ASCAM

Asset Service Condition Assessment Methodology

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ASCAM End Report

Final report

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Management Summary

In this chapter a management summary of the ASCAM project is given

Introduction

Maintenance managers on all levels are faced with the same dilemma. On the one hand they are given “end-user services levels” (objectives like reliability of traffic time, traffic safety, sustainable maintenance program) on the other hand they have their assets, the asset condition and a (dynamic) portfolio of measures which can be taken to ascertain the “end-user service levels”. The dilemma arises through the need for an optimal trade-off between budget available and budget needed for ascertaining the service levels.

The aim of the ERANET ROAD transnational research program “effective asset management meeting future challenges” is to improve technical, economical and sustainable performance of the European road network. It focuses on a cross asset approach, key performance indicators and the incorporation of environmental issues. Within this program, ASCAM (Asset Service Condition Assessment Methodology) is one of the two projects dealing with topic D: Framework for optimized asset management.

The **ASCAM project** focuses on a framework for optimized asset management. The research question in the project is:

> *Can we show that a framework, to connect existing asset management practices into a holistic, integrated cross asset and pro-active approach, is **feasible** and of (practical) **added value** for NRA’s.*
>
> *The requirements for the framework are:*
>
> - *Capability to connect (technical) measures to end-user service levels*
> - *Add value by connecting inspection and monitoring information to the necessary measures*
> - *Ability to compare maintenance strategies (measures and costs) in terms of end-user service level.*
> - *Add relevant topics like “grand societal challenges” (mobility, climate change) to the end-user service levels*

Solving the dilemma described above by introducing holistic, pro-active, cross asset management in national road authorities is a formidable task, which will include all stakeholders, ot the least the NRA’s themselves. This project is aimed at delivering the framework and assess the feasibility (i.e. the proof-of-concept) of this framework. The position of these results in the further realization of the envisaged asset management transition is described in a roadmap given after this summary. As part of this roadmap first ‘pilot projects’ are described, with the purpose of showing the added value of this kind of asset management on a limited scale for a specific NRA.

Research method

In order to get an answer to these questions the project team first made a rough description of the framework (WP1). Then a survey of existing asset management practices and state of the art methods and principles was done for three asset types in the road network (pavement, structures and road equipment, WP2, WP3, WP4). The survey was done by a literature survey, questionnaires and interviews at National Road administrations. The response was not as extensive as expected, but enough to get an overview of current practices and existing knowledge and information. With this input the demonstrator could be build and a virtual road (the E2020) could be used as in a case study to demonstrate the feasibility of the framework (WP1). An analysis of existing and especially missing data and relations showed the practical added value at this moment. By presenting the results to NRA representatives another perspective on the added value and possibilities for implementation (practical added value) could be added to the results (WP5). Finally reactions of, and comparison with, other projects within the ERANET program resulted in some more impressions on the added value and implementations opportunities.

Conclusions

Is it feasible to build an end user value framework?

The calculations performed with the demonstrator of the framework has shown that it is possible to build a tool which, in theory, can **connect technical measures to end-user services levels (EUSL's)**. The assessment of the information gathered in the WP's 2, 3 and 4 against the framework information need, has shown that in most countries relevant data for the framework can be found, and that the the information available in maintenance management systems can be used in the framework. The limited information available on the relationship between (technical) condition (skid resistance, evenness, etc.) and EUSL's (safety, etc.), was identified as the weak link.

The Monte Carlo simulation performed with the demonstrator showed that uncertainty of (predictions of) the technical condition can be taken into account. The demonstrator calculations showed that also risk (the possibility that a certain unplanned measure has to be taken, causing extra hindrance and unreliable traffic time) was added as a EUSL. This opens the possibility to show the **added value of inspection and monitoring in deciding for the necessary maintenance measures**.

Different numerical runs with the demonstrator, were performed, in which successfully **different maintenance strategies could be assessed (corrective, condition based and time based) from a EUSL perspective**. The demonstrator included safety, traffic delay (mobility), risk, cost and noise (in the vicinity of the road) as EUSL. Because of the open character of the framework other EUSL, such as the **effects of climate change**, can be added.

The work with the demonstrator showed that ASCAM concepts and implementation is best suited for assessing sub networks, though in principle it can be applied to an entire network. This would however lead to a very complex system, which requires a complex data input system and of which the results are hard to interpret by maintenance managers. Instead for an entire network, multiple implementations of different sub networks could be used, of which the results are aggregated on a network level.

From a framework implementation point of view differences between the three asset types considered are not significant. From an 'availability of input data' point of view, it was shown that of the three asset types, for pavements the most information is available. Therefore for NRA's it is easiest to start working with ASCAM methods for pavements. For structures the step from the commonly used ranking systems of the condition (e.g. from 1-5), to describing the asset condition with EUSL relevant aspects, is a major one. In the same sense for road equipment basically the aspect 'visibility' is important and hard to quantify. Also for road equipment the amount of maintenance budgets spent are low, and optimization against EUSL will therefore lead to limited benefit.

The conclusion is that building the framework is feasible, but attention and development is needed for:

- The relationships between condition and EUSL for pavement and foundations, structures and road equipment.

- Assessment of quality of input data with respect to practical decision support.

A roadmap was drafted in which further development of ASCAM principles into NRA's asset management systems is described. This showed that a substantial effort is required, which can be divided in multiple steps each of them bringing added value for NRA's.

Can such a framework be implemented and does it have added value?

Because in the ASCAM concept, measurers, asset condition and EUSL are connected, a vertical cross section is made in the asset management Top-Down and Bottom-UP approaches which link the high level strategic and low level technical aims in asset management. This is of added value for the NRA's. Such concepts are not easily adopted within most road infrastructure communities, however such breakthrough thinking seems necessary to realize NRA transition to a more market driven approach to infrastructure maintenance.

So from a past and present perspective ASCAM concept appropriateness may seem limited because of an ill-fit with available thinking, processes, routines, methods, organization and data. On the other hand, from a viewpoint of desired future maintenance practice ASCAM concepts appropriateness seems spot on, because of the intrinsic characteristics (cross asset, holistic and the user perspective as the leading principal), the adopted risk approached and the quantitative nature of tooling based on the framework.

The presentation of ASCAM to several NRA's showed that introducing ASCAM concepts now seems well timed. At the moment methods and means are emerging which can help to resolve the huge challenges which road maintenance management are facing the coming decades, e.g. ageing infrastructure, high demand on availability and safety. Such methods comprise e.g. life cycle costing or continuous condition monitoring. Benefits of such methods, especially in risk reduction, though well accepted, can hardly be substantiated using present day maintenance systems. This was perceived as extremely well facilitated using ASCAM principles and concepts.

From this perspective, the gap between current practice and the ASCAM framework is rather limited. For practical framework implementation, input from available MMS systems can be used. Immediate benefit would be that a well-founded cross national information exchange on ''good practices'' will become possible.

Implementation of the principle behind the framework will need a change of mind set. In current practises the EUSL is translated in criteria and the mind set in maintenance practise is mostly "meeting technical criteria". Using the full principle behind ASCAM the mind-set is changed to "negotiable decision support information". Differentiation in minimal road condition requirements is possible, because the decision is based on an optimal combination of End User Service Levels.

Recommendations

The recommendations are twofold: recommendations for implementation and recommendations for further development.

Implementation

Implementation of the ASCAM principles should be done by the NRA itself. Research institutes and consultants can help, but cannot implement the principle.

Pilot projects will help to find the necessary (reliable) information for using the framework principles in the NRA-specific circumstances. Due to practical reasons (availability of data) the ASCAM team recommends to use past performance for the pilot projects. Furthermore we think that implementation should start with examples with limited complexity; limited to a small part of the road (a corridor) and to one asset (pavement, because PMS is best compatible with ASCAM principles).

In the pilot projects specific problems could be assessed with the framework principle. These pilot project should show the quick wins of using the framework in a specific NRA perspective. Evaluating the projects will lead to an understanding of the added value of the principle, the link with the current practices and the issues blocking further implementation. NRA specific and generic projects for further development can be specified. From the ASCAM team the following ideas for such projects are suggested:

Severe winter conditions: comparison of information of the results of maintenance practices used in the past with predicted results of alternative scenarios, in terms of cost and value for End Users (more specific: probability of unplanned maintenance and congestion). Quick win of such a project is is the demonstration in stakeholder communication of the cost and risks effects of taking preventive maintenance measures against the consequences of severe winter conditions.

Night work: comparison of the congestion and cost of day and night work scenario for maintenance for specific corridors, to find an objective figure of the results in terms of EUSL and cost.

Quick win of such a project is the quantification and objective demonstration of the cost benefit effects of night work, especially the effects on the availability of the (piece of the) network. The investment in direct cost of night work can be justified (or not) by quantifying the gain in reduction of traffic delays.

