not sufficiently taken into account by present evaluation techniques. Therefore, the inclusion of not only the geometry but also the effects of longitudinal unevenness in the evaluation and rating concept is called for. The newly developed Longitudinal Unevenness Effect Index (LWI) is based on the assessment of vertical vibration values in the human body, load strain and wheel load fluctuations as a reason for road stress. At present an extended LWI test is being carried out as a preliminary step to its integration into the ZEB assessment concept.

The Federal Ministry of Transport, Construction and Housing introduced a new comprehensive body of legislation in 2001 that further pave the way for systematic road maintenance using PMS. This will also provide the opportunity of comparing the results of PMS implementation and maintenance programmes for the 16 German Federal States.

In order to continue to meet the needs of the road users in the future, the feasibility of a new type of construction contract - the functional construction contract - is furthermore being tested. The name "functional construction contract" intends to make clear that the function of road construction, that is the safe serviceability and the durability of the roadway, is the focal point of the contract between the administration funding the construction and the contractor who carries it out. The functional construction contract places new construction measures or basic restoration of a road and its structural maintenance over a period of 20 years under a single contract.

1. Introduction

The German federal road network comprises some 11,700 km of motorways and 41,300 km of federal roadways. These trunk roads represent total fixed assets of ca. € 170,000 million. Motorways are subjected to an average daily traffic volume of 46,800 vehicles/24 h. In many areas traffic volumes of over 100,000 vehicles/24h are not unusual. A further increase in traffic can be expected. Forecasts predict that goods traffic levels in Germany will rise by 68% and passenger traffic by 20% from 1992 to the year 2010.

In this light, the economic and social significance of guaranteeing the constant functionality of the present road network is evident. Even small disruptions in the network caused by traffic restraints or through the failure of parts of the network lead inevitably to large traffic obstructions and in consequence considerable costs for the user and the national economy. There are, however, only limited budgetary resources available for the maintenance of the road network. It is therefore of far-reaching importance that the maintenance measures are managed using a system which, taking the available funds into account, guarantees that the measures can be taken at an optimal time with regard to both construction and traffic, ensuring the users sufficient quality in the future as well.

The motorways and federal roads are the property of the Federal Ministry of Transport. However, it is laid down in law that the Federal States are responsible for the planning, construction and maintenance of this federal trunk road network. The States use planning documents to inform the federal government of the funds required. In the past, maintenance measures were commissioned based on more or less subjective descriptions of the condition of the pavement, which meant that in some cases the rhetorical abilities of individuals also played a role in the distribution of funds. In order to provide a more objective basis for decisions that were previously made on a subjective basis, a system to rate and evaluate the condition of federal trunk roads in Germany (ZEB) was introduced in 1992. On the basis of the ZEB, a national standardised Pavement Management System (PMS) is being developed. Routinely applied by the Federal States, the PMS can allow optimisation of road maintenance through standardised, economic assessment of maintenance measures.

2. Condition Rating and Evaluation

The road network is evaluated every four years, though the measurements are taken annually - two years on motorways and the two subsequent years on federal roads. Factors measured include longitudinal evenness, transverse evenness, skid resistance and surface damages such as cracking, patches, edge damages and corner demolition. The relevant condition values and extents are shown in Table 1. Condition rating is only possible through automatic measurement systems that flow with traffic (at a measurement speed of > 60 km/h). Visual condition rating would imply a higher safety risk for the measuring team and the road user and lead to traffic jams; really objective data could not be measured by this way.

The following measurement systems are employed for condition rating:

- Longitudinal evenness: HRM (High-speed Road Monitor) measurement principle
- Transverse evenness: Laser sensor on a beam mounted perpendicularly to the traffic flow
- Skid resistance: SCRIM (Sideway-force Coefficient Routine Investigation Machine)
- Surface damages: Video recordings under stroboscope light.

In Germany, the longitudinal profile is established through the laser measurement technique using the HRM principle to arrive at the longitudinal evenness rating. The HRM serves as the calibration standard. The laser sensors are mounted on a beam and measurements of the distance to the road surface are carried out at 100 mm intervals along the traffic stream. The longitudinal evenness is established using measurement systems that approach the real longitudinal profile upon which the parameters for condition rating can be calculated. The evenness value Φ_h (Ω_o) is used as the relevant condition value for rating. The condition value Φ_h (Ω_o) is established from the spectral density and represents the extent of unevenness in a smooth spectrum with 6 m wavelengths.

