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ASSET MANAGEMENT: TECHNICAL INPUTS TO DECISION MAKING

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ABSTRACT

The Austrian Asset Management System is used for a net-wide objective maintenance planning process in consideration of different aspects and demands on different decision levels (project-level, network-level, policy-level). At the moment it is applied on the federal road network (motorways and expressways) with a total length of more than 2,100 km as well as on the state road network in most Austrian states.

The primary aim of the system is to allocate a comprehensive basis for an objective maintenance planning process of both pavement construction and structures (bridges, tunnels, etc.).

The Pavement Management System (PMS) employed for systematic pavement maintenance planning is based on LCC-analysis (life-cycle-cost-analysis) that provides a framework system for decision-making on maintenance measures in order to optimize efficiency in terms of the use of the resources available or in terms of pavement condition. For the practical application the commercial software VIAPMS™ is used.

The objects along the road network are treated by the BAUT system, the building database Austria hosts bridges, tunnels, noise barriers, retain walls and many other types of structures. The aim is to reflect the maintenance work flow of the road administrations. Starting with input of inventory data, storing inspecting results, forming the basis of cost prognosis for rehabilitation measures, the system provides also the treatment of roadwork sides. At the end a number of data mining tools and graphical representations are available to support decision makers in their daily work.

The combination of both PMS-results and assessment of structures is done by using advanced visualization techniques to generate strip maps and thematic maps.

Condition data of pavements and structures are an essential input during the assessment and analysis process. The condition surveys of the pavement are carried out in form of visual inspection and measurements by using high speed measurement devices.

The condition of an object is investigated every 2nd year and every 6th year by a minor respectively major inspection. Thereby the elements as well as the whole structure is rated by a number between 1 and 5, standing for perfect condition and non operable. These data are forming the basis of a special aging model for objects employing the cohort survival method.

The technical results of the different analysis and assessment processes of both pavement constructions and structures can be used either as basis for the generation of the annual maintenance program or to highlight the needs for maintenance budget at policy level. This output allows the road administration authorities to show clearly the policy makers the long term development of the condition distribution of the pavement and the structures for different budget preconditions and to convince them to spend the needed money into road maintenance.

1. INTRODUCTION

Austria's federal road network has a total length of about 2,100 km, including approx. 1,700 km of motorways and approx. 400 km of expressways. Since 1997, this road network has been managed by ASFINAG (Autobahnen- und Schnellstrassen-Finanzierungs-Aktiengesellschaft), which conducts its maintenance in cooperation with 4 subsidiary maintenance companies.

Beside the federal road network more than 34,000 km of state roads of two different categories (category B 10,000 km, since 2002 in the responsibility of the state governments, and category L 24,000 km) compose the most important part of Austria's road infrastructure. This network is maintained by the road administration authorities of Austria's 9 state governments.

Continuous deterioration of the pavement condition due to increasing traffic volumes (mostly heavy vehicle traffic) and ageing have led to an increased demand for maintenance to ensure a proper level of service on these road networks. The situation is aggravated by the high percentage of special structures (about 160 km of tunnels and 200 km of bridges on the motorways and expressways) due to Austria's special topographical situation, which represent a significant factor in maintenance planning. The map of Austria in figure 1 shows a schematic representation of the motorways and expressways.