Landslides: using the valuation of risk from an End User perspective as a way to find decision support information on the necessity of measures. Again quick win here is quantification of cost and risk reduction.

Budget restraints: Using the ASCAM principle to predict the short (1 to 4 years), middle (4 to 8 years) and long term (Life Cycle Costs) effects for End Users of scenarios to meet the (short term) budget restraints for a (for example) corridor. Quick win is the public acceptance of consequences on short or long term and help to find alternative solutions.

Further development

As stated in the conclusions the demonstration of the feasibility to build the ASCAM framework has shown that some issues need to be further developed. If the NRA want to make the transition to a more market driven (i.e. End User Value driven) approach, this work showed that an effort obtaining the data and the relationships between asset condition and these End User Service Levels need to be defined. This actually is a well-accepted in asset management in other field, e.g. process industry were relationships between throughput of an installation and asset condition is of high importance.

The implementation aimed pilot projects will help to find solutions to some of these issues, but a more fundamental applied research on this short comings is strongly recommended. Such information can be obtained by combinations of large scale monitoring programs, expert systems, advanced data mining techniques of existing databases (e.g. pavement conditions, like skid resistance and EUSL), an etc.

A roadmap for introducing the ASCAM framework in Asset Management practices is given in more detail for further development is presented.

Roadmap: The ASCAM project in the Development of Optimized Asset Management

Introduction

In the preparation for the Asset Management call within ENR, it was recognized that the traditional approach to managing roads, which is based primarily on the condition of the pavement and structures, is inadequate for today's needs. They largely ignore the wider issues such as stakeholder expectations, whole life costing, sustainability and the environment. This call therefore seeks to redress the problem by integrating these issues into a framework for pro-active cross asset management optimized against multi-stakeholder requirements (End User Service Level (EUSL) driven).

In accordance with the Asset Management DoRN, within ASCAM we investigated and work on the development of a cross-asset framework to provide a generic background to EUSL driven cross asset management concepts, methods and tooling as described above. To come to such a new framework an underlying principle (or paradigm) on which the new developments are based must be introduced. This principle should incorporate the fundamental step forward which is envisaged in the above; cross-asset, holistic, EUSL driven, pro-active, risk based, etc. From such a principle a development and implementation route must be followed to gain the actual advantages associated with asset management based on this principle.

Conceptual roadmap

So, for transforming the asset management community to the vision as given above, a major development is needed. Methods to guide such developments are available in abundance. Characteristic for many of them is a division in different stages from fundamental research to implementation. Such a phasing could roughly consist of the following steps;

- Fundamental research; a unifying EUSL cross asset management principle
- Applied research; a consistent framework of EUSL driven asset management concepts
- Proof-of-concept; checking feasibility of the introduced framework concepts
- Prototyping; methods, tooling, etc. based on the framework, NRA specific
- Pilot project; implementation in dedicated projects, NRA specific
- Practical implementation projects; tests in a real operational environment, NRA specific

Only in the last step, finally, the adaptation of the results in the main operation of the asset management organization is achieved. These steps are visualized in the figure below. Note that with prototyping here NOT a prototype of the ASCAM tool is meant, but rather prototypes of different kinds of tools, methods etc. which are based on the ASCAM framework. These tools will inevitably be NRA specific.

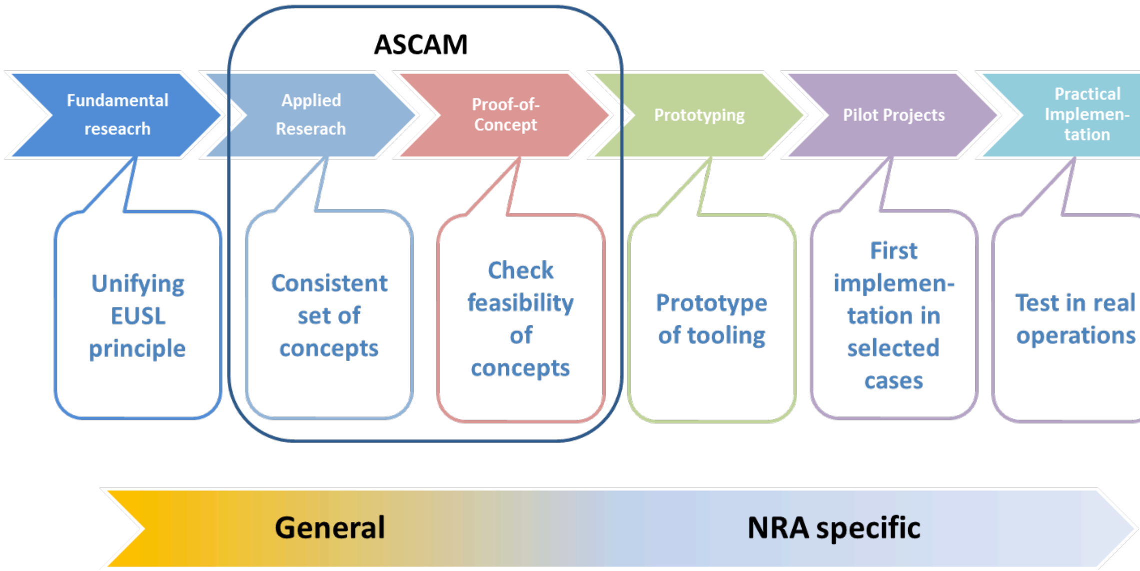


Figure 1 Schematization of development from fundamental research to implementation.

The ASCAM project started from an existing EUSL Asset management principle. Based on this principle the ASCAM project developed a consistent set of concepts (framework) and their mutual relationships, on which such asset management should then be based. Also a proof-of-concept of these framework concepts was given. This development helps in substantiating the level of abstraction of 'EUSL driven holistic Asset Management'. After defining the framework and delivering this proof-of-concept, it becomes possible to assess the further route forward from current asset management to the envisaged one. The demonstrator which is part of the ASCAM project IS the proof-of-concept, and therefore on a conceptual level which is general and not NRA specific.

After the ASCAM project, prototypes of tooling and methods should be developed based on the framework and tested in new (next) projects, which will be more NRA specific. The demonstrator developed in ASCAM therefore finishes a major step, but not the final step, in this development. The ASCAM project therefore is positioned in the area of applied research and proof-of-concept, and as end product has delivered the proof-of-concept of EUSL driven asset management in the form of the ASCAM demonstrator. Knowledge and information gaps were identified mainly in the relationships between asset condition and EUSL, but did not preclude the conclusion of a successful proof-of-concept.

Working with the demonstrator, showed that applying it to a specific case of limited scope for a specific NRA for which the necessary data and relationship is could give realistic results, showing the added value on a project scale. In the ASCAM deliverables it was therefore suggested that this would be the way forward for introducing the transition envisaged in the DoRN. Also, this would be a way of a first, small scale implementation of ASCAM results. Note that this does not imply prototyping of tooling, etc, since still does would be tailor made work for 1 case with a limited scope, etc.

Technical ASCAM roadmap

In the project the proof-of-concept of EUSL driven Asset Management was delivered as described in the ASCAM deliverables, this is not described separately here. The concepts for EUSL driven asset management were derived and existing information on (amongst others) assets, asset condition and development, maintenance methods, measures, costs, EUSL , and their mutual relationships was studied. It was concluded that a lot of information is available but some gaps exist.

Further development from the proof-of-concept is NRA specific, it is therefore not possible to give a concrete and specific roadmap. Further development should start with on-going developments at different NRA's. These development can be steered, with the help of the framework towards EUSL level driven Asset Management. The level of detail which can be given here is therefore limited.

In this paragraph a global outline on the CONTENT of this further development of ASCAM based methods and tooling is described. It is important to understands that as indicated in figure 1 this further development will already involve NRA specific steps.

But first, it is important to stress that besides these technical (content) driven development routes, also attention needs to be paid to acceptance and adaptation of the innovative ideas behind the framework. In our opinion this is best done by demonstrating the (potential) added value of the framework in 'pilot project', which are described in further detail in chapter 6. These pilot projects would also deliver input for validation and steering the developments as described in this roadmap, but this is not necessarily their main purpose.

The most important technical elements of the ASCAM framework which need to be developed are;

- a network decomposition from a EUSL perspective
- time dependent asset condition degradation
- quantification of the effect of maintenance measures on asset condition
- incorporated uncertainty
- relationships between asset/component conditions and EUSLs
- Information/database systems

As stated above the ASCAM framework helps with the further developments undertaken in different NRA's in the direction of EUSL driven Asset Management. A probable prioritization can be given when in these NRA development initiatives the technical aspects can be incorporated along the line given by the ASCAM framework, see figure 2.