The transverse profile is also established through laser sensors mounted at 100 mm intervals on a beam along the front of the measurement vehicle. In addition to rut depth, hypothetical water depth is also relevant in establishing transverse evenness. This value is calculated through the establishment of a theoretical water film thickness in the ruts obtained from the transverse profile and the cross slope without including the gradient.

In the SCRIM procedure developed in Great Britain, the skid resistance of the roadway surface is established by measuring the force arising as the return force between an odometer placed at a 20 ° angle and the traffic stream. At present, 12 SCRIM measurement devices are being implemented for routine establishment of skid resistance in Germany.

The surface damages relevant for condition rating - cracks and patches in asphalt road surfacing, cracks, corner demolition and edge damages in concrete road surfacing - are established via bipartite or tripartite video cameras, which divide the sector to be measured into two or three parallel strips. The films are evaluated with the support of visual condition evaluation. The condition value for surface damages in the case of asphalt road pavement represents the percentage of damaged areas. For cement road pavement there are two condition values: one describes the average damage severity of a section of roadway; and the other defines the number of affected slabs.

The measurements, covering some 22,000 to 28,000 km/year, are carried out by private operators. The quality of measurement results is tested by the Federal Highway Research Institute through suitability tests and cross-checks. The measurement device operators combine longitudinal and transverse evenness measurements with surface damage measurements in a single measurement vehicle, such that it is only necessary to drive over an area once to measure the three condition characteristics.

In order to guarantee the correct allocation of the condition data on the measured sector, an ordering system that can react flexibly to possible alignment changes (for ex. construction of by-passes) or changes of designated road classes is needed. In Germany, this is carried out through a so-called network node scanning system, which provides the basis for the roads database. The entire road area is divided into separate sections, each with a network node at each end. In the area next to the traffic lanes, an information board (showing station characteristics and the like) is possible for orientation purposes.

The measured raw data refer to particular 100 m sections and are combined into so-called condition indicators. The units of the various condition indicators differ (mm, %, etc., see also Fig. 1). For subsequent ratings the condition indicators are converted into unitless and therefore comparable condition values. This is done using an X-Y co-ordinate system, in which the condition indicators on the abscissa are converted to the condition values on the ordinate axis with the help of standardisation functions (s. [1]). The condition values can range from grade 1 (very good) to grade 5 (very poor).

Target values, alert values and threshold values are defined for each condition indicator. In regular cases, the target value (grade 1.5) corresponds to acceptance specifications for new or renovated roads, though this description of the target value is not valid for certain condition characteristics such as cracks. It is therefore often referred to as the 1.5 value. The alert value (grade 3.5) describes a situation requiring maintenance planning. The threshold value (grade 4.5) characterises a situation where maintenance measures or traffic restrictions should be introduced.

Characteristic / Indicator	**Dimension**	**Target Value / 1.5 value**	**Alert Value**	**Threshold Value**
Longitudinal unevenness $\phi_{h(\Omega_0)}$	[cm³]	1.00	3.00	9.00
Rut depth	[mm]	4.00	10.00	20.00
Hypothetical water depth	[mm]	0.10	4.00	6.00
Skid resistance (SCRIM) 80 km/h	[-]	0.53	0.39	0.32
60 km/h	[-]	0.60	0.46	0.39
Asphalt: Net cracking	[%]	1.00	5.00	10.00
Patches	[%]	1.00	10.00	15.00
Concrete: Longitudinal and transverse cracks	[m] / [%]	0.10 / 1.00	2.00 / 23.00	4.00 / 35.00
Corner demolition	[--] / [%]	0.01 / 1.00	2.00 / 23.00	3.00 / 35.00
Edge damages	[m] / [%]	0.10 / 1.00	4.00 / 23.00	8.00 / 35.00

Figure 1: Limit values for condition indicators for federal trunk roads

The condition values are subsequently weighted and converted to produce two overall values, the service value and the structural value (s. [1]). The service value is ascertained by placing the weighted condition values through a logarithmic function.

The following percentages are employed for service value:

- The maximum of the longitudinal evenness value or the rut depth at 25 %
- The hypothetical water depth at 25 %
- The skid resistance at 50 %.