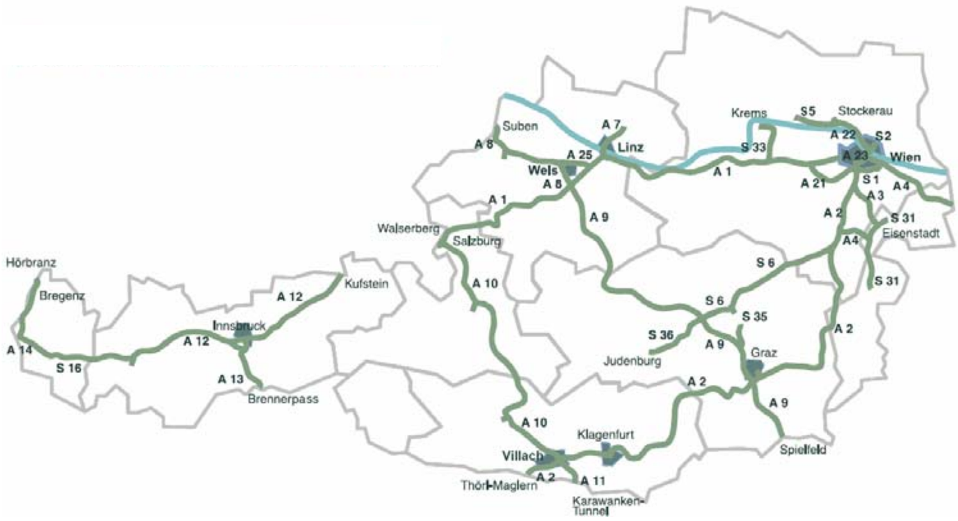

Figure 1 - Austria's federal road network (motorways and expressways), ASFINAG

In July 1998, the Institute for Road Construction and Maintenance (ISTU) at Vienna's University of Technology was commissioned by ASFINAG and the Federal Ministry of Transport, Innovation and Technology (BMVIT) with the development and implementation of specific components of the Austrian Pavement Management System (PMS) in cooperation with the road administration authorities. This was the first step in development process of the Austrian Asset Management System, which should be the basis for an objective future orientated maintenance planning. Since 2001 the different components of the Austrian Asset Management System are used in practice for the development of the long term and short term construction program and the budget allocation on the motorways and expressways.

About 3 years later the road administration authorities of 5 Austrian state governments started also with the implementation process of a computer assisted PMS on their major state road networks.

2. STRUCTURE OF THE AUSTRIAN ASSET MANAGEMENT SYSTEM

As already mentioned in the introduction Austria's mountainous topography causes an intensified adjustment between the maintenance activities of the pavement and the structures (bridges, tunnels, etc.) in the context of a comprehensive Asset Management System. This system is used for a net-wide objective maintenance planning process in consideration of different aspects and demands on different decision levels (project-level, network-level, policy-level).

The following figure 2 gives a schematic overview of the components of the Austrian Asset Management System, which is used on the federal road network.

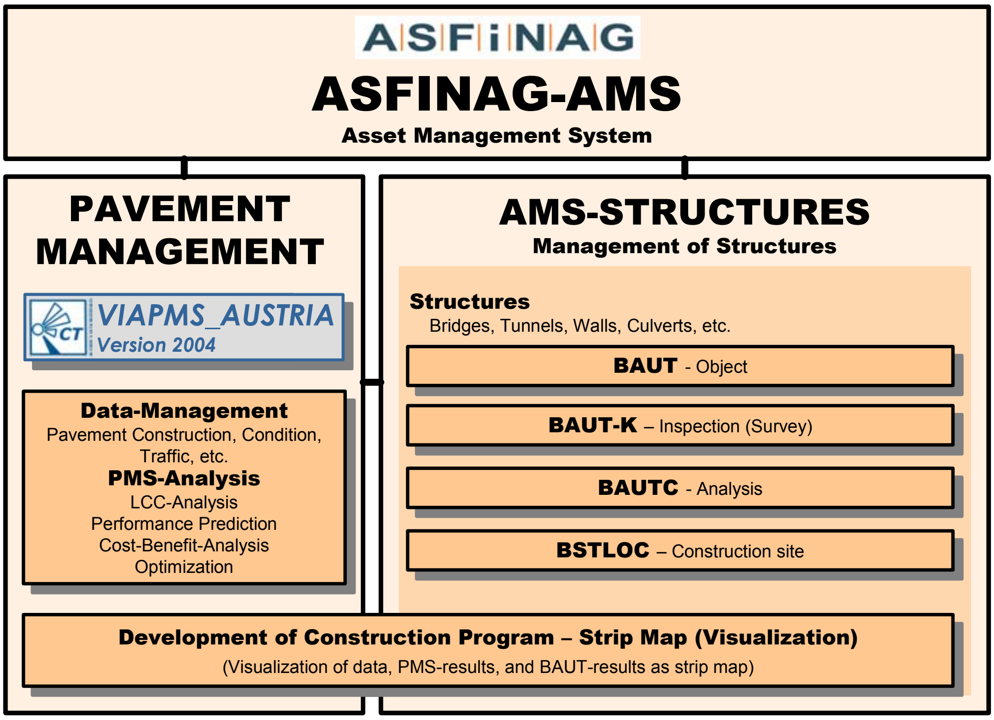

Figure 2 - Components of the ASFINAG Asset Management System according to (Weninger-Vycudil, 2003)