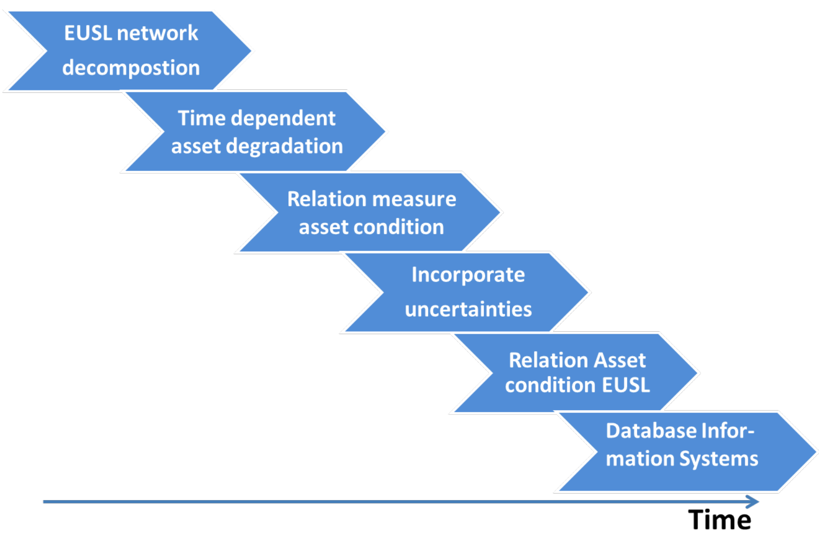


Figure 2 Probable prioritization of development of the main components of the ASCAM framework

A network decomposition from a EUSL perspective

When a prioritization must be given for these developments it seems appropriate to first make a network decomposition from an EUSL perspective. Immediate gain from such a decomposition would be the gain of insight on which components of the asset do really contribute to the EUSL of the network and which not. From such a decomposition and assessment it will also follow which maintenance measures do not really contribute to the EUSL of a certain NRA. It can directly serve in prioritization of maintenance measures to be taken.

Time dependent asset condition degradation

The second major development route is the incorporation of the available information, and obtaining the missing information, on long term asset condition behaviour. This information can be used to identify the long term maintenance need and to help determine which preventive measures are appropriate to be taken now. This will help to obtain best value for money in the future. It also will help to demonstrate the need for maintenance budgets now and in the future as well as to optimize smoothing maintenance budget over a long period of years. Existing information available in one country can be used in others.

Quantification of the effect of maintenance measures on asset condition

Quantification of the effect of maintenance measures on the relevant asset condition (from an EUSL perspective), also on the time development, will again help in optimal maintenance planning. Unnecessary maintenance measures can be omitted. Optimal maintenance measures and frequencies can be determined, especially when uncertainty is incorporated.

Incorporate uncertainties

Quantification and reduction of the uncertainties can for instance be obtained by combining the information from models of long term degradation of asset conditions and short term inspections. A structured way of collection, storage and analysis of data from a perspective of NRA objectives and strategies is necessary. It will help for instance in quantifying the effect of postponed maintenance on future budgets and future EUSL and associated risks.

Relationships between asset/component conditions and EUSLs

The final step in integrating all aspects is the development the relationships between asset condition and EUSL, e.g. how does pavement condition affect driver safety or comfort? With the development of these relationships, which is the most innovative concept in the ASCAM framework, the full potential of EUSL driven asset management is developed and obtained. Investments in maintenance measurers can then be compared to the reduction in the risk of e.g. non availability or (un)safety of a sub network. This can be done in a transparent and objective way and be demonstrated to technical maintenance managers, maintenance policy makers as well as politicians.

Information / database systems

The use of these systems will deliver the opportunity to do high level data analyses, with which trends can be discovered; effectiveness of measure and inspections, effect of ageing of components, effects of different suppliers, effects of pricing, etc.

1 Introduction

In ASCAM a framework is built for End User Service Level based Asset Management. The framework connects existing maintenance methods, data systems, etc., of which an inventory was made as part of this project. In this end report the all the research performed in the different work packages is surmised and overall results are presented and discussed as well as overall conclusions and recommendations are given.

In this introduction first the background of the research is given, next the ASCAM research aims are described and finally this report is introduced to the reader.

1.1 General introduction

Key Challenges for Future Infrastructure Asset Management

Maintenance managers on all levels are faced with the same dilemma. On the one hand they are given “end-user services levels” (objectives like reliability of traffic time, traffic safety, sustainable maintenance program) on the other hand they have their assets, the asset condition and a (dynamic) portfolio of measures which can be taken to ascertain the “end-user service levels”. The dilemma arises through the need for an optimal trade-off between budget available and budget needed for ascertaining the service levels.

From this, a key challenge for modern asset management follows; ‘*Can we show that a framework, to connect existing asset management practices into a holistic, integrated cross asset and pro-active approach, is **feasible** and of (practical) **added value** for NRA’s.’*

Nowadays Road Infrastructure Asset Management

Infrastructure management of all assets which constitute a road network has been performed for over three decades. Countless publications dating back as early as the 1980s can be found on pavement management systems and corresponding optimization strategies e.g. Finn (1983), Nesbitt and Sparks (1987), de la Garza et al. (2011), as well as bridge management systems e.g. AASHTO (1992), Frangopol et al. (2001), BRIME (2001), Kaneuji et al. (2006) or generally on structures and other sub-assets e.g. Shetty et al. (2005), Lundkvist and Johansen (2009). Many of these have evolved into complex life-cycle models that are in use today, such as PONTIS (product of the American Association of State Highway and Transportation Officials) and the Austrian Pavement Management System (Weninger-Vycudil et al., 2009). While these management tools work fine for their specific asset type, what is missing is amongst others is a connection between the condition state of different assets e.g. bridge & pavement. Bridge and the pavement will follow their own unique degradation curve and thus deteriorate at different rates, this makes it practically impossible to define an absolute technical condition of that particular road stretch. Also missing in these systems is the relationships between asset conditions, measures and costs, with end user value. Therefore with the concepts and systems used nowadays the above described dilemma cannot be solved, and they fall short in tackling the key challenges as defined above.

End User Service Level Based Asset Management

ASCAM proposes the development of a framework, and related tooling, with which the effect of a diversity of measures to end-user service level can be compared. The feasibility of this principle was shown earlier by TNO. In this project a feasible concept with which existing knowledge on structures, pavements and road equipment can be coupled together using this principle is described. To address to above challenges ASCAM focuses on a framework for optimized asset management and seeks to relate asset condition prediction to measures and network value (end user service levels). In doing so a framework is created which connects existing asset management practices into a holistic, integrated cross asset, pro-active approach. Also it can relate technical to societal issues, like pavement degradation or failures in the "dynamic traffic management systems" to end-user service levels such as efficient traffic flow, safety, reliability of travel time, noise hindrance or environmental issues. The framework enables policy makers, maintenance managers and their specialist to communicate on different levels and to overcome the boundaries between fields of knowledge.

The framework is meant to predict the cost and effect of maintenance strategies for (a network of) roads over a time span of years. It is based on predictions of the degradation and condition of objects of the assets and on the relationship between their condition and service indicators. These service indicators are defined here from an end user perspective (EUSL). Measures constitute costs and can influence the condition of the objects. On the other hand measures are meant to ensure proper operation of the network and lower the risks of not meeting the EUSL. By using societal cost benefits models these risks are expressed in monetary values and can directly be compared with the costs of measures. These are the main parts of the framework.

ASCAM objective

The aim of building the ASCAM framework is to demonstrate the concept of EUSL based asset management. It will develop the constituting concepts of the framework and show how the concept of EUSL based asset management can be put into practice, the advantages, disadvantages and missing links. In a final form the framework will process actual information from maintenance practice on these parts and will deliver cost prediction and risk predictions of the actual network. It seems not feasible to adapt existing maintenance practices, with the existing data collection, to the framework needs. It is more desirable that the framework and its implementation are closely connected to existing data and practices. Therefore as part of the study presented here this information is gathered and an assessment from the viewpoint of the framework is performed. Of course, on forehand, it's clear that this practical information is available in different forms for different assets and for different NRA's. Still by applying the framework principle the envisaged outcome can be obtained. It is however necessary to implement NRA specific sets of the information on the constituting parts of the framework.

1.2 ASCAM Research Objectives

The research objective of ASCAM are as follows;

Can we show that a framework, to connect existing asset management practices into a holistic, integrated cross asset and pro-active approach, is feasible and of (practical) added value for NRA's?

The requirements for the framework are:

- Capability to connect (technical) measures to end-user service levels
- Add value by connecting inspection and monitoring information to the necessary measures
- Ability to compare maintenance strategies (measures and costs) in terms of end-user service level.
- Add relevant topics like "grand societal challenges" (mobility, climate change) to the end-user service level.