The service value refers to traffic safety and driving comfort and is therefore road user orientated.

The structural value is ascertained in a similar fashion, with differing weightings for asphalt and cement road surfacing. The structural value places the interests of the financing authorities in the foreground. The poorer of these two values - service or structural - is selected as the relevant overall value of the 100 m long section.

Through these standardised ratings of the condition indicators and the establishment of alert and threshold values for structural and service values, a sort of requirement level is defined for German federal trunk roads providing criteria for road maintenance planning. This nation-wide procedure provides the prerequisites necessary for establishing unitary action criteria as well as action times.

The first survey for condition evaluation was carried out from 1992 to 1995. It included first lanes on all motorways and also the overtaking lanes on motorways in the 5 new Federal States of former East Germany. On 2-lane federal roads only the lanes on one side were measured. The second survey was carried out between 1997 and the year 2000. This time, all lanes were measured on motorways and federal roads with 3 or more lanes. The third survey will be completed in late 2002 for motorways, whereas the survey on federal roads will be completed by late 2004. The condition evaluation surveys are planned to be repeated every 4 years. The aim is to provide a more objective basis for the presently subjective evaluation of the road condition and decisions on measures to be undertaken, thus providing the government and the Federal States with better steering instruments.

The ZEB results describe the condition of the road surface at a specific time, as a “snapshot”. Regular subsequent measurements allow an overview of the general developments in the roadway condition. The use of condition values and of the traffic-dependent development of roadway condition means that the method for predicting financial requirements is far more precise than previous methods.

3. Improvement of longitudinal evenness evaluation

Through ZEB, the longitudinal evenness of the pavement surface is ascertained in the form of a continuous longitudinal profile. For some time now, there has been criticism of the present procedure, especially of the evaluation and rating of longitudinal evenness condition characteristics. A determining cause thereof and a weak point of the procedure that becomes evident when maintenance planning is put into practice consists of the fact that the unevenness is not properly characterised in each case according to its degree of unevenness for each form (irregular, stepped, periodical). This has particularly adverse effects on ascertaining damage levels for maintenance purposes. Both stepped, mostly periodical manifestations of unevenness appearing primarily on older cement surfaces of federal motorways often in need of repair as well as individual obstacles (resurfacing, bridge abutments, etc.) are not sufficiently taken into account by present evaluation and rating procedures.

Judging from experience, the fact that some roadway sections presently rated as being in good condition actually have noticeable effects on passengers, freight and the vehicles themselves respectively on the pavement would call for the inclusion of the effects of longitudinal unevenness in addition to the geometrical factors (here: condition value Φ_h (Ω_o)). Adverse effects on traffic safety as well as road stress would then be taken into account.

This new condition indicator is called "longitudinal evenness effect index" (LWI) (s. [2]). The prerequisite for its calculation is that the effects on ascertaining the roadway condition caused by unevenness in a respective 100 m section are of significant importance. The following three types of vibration constitute the basis for calculating the longitudinal evenness effect index:

- Vertical vibration caused in the human body,
- Vertical acceleration effects on the loadroom (load strain criteria)
- Wheel load fluctuation (road stress and driving safety criteria).

These vibration manifestations are also evaluated using three longitudinal profile rating filters: the "human filter" describes the vibration sensitivity of a driver in an average passenger vehicle moving at 100 km/h along the respective road; the "freight goods filter" describes the vertical acceleration that occurs in the loadroom directly above the middle axle of a three-axle semi-trailer when moving at 80 km/h along the respective road; and the "wheel load filter" describes the wheel load fluctuations occurring between the tyres and the roadway of the drive shaft on an 11.5 t lorry, also moving at 80 km/h. All three filters are chosen such that they represent the typical vibration levels occurring on federal trunk roads.

After squaring (energy-related consideration of effects) and standardisation (based on the reference values for “good roads”), three unitless filter results are obtained as road functions. Together, their maximum value - with regard to a 100-m roadway section - provides the longitudinal evenness effect index (LWI).

From the close relation between Φ_h (Ω_o) and LWI, limit values for LWI can be derived. The following 1.5, alert and threshold values are recommended. These limit values are specifically designed for the evaluation of federal motorways and trunk roads.