The combination of both PMS-results and assessment of structures is done by using advanced visualization techniques to generate strip maps and thematic maps.

2.1. Pavement Management System

The system employed for systematic pavement maintenance planning is based on LCC-analysis (life-cycle-cost-analysis) that provides a framework system for decision-making on maintenance measures in order to optimize efficiency in terms of the use of the resources available or in terms of pavement condition. The procedure employs cost-benefit analyses as well as a heuristic optimization process to identify the optimum maintenance strategy in a given set of conditions either budget or pavement condition (Weninger-Vycudil, 2004).

This system is applied on network level to the entire network of motorways and expressways and to major network of state roads of 5 states at the moment (Upper Austria, Lower Austria, Tyrol, Vorarlberg, and Burgenland). The different elements of the Austrian PMS are represented schematically in figure 3.

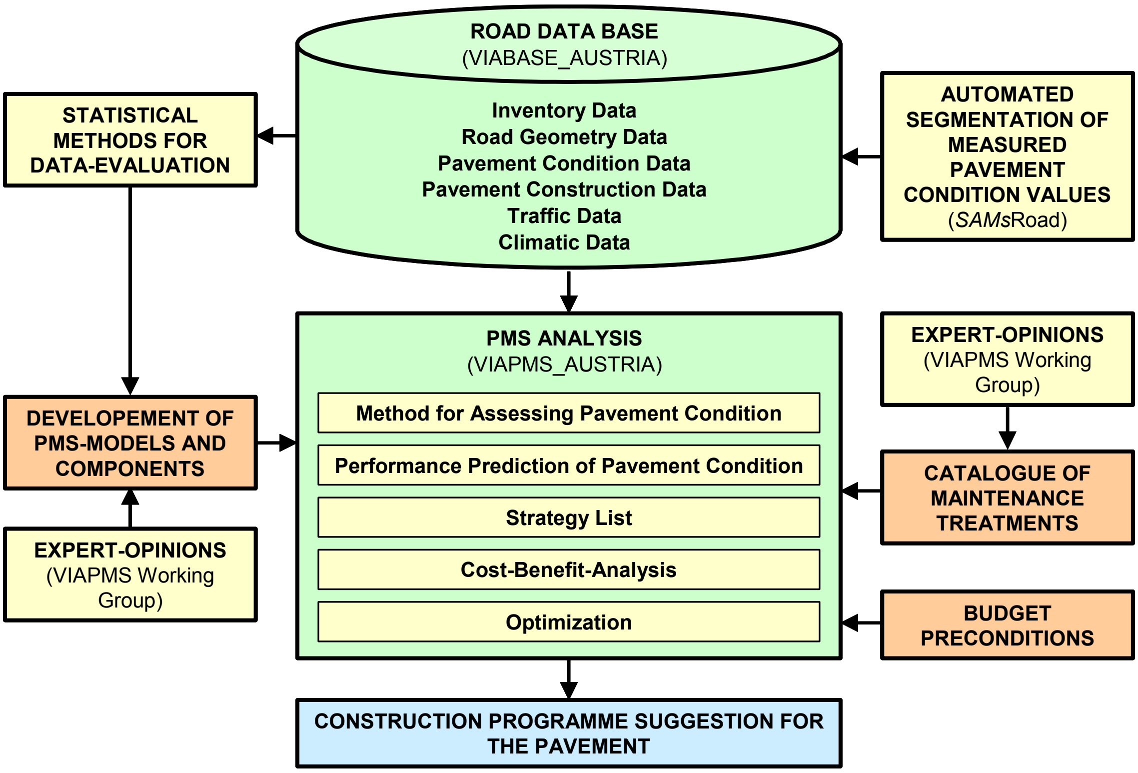

Figure 3 - Elements of the Austrian PMS (Weninger-Vycudil, 2004)