1.3 Aim of This report

In this report therefore in chapter 2 the methods and methodology of the project is presented. In Chapter 3 the results in work packages 1 to 4 are summarized, i.e. an overview of current practices in maintenance is described as well as the framework and demonstrator developed in work package 1. In chapter 4 a discussion of the results obtained is presented. In this chapter emphasis on the second part of the challenge this project set out to meet on the possibilities to implement EUSL based methods and tooling is given. Or in other words the appropriateness of the framework in a practical context. Input for this discussion is from feedback obtained from presenting the framework to several NRA's and comparison with the results in other projects in the ENR Asset Management call; SABARIS, EXPECT and Procross. Finally conclusions and recommendations are drawn in chapter 5 and 6 respectively.

2 Methods

The following approach was followed within this project in order to develop and deliver the proof-of-concept of this framework and to assess it's appropriateness for practical implementation. Five work packages were established. In one (WP5) all management and dissemination activities were performed. In three of the remaining four work packages (WP2, 3 and 4) an inventory of existing asset management practices in the EU was made, divided over asset management type; pavement, structures and road equipment. The results were intended and used in the work packages 1 (WP1) for assessing the feasibility and appropriateness of the framework which was developed in this work package. Also in work package 1 a proof-of-concept in the form of a numerical implementation was made. With this demonstrator the effects and possibilities of applying the framework on asset management was demonstrated.

The following activities were developed within the project. At the beginning of the project the document "ASCAM Modelling Philoshophy & Guidelines for Data Requirement" was written. This document describes the ASCAM philosophy of cross asset management, from a more theoretical viewpoint and indicates the type of information that is required to build the proof of concept framework.

The next step in the project was to develop asset specific questionnaires which could be sent out to the NRA's representatives in order to get the information needed to build and assesse the appropriateness of the framework. Next the questionnaires were sent out to the NRAs of the participating countries in order to gain information on current practices and data used within them. This was done in WP2, 3 and 4 to obtain the state of the art of asset management in the domains of pavement, structures and road equipment respectively. The questions asked road operators about their existing practices in (cross-)asset management and went into detail on;

- the technical parameters used to measure an asset's condition,
- existing degradation models,
- typical repair or maintenance activities
- possible links between technical and societal aspects
- suitable decompositions of the assets for maintenance measures
- assessment of the trigger/degradation aspects that leads to interventions
- costs structure of measures
- key performance indicators used in existing practices

The feedback was complemented by studies from previous research projects on road asset management, such as the World Road Association (PIARC) report on high level management indicators (PIARC, 2011), or the European Cooperation in Science and Technology Action 354 (COST, 2008).

Also a second task was defined in WP2, 3 and 4. In this second task an assessment and elaboration of the former results in terms of the framework with emphasis on relationships between measures, asset condition and end user service levels was performed. Goals of this task were to deliver input to the framework on, and identify implicit relationships in, existing practices between measures/interventions, asset condition and end user service levels; e.g. skid resistance and safety, repair indicator of pavement damage (holes) and driver safety, etc.

In work package 1 the work was performed on building the framework on a conceptual level as well as on a more specific level which would be suitable for a numerical implementation in a demonstrator. The activities performed were a desk study of the results of WP2, WP3 and WP4 on the maintenance management concepts used across the EU at the moment. Also the information on the second tasks performed in WP2, WP3 and WP4 were input for this desk study. Finally also the results of a brainstorm session with the project team during the intermediate project workshop were used.

Next the framework was translated to a more specific level by making a numerical implementation using EXCEL©. Again this was done in a desk study and again, as much as possible, the input of the information of the other work packages was used, but now the more specific information and data. For the ASCAM project we have chosen (in the Description of Work) to focus on some important EUSL. As the project is about a “proof of concept” the choice for safety, availability, risk and noise can be considered as sufficient. A spectrum of stakeholders (driver, operator, neighbourhood) is represented and the issues are relevant in current practice of most (all) countries. Extension to other EUSLs of course is possible, but was not a part of the ASCAM project.

As expected a gap in the information needed to fully establish a demonstrator in which maintenance measures were related to EUSL was encountered. To fill this gap used was made of dummy analytical functions which were derived from authors experience. In the work performed, EUSL were expressed in a common metrics for which monetary values was used. Conversion of EUSL values in this desk study, as for instance noise levels or availability, to these monetary values were done based on information of an internal TNO societal cost benefit model, Gorris, et al (2011).

Next the following challenge which this project tackled, on the possibilities to come to implementation within NRA’s of methods and tooling based on an EUSL based framework, was addressed. Or in other words the appropriateness of the framework in a practical context. This was done in a threefold manner. Firstly in a desk study (the results of) the framework and the demonstrator were compared to the maintenance practices used nowadays and described in the information of the other three work packages. Especially the difference between the top-down and bottom up approach in asset management was considered here. Secondly the feedback obtained by presenting the framework and the demonstrator to the NRA’s of the countries involved in this project was used. Finally the findings of the ASCAM project were compared with those of the following other projects in the ENR Asset Management call; SABARIS, EXPECT and Procross. This was done by attending workshops of these projects, communication with partners in these projects and interviews with the project coordinators of these projects. These activities led to input for discussing the possibilities of implementing the ASCAM results. Therefore here they are reported in the discussion section of this report.

3 Results

This results section is divided in 5 paragraphs. The first deals with current practices in maintenance approach. It contains an evaluation of the results obtained in WP2, 3 and 4. In the following 3 paragraphs details are summarized for pavements, structures and road equipment on; principles, decomposition, performance indicators, measures and user perspective. Finally a short description of the framework and the demonstrator is given, which summarizes the results of WP1

3.1 General Concepts in Maintenance Approaches

From the ASCAM project work packages (WP 2, 3 and 4) we have obtained an overview of the current practice in countries in the European area for pavement maintenance, maintenance of structures in the network and maintenance of road equipment. Detailed information can be found in the ASCAM reports of WP2, 3 and 4. Here the findings are summarized, using text and information from these reports. For more information on asset management practices in Europe, we refer to the results of PROCROSS, a project in the same ERANET ROAD program.

3.1.1 Assets in the network

The ASCAM project is focused on developing a framework to show the costs and consequences of a combination of maintenance measures in a certain timeframe. We want to express the consequences in service levels for the end user (or stakeholder) and we should be able to implement basic maintenance concepts in this framework. The added value of the ASCAM project should be the holistic and cross asset approach. Describing current practices, a distinction should be made between the maintenance approach of the different assets in the network. Pavement, constructions and road equipment are often managed separately, as if they do not function in the same network. Of course in current practice the maintenance of the assets is linked in the overall budget planning. Also in a detailed short term planning of maintenance measures the effect of linking measures to decrease the amount of hindrance for the road user is often assessed. But it certainly is not common practice to synchronize and/or integrate the individual asset management systems of the three distinguished assets (pavement, construction, equipment).

3.1.2 Maintenance concepts

Since in ASCAM we want to show the cost and consequences in a timeframe, we need to use predictions of the lifespan of objects and their technical condition. Even for corrective maintenance, predictions of the (expected) number and costs of unplanned maintenance activities as well as the consequences for the end users have to be estimated. Otherwise a comparison of maintenance scenario's and optimization is not feasible.

In general three basic maintenance concepts were found:

- Corrective maintenance (condition based)
- Preventive maintenance (time based)
- Predictive maintenance (estimated condition based)

Of course a combination of the three basic maintenance principles is the most used in practice. To optimize the cost and value of the assets for (each part of the) network NRA's have developed strategies for maintenance, combining the above mentioned principals. Strategies are depending on goals, type of asset, traffic density, failure type, frequency and consequences, available budget and other relevant aspects. For maintenance of roads NRA's have their own methods, strategies and principles fitted to the circumstances in their country, which can differ substantially from country to country.

3.1.3 Asset management concept

The asset management concept is based on the Deming circle: plan-do-check-correct. It is a **management** principle. In this report “asset management” is used as a principle to optimize maintenance (inspection, repair, renewal, etc.) efforts against the criteria of the NRA. Examples of these criteria:

- find a maintenance scenario with the best cost benefit ratio,
- find a maintenance scenario that fulfills the minimum requirements of the network (safety, etc.)
- find a maintenance scenario that fits into budget and planning constraints.

3.1.4 User perspective

In ASCAM we build the “cross asset approach” through the consequences of measures and road condition for the end users (we have called this the End User Service Levels, EUSL). Not only cost, but also risk and value are taken into account. The value of the network is related to stakeholder requirements and the cost stakeholders are willing to bear for getting the required service. In road maintenance this not always evident. In other projects in this ERANET ROADS program (EXPECT and SABARIS) the research issue is “stakeholder requirements”.

In the maintenance practices the choices made by the NRA’s will be related to EUSL’s, although most of the time not explicit. For example in the Netherlands the hindrance for road users is in many cases an important factor in the choice of the approach of maintenance and repair work. The Dutch technical standard “basic maintenance level (B.O.N.)” is strongly related to a minimum safety and comfort level. During the preparation of large maintenance projects minimizing the hindrance is always part of the decision making process.