		Roadway stress and driving safety	**Freight goods stress**	**Stress on human body**
	LWI **[–]**	**Max. wheel load increase or decrease** (with regard to the static wheel load) **[%]**	**Max. vertical acceleration** on the loadroom **[m/s^2]**	**Root mean square** of the frequency rated **vertical acceleration** **[m/s^2]**
1.5 value	1	17.5	1	0.3
Alert value	3	30	1.7	0.5
Threshold value	9	52.5	3	0.9

Abb. 2: Recommended limit values for LWI, with their respective effects regarding roadway stress, freight goods stress and the human body

Within the framework of a preliminary trial, an evaluation of LWI condition indicators was undertaken using the ZEB data for the A 5 Motorway. For half of the sections researched (49.9 %), LWI and Φ_h (Ω_o) provided the same grading results. In 1.9 % of all cases, LWI provided a better grading than Φ_h (Ω_o) and worse grading in 48.1 % of all cases. These results confirm that LWI tends to rate longitudinal unevenness “more sharply” than Φ_h (Ω_o). The A 5 motorway was specifically chosen because a relatively significant amount of its roadway sections showed unevenness conditions that seemed to be improperly characterised by Φ_h (Ω_o). At present, a more extensive test of the new LWI evaluation criteria is being carried out. If positive results are obtained, LWI will be incorporated into the ZEB evaluation concept described above.

4. Data Representation

For each of the 100m sections monitored, the individual condition indicators and values, service values, structural values and overall values are established from the raw data using the concepts mentioned. This information must be included in the decision-making process for the maintenance programme. It is practically impossible to use this large amount of data if they are only stored on a computer or available as a print-out. Therefore, software was developed that can represent the data on plans and maps. Using the maps it is possible to gain a quick overview of the situation of the road network. The poor sections can be determined and a detailed, object-orientated analysis of the corresponding raw data can be undertaken. Four colour categories show the four respective grades. The target value, the alert value and the threshold values form the boundaries between these colour categories. The colours used and their meanings are as follows.

- Blue: Corresponds to the condition of a new road
- Green: No measures necessary
- Yellow: Reasons for deterioration should be analysed and maintenance measures planned
- Red: Poor road conditions; Maintenance measures should be undertaken or traffic restrictions introduced.

But it is not sufficient to work only with the condition data. For a well-prepared maintenance and rehabilitation programme consideration must be given to other data such as pavement construction data, information on past maintenance measures, traffic and traffic safety data and information about other programmes such as bridge maintenance programmes. Interrelating this information is the task of a Pavement Management System (PMS). Computer-supported PMS allows a complete overview of all relevant data, even for a large road network. ZEB was the first step in this direction. With PMS, these requirements can now be met.

Further computer programmes were developed to represent this data that allow them to be linked to a geographic information system and provide a corresponding environment for PMS data visualisation and preparation (s. [3]). In addition, the necessary data can be checked and corrected in editing windows on an alphanumeric screen display. All data that is relevant for PMS can be shown on a single page as a continuous strip graph (Fig. 3). There is no limit to the length of sections to be represented. Figure 3 shows only a very short section as an example. These graphs allow plausibility checks to be carried out simply and at acceptable cost. The possibilities for depicting the data have met with considerable interest on the part of the road planning administration.