In the context of PMS-analysis different maintenance relevant data are included as follows:

- Inventory data (net-specific information and reference systems)
- Road geometry data
- Pavement condition data from visual inspections and measurements
- Pavement construction data including maintenance history
- Traffic data
- Climatic data

The practical application of the PMS relies on a computer-assisted asset management tool of Canadian origin (VIAPMS^{TM} – dTIMS^{TM}), which employs a deterministic optimization model for selecting the most effective maintenance strategy in the context of life-cycle-cost analysis. In choosing the system, the decisive factor had been that algorithms and models can be modified and defined by the user as necessary to enable effective control or adaptation to the road network and general framework conditions.

Advanced systems like the Austrian PMS seek to assess the need for maintenance measures and maintenance funding over a specified period under study or observation on the basis of predictions of pavement performance. The Austrian PMS employs deterministic performance functions for the prediction of pavement performance. These models were derived directly from the data available in the context of different research projects funded by the ASFINAG (motorways and expressways) and the Federal Ministry of Transport, Innovation and Technology (BMVIT) for the state roads (e.g. Molzer, 2002).

The result of an analysis is obtained in the shape of a proposal for an optimum maintenance strategy for each road section analyzed (as a function of the conditions defined), which can be used for further evaluation at project level. By aggregating section-based results, one can also assess developments in terms of cost and pavement conditions across the entire network level and, finally, determine the maintenance requirements in the road network being evaluated.

2.2. Elements of BAUT

The BAUT system is a client server solution build up my different logical tiers (see figure 4). The software is owned by ASFINAG. The elements hosted in BAUT are bridges, tunnels, galleries, retain walls, noise barriers, traffic sign bridges, various small structures along the road network and geological measure points. Beside crude technical aspects also planned maintenance measures, actual construction sites with a lot of information about traffic impact or done rehabilitation works are input into the database.

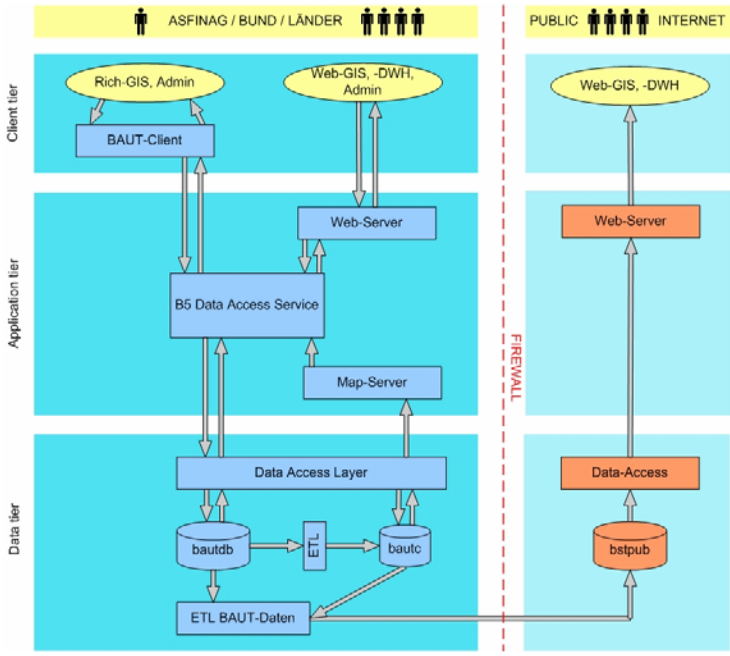

Figure 4 – Logical tiers of BAUT system

The software is owned and developed by the road administration ASFINAG. It is used also by all road administrations in the nine states and by some communities. About 250 users are working with the software.