3.1.5 Measures

In the maintenance management principles measures can be categorized. Each category of measures influence the End User Service Levels in a different way.

Basically it was found that measures can be divided into three categories:

1. Measures intended to change the technical condition of the object (repair, renewal).
2. Measures intended to inform the NRA about the technical condition (inspection). These measures do not change the condition of the object itself, only the knowledge about the condition of the object.
3. Measures intended to change the behavior of end users (speed limits, prohibitions). These measures will change the **use** of the asset (and can indirectly influence the condition and the expected service life).

In this chapter for each asset type (pavement and foundation, structures, road equipment), the first type of measures will be described. Condition assessment is part of the Maintenance Management Systems and is described in the ASCAM WP2, 3 and 4 reports. The last type of measures are considered as emergency measures by road authorities. It should be noted that, these kind of measures can be quite cost effective and can therefore have a beneficial effect on service levels.

3.1.6 Description of current practices

In the description of current practices for pavement, structures an road equipment a generic description of the principles, the decomposition of the asset in objects and/or components and in performances indicators, measures and the approach to the user perspective is included. These are important results for the holistic cross asset ASCAM approach and care should be taken to incorporate them in any application of the framework to ensure that current practices are embedded.

3.2 Practices in Pavement and Foundation Maintenance

Principles

The preconditions for pavements management vary widely from country to country (aspects like traffic density, culture, financial situation, etc.). Therefore also a wide range of maintenance practices in pavement maintenance can be observed, which probably attempt to optimise the cost – consequence ratio of the maintenance performed. Some countries mainly use the principle of corrective maintenance for pavement, which means that in case of problems the pavement will be repaired, but hardly any measures will by taken before real problems arise. In other countries a (long) time based preventive maintenance strategy is chosen, combined with a corrective strategy for minor failures. In reality the time based strategy will be changed to a condition based strategy, if measurements show a better or worse pavement condition. The detailed "short term" maintenance planning will then be adapted to the outcome of the condition parameters measured to save unnecessary costs and hindrance.

Most countries are using a pavement maintenance tool. These tools are designed to structure and use the information about condition, costs maintenance measures, critical values, etc. and can be used to plan maintenance measures. The data in such tools can be analysed to develop a better cost benefit ratio by changing the strategy or deliver management information about the necessity of maintenance budgets, consequences of budget reductions, etc. In some of the tools predictions of material degradation are implemented as well as minimum levels for conditions in order to implement a predictive maintenance strategy.

Decomposition

Pavement and foundation are decomposed in top layer (pavement), sub layer or layers, foundation The sub layers can have effect on the condition of the top layer (e.g. cracks). So measures can be related to top layers, sub layers and foundation.

Another way of looking at the pavement used, is to separate the lanes. The decrease of the condition of the lanes can differ significantly. Heavy traffic can have a serious negative effect on the condition. E.g. in the Netherlands on highways overlaying of the right lane is more frequently done, than of the left lanes.

Performance indicators

Performance Indicators in the Pavement Management Systems or "Performance Indicators" as they are called in WP2, are physical characteristics of the road pavement that indicate the condition of it. They can be expressed in the form of a technical parameter (dimensional) or in the form of an index (dimensionless). The following Performance Indicators (PI) for pavements are used in most of the EU countries:

- Transverse evenness (rutting)
- Longitudinal evenness
- Macro-texture
- Cracking
- Surface defects
- Friction (skid resistance)
- Bearing capacity

These performance indicators are measured with special equipment, like “ARAN” (Belgium, Netherlands), “Scrim tex” (Slovenia).

The value of the performance indicators typically decreases in time. Most pavement management systems are using inspection results (measurements) to assess the condition of the pavement. To foresee maintenance, estimations of the residual life span of the pavement are made. These estimations are based on experience. Some NRA’s are using models to calculate the residual life span. Predictions are being used to plan maintenance, to be able to reserve the necessary budget and to avoid unnecessary unplanned maintenance activities. Most unplanned activities are more expensive and cause more hindrance.

Results on PI are used to assess the condition of the road and to plan maintenance. In some countries the PI value is directly converted into maintenance needs and plans. In other countries the performance indicators are used to calculate Key Performance Indicators and (Combined) Performance Indices. Then the value of these indicators and indices will trigger maintenance.

Measures

In most countries a catalogue of measures is available. Costs are estimated with historical data. Combined with a maintenance planning a yearly budget can be calculated. Indirect cost of maintenance (like traffic hindrance) are not included. Only in some countries in specific cases (e.g. for maintenance of a very intensely used road) indirect costs are calculated, to be able to compare different logistics of the planned maintenance activity.

For Example the Slovenian pavement management system, currently used for motorway on the network level, distinguishes three types of treatments:

Major treatments – in one year time–period only one ‘Major treatment’ can be carried out in one road section. Maintenance actions such as strengthening, over covering, local rehabilitations, reconstruction of pavements are considered as major treatments.

Minor treatments – several minor treatments (patching) can be carried out in one year time on the same road section.

Ancillary treatments – additional, usually minor treatments

A catalogue of maintenance measures was identified.

- local repair of damages, i.e. patching
- surface dressing; adding a thin surface layer to the existing pavement
- reshape/milling of road surface to reduce rutting or improve skid resistance
- repave/renewal of road surface by milling the old pavement and applying a new bituminous layer
- reconstruction of pavements
- strengthening the subgrade and the asphalt superstructure
- strengthening/renewal of the entire superstructure

Measures influence the value of the performance indicators of the pavement. E.g. repavement will influence most of the performance indicators mentioned. In most maintenance management systems the maintenance cycle starts again. In the Austrian case the values of the pavement performance indicators are improved after taking the measure, but not “as new”. In ASCAM WP 2 report a table is shown with the improved values.

User perspective

In most countries critical values for the performance indicators, the (combined) key performance indicators or performance indices are used to trigger maintenance activities. And in most countries these critical values, or “trigger values”, are related to safety and comfort. No explicit relations between e.g. number of accidents and skid resistance are used, but experience, research and/or other input did end up in such trigger values. These values are implemented in the pavement maintenance systems and in guidelines, rules and/or regulations. The user perspective certainly is taken into account. EUSL's for other stakeholders, such as noise hindrance for people living next to highways could be relevant for maintenance decisions, but this is exceptional in maintenance practice. E.g. noise is an important factor for new top layers, but the increase of noise production due to decrease of the noise reduction capacity of a top layer is seldom the reason for repavement. The EUSL's are mostly limited to safety and comfort. Quantitative measurement of the characteristics (e.g. number of accidents as the safety parameter or a vibration index as the comfort parameter) is not available.

Also the traffic density, which can differ immensely, is not an explicit parameter in the road management systems. Looking from the user perspective, a road authority should be less worried about problems on roads with a low traffic density then with a very high traffic density, as more travellers are involved.

3.3 Practices in Maintenance of Structures

Principles

In the past few decades, an increasing number of deteriorating bridges led to the development of a number of Bridge Management Systems (BMS) and life cycle maintenance models. Bridge Management System (BMS) is defined as a rational and systematic approach to organizing and carrying out all the activities related to managing a network of bridges, including optimizing the selection of maintenance and improvement actions in order to maximize the benefits while minimizing the LCC [Hudson et al., 1992]. BMS is designed for managing groups of bridges (can include thousands of structures) with limited financial resources.

The heart of a BMS is a database derived from the regular inspection and maintenance activities. The value of a BMS is directly related to the quality and accuracy of the bridge inventory and physical condition data obtained through field inspections [AASHTO, 1994]. Information such as the bridge name (ID), the location, and the construction date are stored. These data are considered the starting point for the system: drawings, maintenance records, and surveys are reviewed. The database and inventory allow bridge managers to be fully informed about the bridge stock under their control so that they can make informed decisions about future maintenance and repair activities.

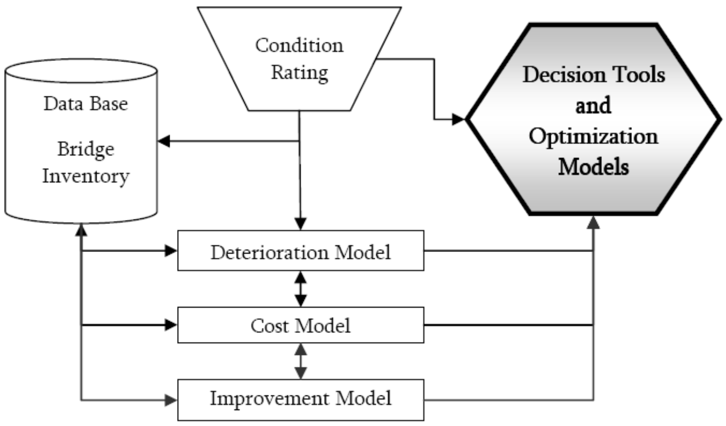


Figure 2: Basic components of a BMS [AASHTO, 2001]

Basic components of the BMS are shown in Figure 2. Mainly there are three aspects addressed by BMSs found in literature: condition assessment, modelling future degradation and optimisation of maintenance, repair and rehabilitation (MR&R) decisions and actions. These aspects are then analysed on project level and network level. Both levels are interrelated and should not be analysed separately which is often done in BMS's.