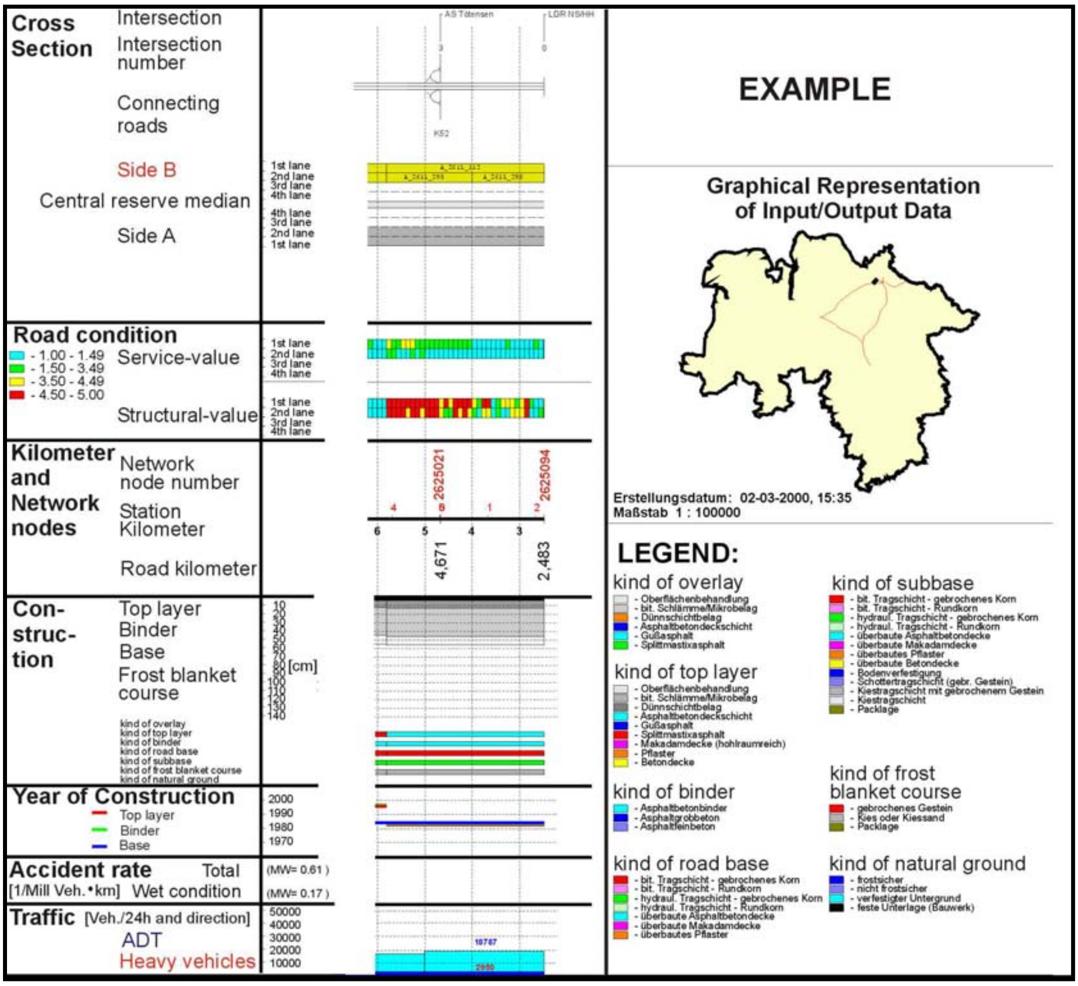

Fig. 3: Example of Graphical Representation of PMS-Data

5. Initial Application of the Pavement Management System (s. [3])

In a research project, existing PMS software (dTIMS, by Deighton Firm in Canada) was used to test the algorithms developed at the beginning of this project for a German PMS on selected road sections, i.e. a motorway in Bavaria and 4 federal roads in Hesse [4]. The PMS results were realistic and comprehensible for practicians and formed the basis for a larger-scale trial, which was carried out as an initial implementation in selected motorway and road planning authorities, beginning in mid-1998. In this initial implementation, the degree to which PMS met the requirements of maintenance in practice with regard to user friendliness and the quality of results was tested. The user friendliness of the system was supposed to guarantee that work and routine procedures of maintenance management and planning, which at the time is being done painstakingly by hand and therefore fraught with errors, was simplified and undertaken in an organised, systematic order to provide greater transparency and, insofar as possible, to exclude highly subjective components that are difficult to understand from the decision-making process. Criteria for evaluating the quality of results were to what degree the PMS:

- employed the available financial resources or reached the desired quality level for specific objectives,
- provided plausible proposals on the type, place and time priorities of maintenance measures for individual road sections,
- which could serve as a basis for the establishment of a medium term maintenance programme (for ex. 5 or 10 years) after network-wide optimisation of all measures proposed and
- allowed plausible strategic statements on a network level on foreseeable condition developments or future maintenance needs.