BAUT offers a tool for engineers to support daily work on structural objects as well as for long term management of the building stock along the road network. Information about administrative and technical data is stored into a hierarchical data structure which offers a great flexibility for further development (see figure 5). The system BAUT offers capabilities for time invariant and variant information like inventory data or inspection results. The history of each input is stored to fulfil today's requirements of e-government. Further on, BAUT supports also typical work flow scenarios like registration of shortcomings, decision of repair action and finally input of information regarding undertaken work or costs.

BAUT contains a description of inventory and time dependent data mainly of those structures, which are critical from a safety point of view. The tool can be applied from either on project level, i.e. retrieving detail data, pictures, inspection reports, as well as on management level by means of summary tables and reports or even OLAP (Online

Analytical Processing) methods. The basis of the software is a hierarchical data model which provides a flexible solution for description of different kind of structures. It is possible to define for example a very simple small bridge as well as a long, technical complicated bridge within the same schema. The strength of BAUT is a compromise between amount of information stored in the database and completeness of data in it considering the necessary resources keeping a database alive.

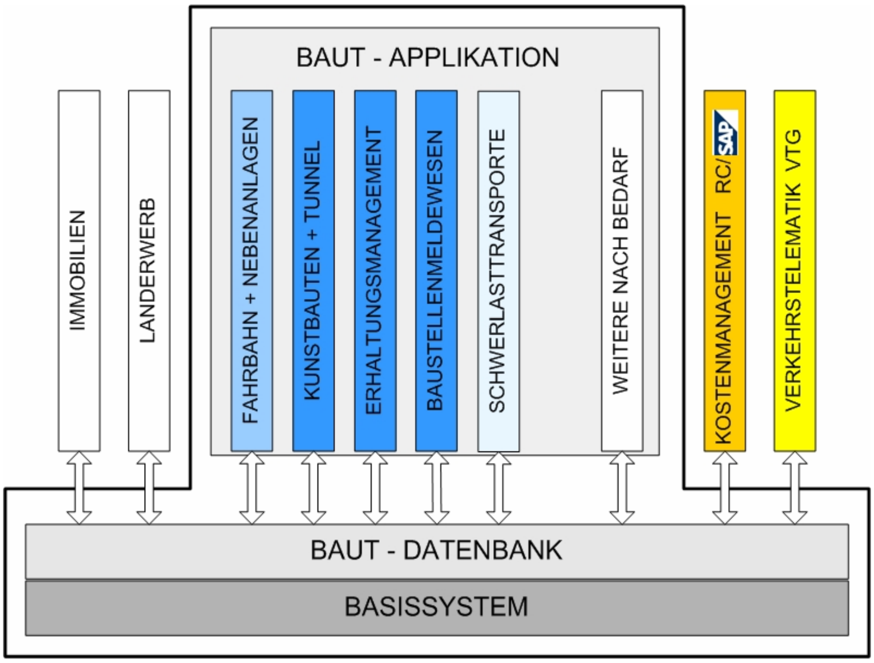

Figure 5 – Data structure of BAUT system

2.3. Condition survey

In Austria, surface characteristics (rutting, skid resistance, evenness etc.) are periodically determined in pavement condition surveys by using the high speed measurement device RoadSTAR (Road Surface Tester of arsenal research, see figure 6) and in form of visual inspections. These visual inspections are performed by using the crack detection system on the RoadSTAR or by manual visual inspection.

The motorway and expressway network has already been measured in three campaigns (1991 - 1994, 1999, and 2004 - 2005) and the state road networks of category B in two campaigns (1991 – 1996 and 2001 - 2002). Furthermore a high percentage of other state roads were measured during the last 3 years in the context of PMS-implementation process.
In addition, skid resistance acceptance tests and tests at the end of the guarantee-period are mandatory on new road pavements of the motorway and expressway network of Austria since 2005.