Decomposition

During condition assessment of the structures in order to determine the overall bridge condition, structures are usually divided into components, as shown in Figure 3.

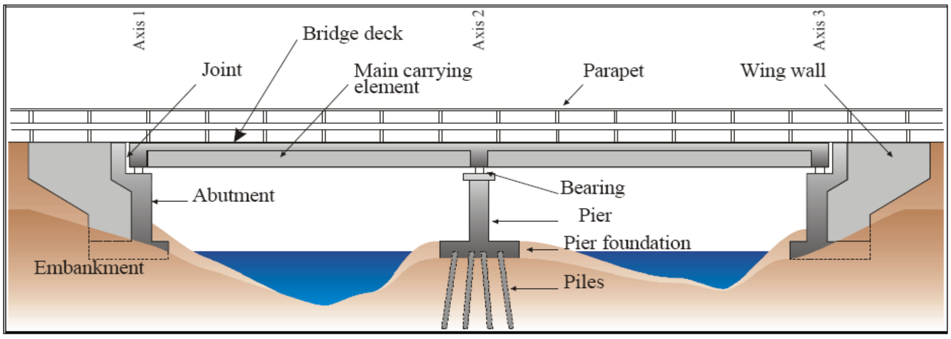


Figure 3: Example of elements of a bridge [BRIME D14, 2002]

The most usual division on components is shown in Table 7, and also applied in e.g. Croatian BMS.

Table 1: Components of the bridge

Bridge equipment	Superstructure	Substructure
Pedestrian ways	Arch	Head beams
Curbs	Deck	Columns
Cornices	Girders	Abutments
Pedestrian guard rail		Foundation
Traffic barrier		
Rail expansion joints		
Bearings		

Performance indicators

In bridge management systems the performance indicators are defined as condition ratings, e.g. from 1-5. Condition ratings are adopted to describe the existing condition of the bridge, compared to its condition at the time of construction. In general, the condition rating can be categorized as bridge (structure) ratings and component ratings.

The main differences between existing assessment methods within BMS are in the level of final condition rating, which differentiate from element to the structure level and even to the network level. Usual condition assessment is performed on the element level and then integrated and / or recalculated into structural level assessment, which may then be used for the prioritisation in the maintenance decision making process on the network level.

Measures

Measures to improve the conditions of a structure, should be part of a maintenance plan. A maintenance plan is based on a decision making system which chooses the best repair option considering the essential parameters: safety, durability, functionality and economy.

Figure 4 (based on Humphreys M. et al. 2007) presents part of a decision making process in managing an infrastructural asset e.g. concrete bridge. The diagram presents a project level decision making process.

In the standard EN 1504-9:2001 11 principles and 37 methods to repair structures are included, such as surface coating, reprofilation of concrete and replacement of elements. In WP3 report more information including cost is available.

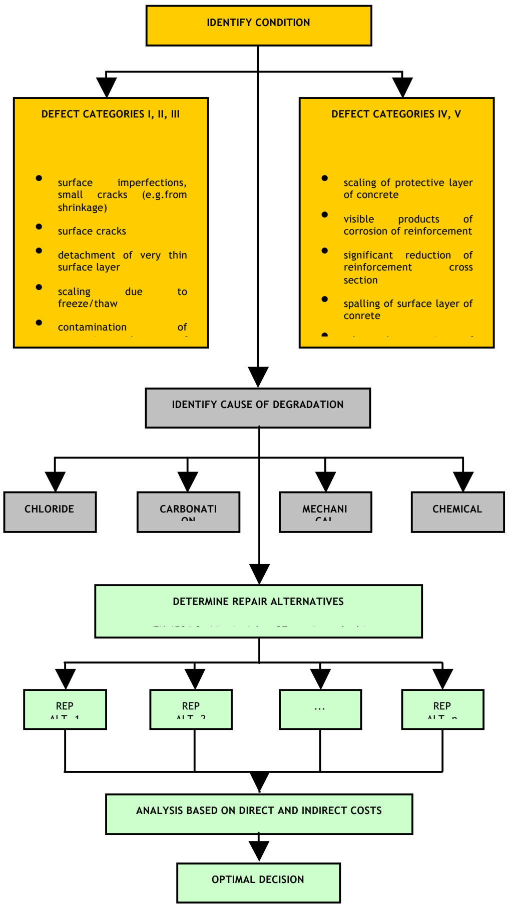


Figure 4: Decision making process in managing concrete bridges (Humphreys M. et al. 2007)

User Perspective

The main issue for structures is safety. For bridges this can mainly be seen as bearing capacity, for tunnels the structural safety and the safety of the road user in the tunnel. For the road user, probably the availability of the structure is more important, because safety is expected to be taken care of. In the maintenance decision making process, as mentioned before, safety, durability, functionality and economy are the important parameters. And decisions are taken on project, not network level.

3.4 Practices in Maintenance of Road Equipment

Road equipment is everything on, or close to the road, which is not asphalt or concrete. Important types of road equipment are traffic lights, road markings, stationary road lighting, signs and rails. Other types are road studs, post delineators, variable message signs (VMS), bollards and game fences. Common for all road equipment is that it is aimed for, at least to some degree, improvement of accessibility, comfort and traffic safety.

Principles

The principles for maintenance management of road equipment vary. For road markings most countries use hand-held or mobile instruments to measure the retro reflectivity of (dry) road markings to assess the night time visibility. Other parameters (skid resistance, luminance coefficient) are measured by hand held instruments or judged visually. In case the markings do not fulfil the requirements anymore the markings will be renewed. In some of the countries inspection results are being stored in databases and could be used to develop a maintenance management model, which at the moment does not exist in any of the countries assessed.

For Road studs, delineator posts, fixed signs and road lighting almost the same conclusion can be drawn. Inspections are being carried out and if the signs do not fulfill the requirements, signs or LED’s are being replaced. No management system but some data storage is available. For variable message signs the critical factor is the legibility. Some types of VMS’s are supervised automatically others are inspected regularly. In Germany for example the inspection and maintenance is done by the contractor. What information is stored by them and what maintenance management system the manufacturer uses is not known.

Decomposition

For most of the road equipment decomposition is not applicable. For variable message signs and lighting LED or bulb can be separated from construction (and software).

Performance indicators

For all road equipment visibility is the main performance indicator. The indicator for visibility can be the retro reflectivity (road marking, etc.). For fixed signs legibility is the indicator, which can be assessed by visual inspection. No “measurable” indicator, except the retro reflectivity, is available. Furthermore the colors should be within the limits of CIE 1931. For VMS and lighting the visibility of the light (LED’s or bulbs) is expected to be according to requirements until burnt out.

Measures

Replacement is normally the corrective measure for road equipment as repair is hardly an option.

User perspective

Road equipment is used to make the driving task easy and guide the driver along the road or street, making the journey safe and comfortable. Generally road equipment gives the driver some visual information. Consequently, the equipment should be visible and/or legible at relevant distance during different climatic conditions. The direct relation between EUSL’s such as safety (number of accidents) and comfort is not available. Nevertheless road equipment is crucial for a safe journey. Although a lot of research on road equipment, has resulted in improved markings, VMS, etc., the exact influence of (partly) failing road equipment on the EUSL’s is not available.

3.5 ASCAM framework and demonstrator

In this chapter a summary of the results of WP 1 is given. First the ASCAM principles are described. Next they are further elaborated in the demonstrator which also composes the proof-of-concept.

3.5.1 ASCAM principles

The framework is meant to predict the cost and effect of maintenance strategies for (a network of) roads over a time span of years. It is based on predictions of the degradation and condition of objects of the assets and on the relationship between their condition and service indicators. These service indicators are defined here from a end user perspective (End User Service Levels - EUSL). Measures constitute costs and can influence the condition of the objects. On the other hand measures are meant to ensure proper operation of the network and lower the risks of not meeting the EUSL. By using societal cost benefits models these risks are expressed in monetary values and can directly be compared with the costs of measures.

With this approach the framework is right in the gap between the well-recognized top-down (managerial) and bottom-up (technical) approach and can possibly help in closing this gap. So the main concepts in the framework are;

- a proper (physical) asset decomposition
- a proper decomposition of the asset components from an EUSL perspective, leading to the EUSL relevant 'aspects' of the asset
- condition and degradation functions of the asset components and/or aspects,
- a database of measures and costs of these measures and how they affect the functions,
- a description of the relationship between the functions and the EUSL,
- A societal cost benefit model comprising the relevant EUSL.