The Canadian program system, which is sold in Europe as "VIAPMS", consists of only a software framework, but is not a finished, usable PMS. In the parameter data designated for this purpose, the available algorithms must be adjusted to fit with German characteristic values relevant to the maintenance domain as per guidelines, fact sheets, working papers and the like. The data preparation and representation environment developed for the initial application of PMS should in the final stage serve as the interface for automatic data transfer between the state databases and the PMS. Within this environment, there is the option of automatically combining the 100 m sections of the measurement engineering condition rating (ZEB) into so-called "homogenous sections" whose length better approximates the real road lengths (i.e. contract sections) used in maintenance practice - the average length being ca. 2 km for federal motorways and ca. 0.9 km for federal roads – (s. [5]). With the help of a partition module, the automatically created homogenous sections can be interactively modified in both the longitudinal and transverse directions in order to adjust them to the greatest possible degree to the contract sections used in maintenance practice.

At the initial application of PMS, running from the beginning of 1999 until January 2002, all 13 of the larger States were involved.

<u>Results</u>

The tools employed can be a significant aid to systematic maintenance planning. Both sectional and network-wide PMS results were rated as plausible and practical by the participating initial users. The practical usefulness of the tools was generally confirmed.

In order to attain such results, many corrections had to be made on the data before entering them, which took an especially long time for the required data on type, thickness and date of construction of the pavement layers. During the initial implementation of PMS, the data on the construction of pavement layers on federal motorways and trunk roads were systematically gathered for long-term planning of maintenance needs. Since the end of the year 2000, the data situation has therefore significantly improved. In some States, the initial implementation provided a strong impulse for the completion and improvement of technical data, since it was evident that the data were necessary and would be used meaningfully, and it was clearly verifiable that supposedly nonsensical PMS results were to a great extent due to erroneous data being entered.

For the operation of the PMS at each administration office, an average of 2.5 man/months were employed in total, i.e. including data correction. Frequent comparisons of the measures suggested by the PMS with actually executed or planned measures have shown that, when certain types of measures are considered along with their execution year, the conformity quota is lower than when they are considered more generally (for ex. only the type of measure). The broader interpretation is definitely recommended for the iterative establishment of maintenance programmes through lumping of measure suggestions from successively completed PMS runs, as these suggestions can and should only be a stimulus and an aid for the engineer in charge of maintenance planning. In any case, the PMS should not only be applied to previous maintenance practice, but, as occurred often in the initial application, should also provide alternative proposals that could be seriously taken into consideration.

Of particular interest to the road planning administrations was the fact that the PMS can show the future development of roadway condition based on different potential budgets. These evaluations could help to make the effects of fiscal-policy decisions more transparent to those responsible, especially politicians.

In the Hesse State Road and Traffic Administration, an investigation of PMS implementation problems at different administrative levels was undertaken. This application enhanced the knowledge gained from the initial implementation, which was primarily at the local planning and building committee level. It is imperative to establish computer-aided co-ordination of the PMS results achieved on the local level in order to establish a nation-wide maintenance programme. The prospects are promising if there is a more intensive exchange between authorities in all phases of the iterative approach to this programme, because in central offices the particularities of local situations and errors in the entered data are generally not recognised.

With regard to the optimisation results of PMS, the initial application demonstrates the particular significance of how the length of roadway sections were selected for maintenance measures. The initially automatically established sections for motorways were 2 km in length on average, as already mentioned, and consequently considerably shorter than the contract sections later used in practice. Combining these sections to contract sections before the PMS has executed optimisation calculations has decisive effects on the urgency ranking of maintenance measures. It is therefore sensible to allow the PMS to initially work with the unmodified homogenous sections and only afterwards combine the homogenous sections to create realistic contract sections. The reasons for the combinations then remain transparent.

The ZEB allows an evaluation of the road surface but does not provide a thorough description of the condition of the overall structure. Hence, an additional road structure evaluation is carried out through the PMS, which, because of the few data available, is limited to the thickness and age of the individual layers. However, when only the structural value is poor but the surface condition according to ZEB is rated as good, the PMS will not suggest any measures. This procedure leads to far more plausible PMS results.

"For the ranking of strategy options and for measure optimisation, the rating of maintenance measures has decisive significance. The evaluation procedure contained in VIAPMS is based on an analytical utility approach, in which the road condition rankings are linked to partial utility goals. If the partial utility goals exceed defined thresholds, this is cause for planning maintenance measures in order to maintain or re-establish the service value and/or structural value of the roads. Maintenance measures executed lead to sharp changes in the rating of the road condition and to modified future condition development in the time period examined. The comparison of the effects of these measures with a condition development that would occur should maintenance measures not be carried out provides criteria for the qualitative application of each respective maintenance measure. Weighting this criteria with the surface area of the respective road section and the average daily traffic volume (DTV) provides the utility value of the maintenance measure according to this system-internal utility definition."[6]

At present it is being considered to add to the described evaluation a monetary amount-based evaluation concept. The user components, time, vehicle use, accident and noise costs are being evaluated whether they are feasible.