The RoadSTAR enables measuring the following important surface properties and road geometry parameters under normal traffic conditions:

- Skid Resistance (18 % slip, blocked wheel, ABS (Automatic Breaking System)
- Macro-Texture (MPD - Mean Profile Depth, ETD - Estimated Texture Depth)
- Transverse Evenness (rut depth, theoretical waterfilm thickness, profile depth)
- Roughness (IRI, Ride Number, longitudinal profile, FFT-analysis)
- Road Geometry (curvature, crossfall, gradient, height profile, dGPS-coordinates)

- Crack detection (high speed video system)

① Measuring wheel including braking torque measurement	⑤ Gearbox for producing 18 % slip
② Pneumatic cylinder	⑥ Water tank
③ Wetting unit	⑦ Device storage
④ Prewetting system	⑧ Drivers cabin - digital data acquisition

Figure 6 – RoadSTAR (Road Surface Tester of arsenal research)

Since, as a rule, each performance indicator (characteristic) covered represents only one aspect or one property of the road pavement, the individual dimensional values (technical parameters) obtained for the various characteristics first have to be standardized as dimensionless indexes (see Molzer, 1997), then aggregated into sub-indexes by applying weighting and combination rules, and finally aggregated into an overall index.

For transforming dimensional values, standardization functions (normalization) have been defined which enable an assessment of the damage or defect as a function of the importance of the road section (carriageway, ramp). The dimensionless values thus obtained are aggregated by applying weighting and combination rules to yield a comfort and safety index (CSI) expressing riding safety and riding comfort and into a structural index (SI) standing for the structural status of the pavement. The total condition index (TCI) resulting from the sub-indexes can be used, on the one hand, for calculating the benefit of a maintenance strategy as well as for defining the target function as part of the optimization process.

The combination of the procedure with deterministic pavement condition prediction models relating to individual characteristics permits the use of the procedure at any time during the period being analyzed and, beyond that, the prediction of sub-indexes and the overall index.

In Austria an inspection for every type of structure is regulated in codes abbreviated as RVS. It describes the amount of investigations and the time span between such inspection events. The code also defines a condition rating system which follows a scale from one up to five. The first level one stands for newly built and perfect condition and the last level five expresses that the operational condition is no longer fulfilled and immediate action has to take place.

During regular inspections every 2 respectively 6 years in average, shortcomings are recognized and reported. This results in a classification of the whole structure as well as of each element on the condition rating scale. Further on, each element itself is subdivided into sub-elements critical for the construction. These check lists are implemented in BAUT. There is the possibility to define dynamically a set of such lists and tailor it to the special needs of each administration.

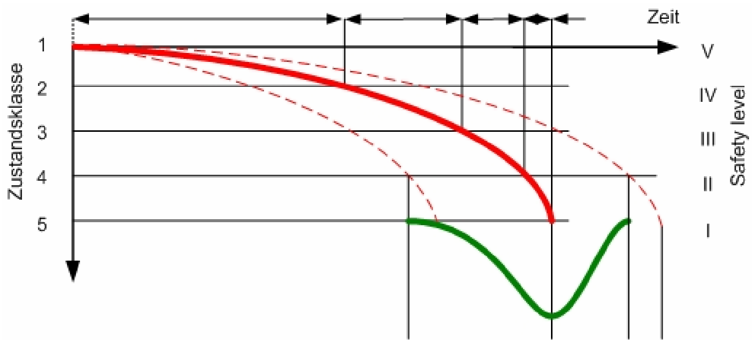

Figure 7 – Performance prediction of structures (schematic)

The purpose for conducting condition ratings is to determine the remaining life time till rehabilitation works have to be done. In case, data over nearly the life time of the bridges would be available, the quality of predictions would be very good. Actually, only data over a period of 10 years are stored in BAUT and can therefore be used for analysis. This sounds insufficient at first, but with modern analysis methods good extrapolations can be obtained (see figure 7). It would be unrealistic to await a completed dataset. Due to the costs and time constrains, the man power for inspections is limited and the growing network increases the number of bridges. Also practical considerations regarding impact on traffic or weather conditions limits the time where inspections can take place.

2.4. Visualization

The combination of both output of PMS-analysis and assessment of structures is done by using advanced visualization technology. This effective maintenance planning tool allows the road administration authorities to combine and compare the needs of maintenance activities of different assets and to present all information in a descriptive and clear manner to the decision makers. The visualization is carried out in form of

- strip maps and
- thematic maps.