The uncertainty of all the elements in the frame-work is the reason that maintenance management is not as straightforward as it seems to be. The frame-work offers the opportunity to clarify the effect of this uncertainty. First of all it offers the opportunity to investigate the effect of different maintenance scenario on EUSL, the risk not to meet them and costs. However also within one maintenance scenario uncertainty remains, e.g. with respect to degradation rates or the importance of certain EUSL over a longer period of time. With these uncertainties costs or risks (of not delivering the EUSL) are associated.

By incorporating an option to account for these uncertainties in e.g. a numerical implementation of the tooling based on the framework, investments in monitoring systems (an uncertainty/risk quantification tool) can be rationalized. For a proof of concept the ability to randomize the events was incorporated to show the effect of monitoring.

When all this information is in place, calculations based on different maintenance scenarios, is relatively easy with a numerical implementation. In a final form the framework will process actual information from maintenance practice on these parts and will deliver cost prediction and risk predictions of the actual network. This practical information is available in different forms for different assets and for different NRA's. Still by applying the framework the envisaged outcome can be obtained. It is however necessary to implement NRA specific sets of the information on the constituting parts of the frame-work.

3.5.2 ASCAM demonstrator – proof-of-concept

In Work packages 2, 3 and 4 of this project an evaluation of current asset management practices was carried out. Attention was paid to gathering framework relevant data sets and relationships; asset decomposition, functional decomposition, etc. Special attention was paid to the relation-ships between asset condition and EUSL, being the most innovative part of the framework. Not much information on these relationships is used in current asset management, and conceptual relationships were constructed.

As an example a relationship between condition and safety is given here. For all others see. Report WP1. In the demonstrator we implemented a factor F_SAFETY in order to account for a relation between component's conditions and the number of accidents:

$$F\_SAFETY = a + b*(1-c)^2 \qquad (1)$$

Depending on its parameterization for a and b, this function can e.g. have values between 0.5 (for excellent condition, c=1) and 1.5 (for very poor condition, c=0). The condition dependent number of annual accidents N_{acc} and the yearly costs C_{acc} are then calculated as;

$$N_{acc} = F\_SAFETY\ P0 * (L*I) \qquad (2)$$

$$C_{acc} = C0*N_{acc} \qquad (3)$$

With L the length of road segment [km] and I the traffic intensity [veh/year]. Values used are 2.10-7 [-/vehkm] and 31 kEuro/accident for P0 and C0 respectively. Of course the framework is open for alteration of these values and relationships. From a small cross section of this information and the constructed EUSLs an numerical implementation of the framework was made as a demonstrator, screenshots of the demonstrator are shown in Figure 5.

The demonstrator enables the comparison of different maintenance strategies for cross-asset management on a mutual scale, taking EUSLs costs into account in relation to the intervention costs. The user can define a small network composed of segments, each populated with objects to be selected from a small database. Some network related meta data can be defined, e.g. traffic intensity, traffic growth, time window etc.

The level to which this subdivision is applied in the demonstrator is on practical grounds. A typical resulting description is;

- Segment (defined as a length)
- Type of environment of the segment
- Characterization of objects considered in the segment (e.g. pavement, etc.)

The objects are decomposed into components (e.g. foundation and top layer for a pavement object). The components have aspects (e.g. bearing capacity for foundation component, rutting and skid resistance for a top layer component). These aspects all have conditions evolving in time, which influence the EUSLs and hence whose values are strongly related to planning scenarios for interventions.

As an example of the demonstrator's functionality, a small network model is presented. It consists of: a 2 lane highway with 0,5 km of pavement (foundation and top layer) and furniture (road markings and road studs), followed by a second segment of 0,5 km with a bridge (columns, girders and slabs), pavement (top layer) and furniture (road markings and road studs). The total number of aspects selected in the example is confined (like only rutting for the pavements) in order to be able to define maintenance scenarios with a limited number of types of intervention measures (10). The time window looked at is 40 years and a traffic intensity of 50 million vehicles per year is assumed.

Figure 5. Screenshots of ASCAM demonstrator.

In the current demonstrator example the influence of three different scenarios for the same network is compared:

- Scenario 1 consists of corrective maintenance (condition based) in which interventions are en-forced when a condition has reached an absolute minimal acceptable level. The costs of measures are penalized by extra costs for ‘unplanned’ interven-tions
- Scenario 2 is a preventive maintenance scenario in which the intervention years are de-fined according to acceptable user defined condition values (estimat-ed condition based). The measures are accounted for as being ‘planned’ measures.
- Scenario 3 also is a preventive maintenance sce-nario. However, the interventions are now defined to take place with a fixed returning period (time based). Again, the corresponding measures are characterized as ‘planned’ measures.

Figure 6 shows the development of the EUSL and maintenance costs for the three scenarios over the 40 year time window. An annual traffic growth of 2% and a financial discount rate of 1 % is taken into ac-count. The growth of the EUSL costs over the years, the impact of the measures on the EUSLs, as well as the different character of the three scenarios is visualized.

In Figure 7 the summary of the numerical run is presented. This figure shows the EUSL’s costs together with the total maintenance costs in a bar plot and corresponding table per scenario for comparison. Clearly, as was to be expected, the corrective maintenance scenario performs worst, on all EUSL aspects but predominantly with respect to safety. The both preventive scenarios perform very much alike within the current example settings. Fur-her optimizations, however might still be possible for both scenarios. Especially when taking the cross asset character of the tool into account, planning of measures coinciding in time could be quantified to be beneficial.

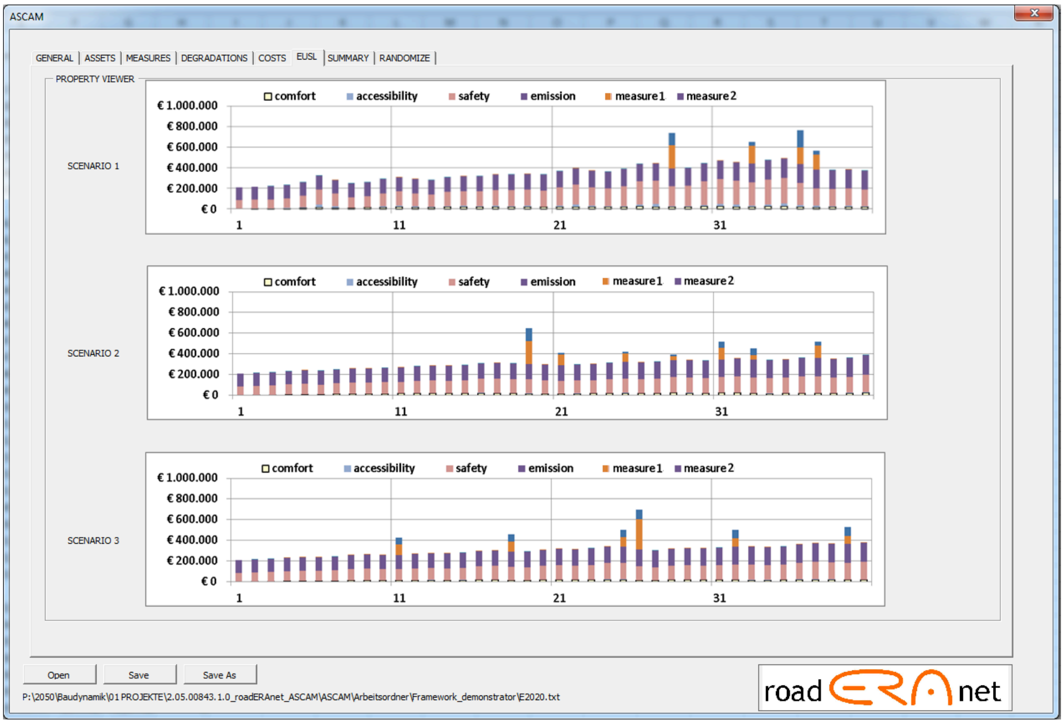
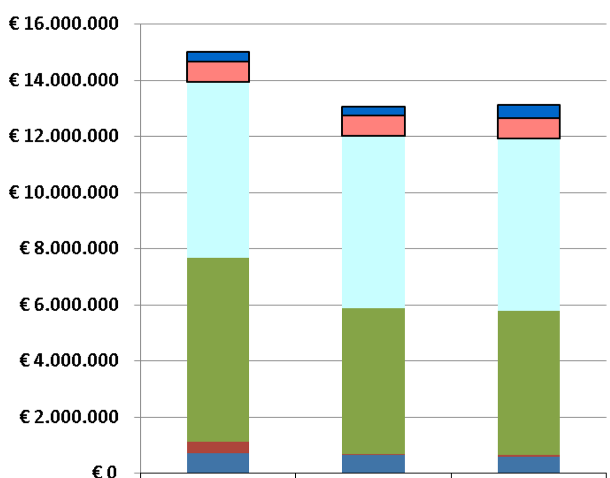


Figure 7. Development in time of maintenance and societal costs for three different maintenance scenarios, scenario 1 (top), scenario 2 (middle) and scenario 3 (bottom).