Deductions for practice

The software licences necessary for the continued application of the PMS were taken on by all initial users on a long-term basis. The practical situation of PMS use is presently varied. In ca. half of the States involved in the initial application, PMS is already being employed for the establishment of maintenance programmes. In internal administration use, the initial stage of a centralised PMS implementation (for ex. state authorities, in general only for motorways), a partially centralised implementation (selected local planning and building committees) and a decentralised implementation of PMS (PMS at all regional road planning administrations, co-ordination at the state administration level) is to date being pursued. An alternative was already undertaken towards awarding a contract to an engineering firm with co-ordination through the respective state administration (after agreement with the regional road planning authorities).

In general, it can be said that the goals of the initial implementation of PMS were not only attained but also unexpectedly surpassed. The initial implementation of PMS as a feasibility test has in some places undergone a smooth transition into regular application, and in initial stages, is even being used routinely. It goes without saying that all model parameters that are relatively correct according to initial users are constantly being questioned and adapted to new research results. Improvements are also necessary with regard to user friendliness. The user now has a tool available that provides assistance for maintenance management and planning through:

- establishment and rating of the technically possible alternatives for rehabilitation / restoration measures on the project level,
- creation of a maintenance programme for the respective road network based on the optimised alternatives,
- rapid implementation of strategic objectives in quality or financial scenarios for parts or the whole of the network.

Prospects

We must not lose sight of one aspect: we are still very much in the early stages of PMS application in Germany. This report describes experiences undergone during the initial application of PMS at ca. 25 authority offices. In Germany there are, however, 140 road planning authorities and further authorities that would be included in a blanket application of PMS. The next step would be to include new interested parties. Following that the PMS would be extended to further individual States, first for a particular category of roads e.g. motorways, but eventually including the entire network of federal roadways - motorways and trunk roads. There remains, therefore, much to do before blanket PMS application occurs in Germany.

Who will this new tool help? Maintenance planning is clearly the task of the state road planning administrations. Introducing a PMS software programme in the States is therefore of primary importance. Neither the Federal Ministry of Transport, Construction and Housing nor the Federal Highway Research Institute will use a PMS as a steering instrument, e.g. in order to verify maintenance planning results. Why not?

1. Both the German Basic Law and the Act on Federal Trunk Roads stipulate that maintenance planning is the task of the States.
2. It would be extremely difficult, if not impossible, for the federal government to keep all the necessary object-related data on the entire federal trunk road network constantly up to date.

The aims as the federal government sees them are:

- to provide the state contract administrations with an operational instrument with which they are able to rank the need for maintenance measures according to standardised and systematic procedures and evaluation algorithms;
- to put the federal government and the states in a position to check statements regarding financial requirements via a constant overview of the current condition of the roads at network level and if necessary to take action. This includes in particular estimating condition development i.e. especially estimating the development of roadway condition and the required investment in light of qualitative and quantitative maintenance goals,
- to prevent the required maintenance measures from exceeding financial, construction or personnel capacities through the use of the PMS.

The management systems for pavements and bridges (as well as for the remaining parts of the network such as noise protection devices and road equipment) must in the medium term be brought into line with one another. Only in this way is it possible for objectively comparable statements to be made for the whole network about the urgency or cost-benefit relationship of measures and for all maintenance measures to be co-ordinated in a meaningful manner with regard to both financial and constructional considerations.

Considerations on whether to implement PMS raise the question of the costs in relationship to the benefit of systematic road maintenance. About 1,000 million € are spent per year on maintenance of the federal trunk roads (without bridges and road equipment). Rating and evaluating the condition of federal trunk road surfaces on a regular basis would cost about 2.3 million € /year. A PMS requires further data, most of which are, however, already available, but which must still be prepared for IT use. The integration of these data into a PMS would cause further costs, as would the development and maintenance of the PMS software and the training of personnel. If, as an initial rough estimate, the figure of 2.3 million €/year were doubled or even tripled, expenditure would stand at 4.6 million €/year or 7 million €/year, as compared with 1,000 million €/year for maintenance investments; this corresponds to approximately 0.4% to 0.7%. The PMS would therefore have to cause savings in maintenance investments of about 1%. If consideration is given to the fact that so much data is processed by PMS that it would simply not be possible for an engineer to keep track of it all, then economic advantages are highly probable.