The strip maps are the basis for the definition of the annual maintenance program including information of further investigations on project level. The thematic maps visualize

different aspects and characteristics of the pavement and structures and will be used primarily in the decision process at policy level and for public relationship purposes.
The display formats are standardized for the federal road network as well as for the state roads in some states.

Furthermore BAUT offers a generic approach to produce thematic maps, a longitudinal representation of various themes along the routes of a street. The condition of pavement and bridges are presented in combination with structural information, which is exemplarily displayed in figure 8.

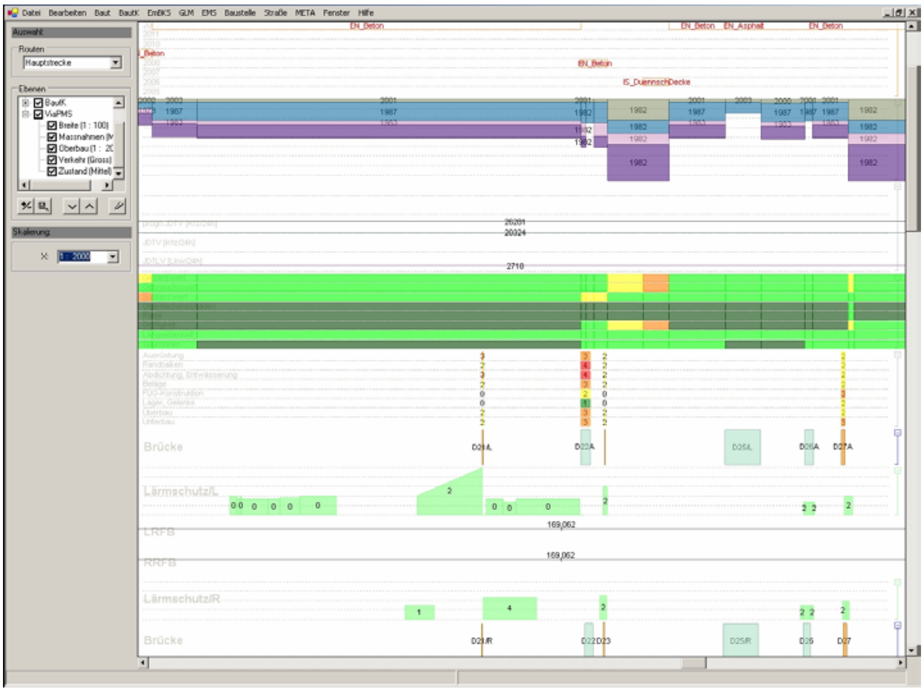

Figure 8 – BAUT data visualization

3. TECHNICAL RESULTS FROM EMS AS INPUTS FOR DECISION PROCESS

The technical results of the different analysis and assessment processes of both pavement construction and structures can be used either as basis for the generation of the annual maintenance program or to highlight the needs for maintenance budget at policy level.

3.1. Annual maintenance program

For the generation of the annual maintenance program the section based results of PMS-analysis and the output of the structure based assessment of bridges, tunnels, walls, etc. are preprocessed for the practical execution of maintenance planning. The final decision of a respective maintenance treatment includes also further investigations on project level and additional aspects beyond the system limits (e.g. political demands).

Subject to the importance of the respective road network and the proposed maintenance activities this final process will be carried out either as engineering post-processing by the local maintenance engineers (mainly state roads) or in form of an intensified subsequent planning process by a separate planning division (mainly federal road network).

3.2. Highlighting of needs for maintenance budget at policy level

One of the key tasks throughout the decision making process is the highlighting of needs for maintenance budget for the different assets. This output allows the road administration authorities to show clearly the policy makers the long term development of the condition distribution of the pavement and the structures for different budget preconditions and to convince them to spend the needed money into road maintenance. Furthermore it is also an instrument to confront the policy level with the consequences of a negligent approach to road maintenance. The net-specific results include as follows:

- Condition distribution for single and combined indicators for the whole analysis period subject to different preconditions
- Cost (investment) distribution for the whole analysis period subject to different preconditions
- length of maintenance sites and cost summary for the whole analysis period subject to different preconditions
- Backlog development for the whole analysis period subject to different preconditions

The following figure 9 represents exemplarily the development of the condition and cost distribution of the pavement construction for the federal road network under two different budget preconditions (budget scenarios).