6. New Legislation passed by the Federal Ministry of Transport, Construction and Housing

The Federal Ministry of Traffic, Construction and Housing passed a new body of legislation in the year 2001 that support systematic road maintenance through the application of PMS. These will provide the opportunity of comparing the results of PMS implementation and maintenance programmes of the 16 German States.

For federal trunk roads, the “Guidelines for the Planning of Maintenance Measures for Road Surfaces (RPE-Stra 01)” [7] were introduced to provide a resource for accumulating experience. They are designed to lead to standardised rules for the planning of maintenance measures. The RPE-Stra 01 establish a framework of guidelines and support the creation of co-ordinated, medium term maintenance programmes. Decisions on maintenance measures are made on the basis of systematic analysis of the respective network from the most objective point of view possible. The RPE-Stra 01 describe all major technical-administrative planning stages of efficient and systematic road maintenance.

They adapt procedures developed through research to practical administrative use and unify the various maintenance planning programmes of the States for federal trunk roads. The RPE-Stra 01 specify the process of analysing network quality (condition), from the choice of an appropriate maintenance strategy to the establishment of co-ordinated medium-term maintenance programmes and their implementation. The network-wide maintenance planning for federal motorways takes into account longer sections (maintenance measure areas) and co-ordinates and optimises maintenance measures for road pavement and bridges. The objective is to counteract adverse development of the age structure and the surface condition and to keep traffic restraints due to construction work to a minimum, especially on roadway sections with a high traffic volume. The application of RPE-Stra 01 reveals the need to maintain network-wide up-dated data.

7. Functional Construction Contracts

As an alternative or supplement to systematic maintenance planning by the road administrations of the Federal States the feasibility of a new type of construction contract - the functional construction contract - is now being tested.

“The types of contract for road construction and maintenance measures commonly used at present generally foresee the execution of road construction and maintenance services and the subsequent guarantee of non-defective quality of the structure for a period of 4 years. This procedure has lead to a situation where, when a road construction or maintenance contract is awarded, road surfacing is hardly evaluated in light of the use characteristics within the utility period nor with regard to the effort needed to maintain these characteristics. The functional construction contract should promote an interest in a longer utility duration of the construction element - "road" - with the maximum overall economic efficiency possible.” [9]

The term "functional construction contract" intends to make clear that the function of road construction, i.e. the safe serviceability and the durability of the roadway, is the focal point of the contract between the administration funding the construction and the contractor who carries it out. The functional construction contract places new construction measures or basic restoration of a road and its structural maintenance over a period of 20 years under a single contract. This implies that the use characteristics of a road are defined exclusively according to the functional requirements of road condition – for ex. longitudinal and transverse evenness, skid resistance and non-existence of cracks – and are no longer linked to technical engineering indicators such as construction material mixtures, binder type and amount, rate of compaction, voids content, etc.

The latter are established for classical construction contracts through thorough technical specifications and additional technical contract stipulations and evaluated through a wealth of procedures for testing compliance. The requirements for road surface condition defined in functional construction contracts should replace these detail requirements and their testing.

This new contract form increases the contractor's interest in and responsibility for the durability and fitness for purpose, therefore providing overall economic efficiency advantages. Such a contract form should promote privatisation efforts and the dismantling of state-managed companies, as well as make use of the possibilities of road condition rating.

In the year 2002, the first two pilot projects were begun in Germany. In Baden-Württemberg, 10 km of the A 81 Motorway are being thoroughly repaved in asphalt; and in Rheinland-Pfalz, 10 km of the A 61 Motorway are being repaved in cement. Medium-sized construction companies have shown a strong interest in this new contract form. The number of candidates was higher than in comparable limited competitions for conventional construction contracts. Sufficient data on the actual advantages and economic feasibility of the pilot contracts will only be available after 5 to 15 years of experience.

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