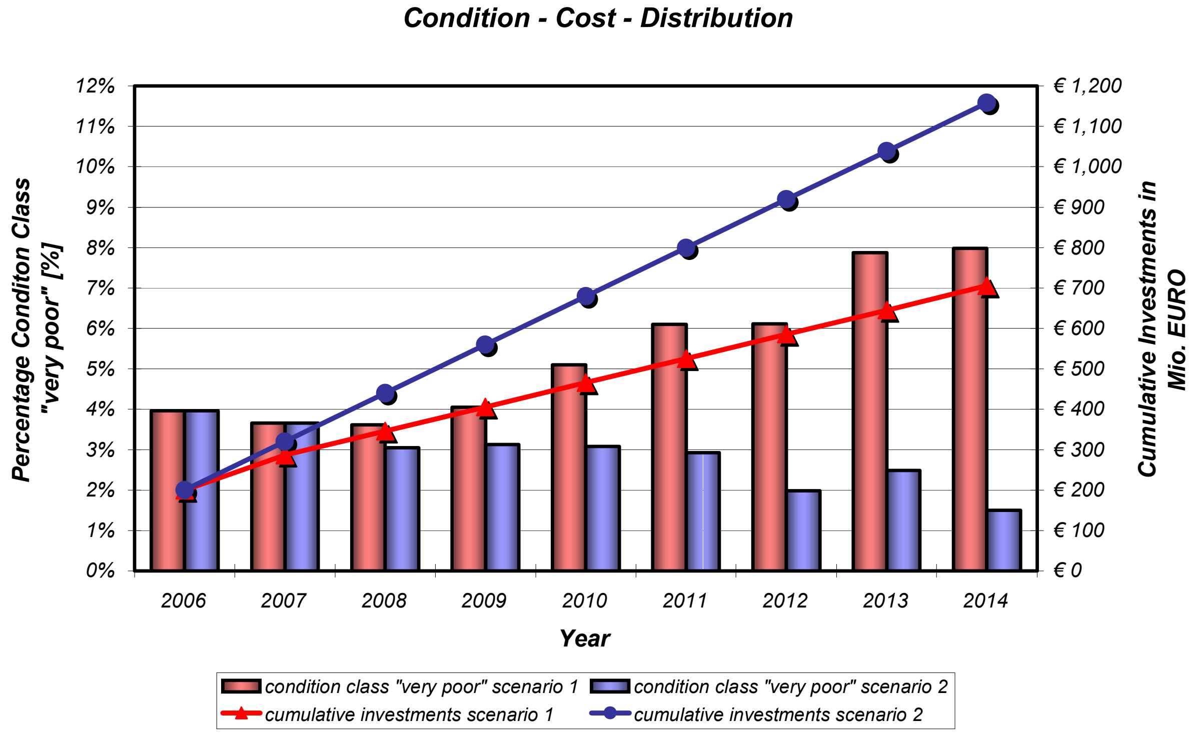

Figure 9 – Condition – cost – distribution for two different budget scenarios (PMS-output)

4. CONCLUSION

The quality of any Asset Management System is critically dependent on the quality and quantity of available underlying data. Therefore, the main focus of any follow-up work is on a significant improvement of the data used in the process. This includes not only the collection of new data but also the maintenance and updating of existing data as part of a nation-wide data management system.

The nation-wide implementation of the system depends, however, not only on the availability of the different components or elements but also, to a large extent, on the administrations' willingness to give this system preference over the currently used and time-proven methods. As in many fields of technology, one has to learn first to work with the system to understand the results and recognize the potential benefits.

Asset management has become standard practice in road maintenance in many countries, as road administration authorities come to appreciate the rationale behind them and their benefits. In Austria, too, this system will have to gain acceptance in the short or medium term as it is the only instrument available that can underline the necessity of allocating adequate budget resources for structural road maintenance as well as impressively highlight the consequences of a negligent approach to road maintenance.

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