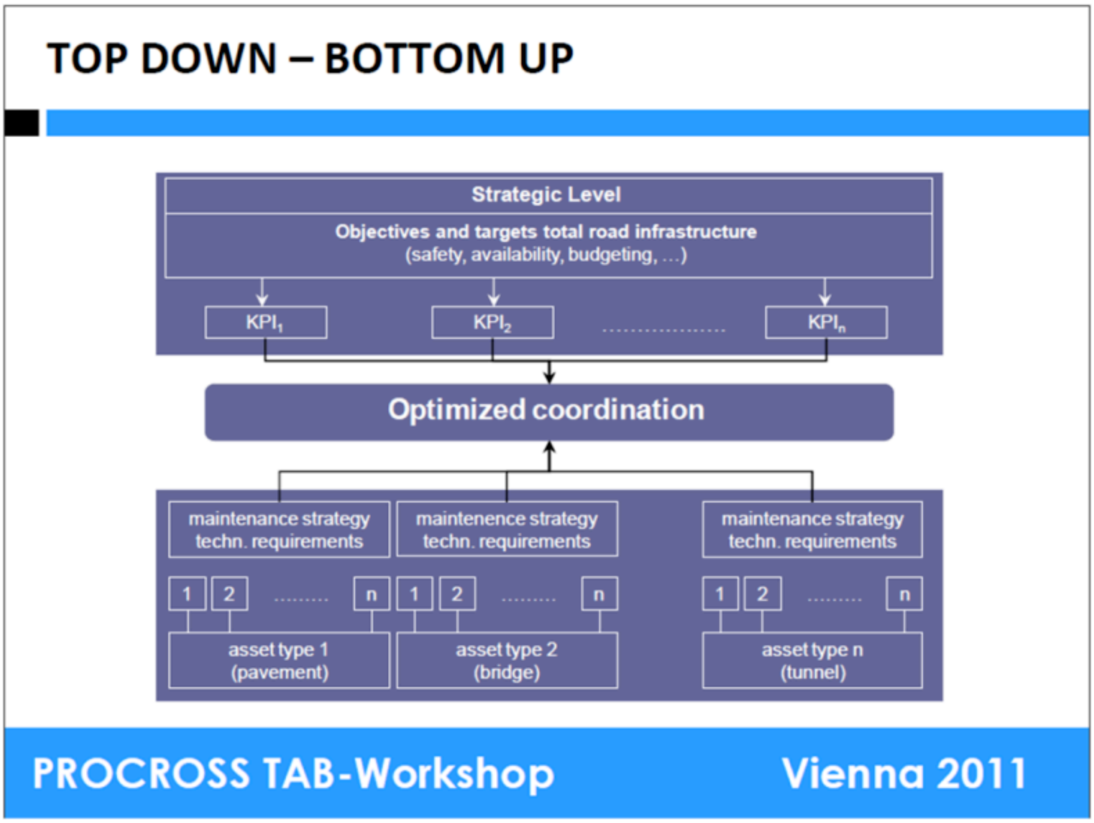


	scenario 1	scenario 2	scenario 3
measures (I)	358104	335387	464398
measures (D)	717026	718762	748356
noise	3152	1202	1107
emission	6262194	6153057	6142174
safety	6575131	5175638	5124637
accessibility	389613	42839	56496
comfort	724416	650026	596823

Figure 8. Summary of realized costs over 40 years; Costs decomposed per EUSL and intervention cost per scenario (Top).

3.5.3 ASCAM implementation from a data availability point of view

To utilize the framework, the framework ideas should be added to local (NRA) circumstances, systems, data systems and practices. NRAs have their own goals, data structures, inspection plans, maintenance strategies, critical condition parameters/values, etc. [detailed information will be found in the PROCROSS results]. The framework can be used to structure this information and practices in such a way that the "top down" approach (policy driven) will meet the "bottom up" approach (technically driven), see figure 9.



Figrue 9 Slide from a Procross workshop (september 2011), detailing the top down and bottom up approach of asset management

The framework is a based on the assumption that for the main components in the framework quantitative information and relations are available. This is partly true and even more true than we expected at the beginning of the project.

The main components in the framework are:

- The (physical) asset decomposition
- The decomposition of the asset components from an EUSL perspective, leading to the EUSL relevant 'aspects' of the asset (performance indicators)
- Condition and degradation description of the asset components and/or aspects
- A list of measures, direct and indirect costs and the effect on the performance indicators
- Description of the relationship between the aspects or (performance indicators) and the EUSL
- A societal cost benefit model comprising the relevant EUSL.

As is described in chapter 3, most of the NRAs have their maintenance management systems for pavement and structures (bridges). For road equipment no such maintenance management systems are found, although information is available in most of the countries. These management systems comprise the decomposition of the assets, performance indicators and degradation predictions. A table of “standard” measures is available or easy to produce for most countries. Indications of direct costs of measures in most countries are available or can be derived from the financial systems. Indirect cost is a more complicated issue, as is the condition and degradation curve of repaired assets. This information is usually not stored in an accessible database. Most of the “bottom up approach information seems to be available and accessible.

To unlock this information for use by the framework the following must be done. First the NRA specific goals, needs and objectives of the framework implementation in tooling or methods need to be defined. From that an implementation (like the demonstrator) can be made, which is architecture/design is such that the information available at the specific NRA can be implemented. Next an numerical implementation is made in which the actual link with the different data systems is realized. The latter is much more an IT effort, no asset management effort.

From the “top – down” approach perspective, the important issue is the EUSL. The user perspective in existing maintenance management systems is implicitly taken care of. But the effect of decisions on the real EUSL cannot be explicitly shown in these systems. For example, the effect of not repairing the bearings of a bridge is related to the structural safety of the bridge. But how this structural safety is related to the safety of the drivers passing the bridge and what cost – benefit ratio this repair will have for the “functioning of the network” (availability, traffic density, queues, etc.) is not included in these management systems. Here an effort in developing more explicit relationships is necessary, e.g. through an expert system.

4 Discussion

In this chapter we will (further) discuss the framework and the steps to be taken to utilize it. It will show that the principles of the framework have a clear link with the practices of most of the NRA’s although gaps in information have to be solved.

The possibilities of merging existing management systems and the principles of the framework are discussed. But really, a comparison between the dimension of the added of asset management from a framework perspective, against the effort of developing the relationships between asset condition and EUSL, is what this chapter is all about. The scope of the ASCAM project is the expansion of the decision support information to combine the policy level to the technical level. This is done by discussing the results from studying practical nowadays asset management, summarized in the former chapter and in the reports of WP1, 2, 3 and 4, as well as from interviews with other projects in the ERANET ROAD projects. Finally also briefly the feedback of the several NRA’s on the demonstrator is discussed.

4.1 Framework appropriateness from a practical viewpoint

In this paragraph the appropriateness of the framework for nowadays asset management is discussed. Use is made of the information gathered in the WP2, 3 and 4 on asset management and the well introduced distinction in the top/down and bottom/up approaches conventionally discriminated in asset management.

4.1.1 Bottom up

Decomposition and performance indicators

In pavement management systems the decomposition of the network itself (location, length, width, number of lanes, etc.) can be used to decompose the road into its relevant components. As this information is available and the level of detail has proven to be practical for the maintenance planning, it is sufficient for utilization of the framework.

Maintenance management of pavements starts with the technical parameters of the pavement, that are indicating the condition of the pavement in relation to the functionality. Pavement is the leading asset, sub structure can be cause of problems. So for each country these existing performance indicators can be directly used in the framework (transverse evenness, longitudinal evenness, macro-structure, cracking, surface defects, friction (skid resistance) and bearing capacity).

The bridge management systems are using a more detailed decomposition. A structure (bridge) consists of elements. And each component or element can have its own function, expected lifespan and condition. The decomposition has proven to be relevant and practical in the process of maintenance planning. The function of the elements or components is leading in the framework. The drainage system will have another impact on the EUSL than the foundation elements. For example in Austria the evaluation system of maintenance condition implemented in the new guidelines for condition assessment of road bridges is based on a grading system with 5 levels. An evaluation of the components as well as the evaluation of the object as a whole is performed. No direct relation between the score of the components and the object is defined. The evaluation is “expert” based, with of course a rock solid foundation. These grading can be a sufficient basis for implementation of the framework.

The essential extra needed for the framework is the explicit and documented relation between the grading of the components (or the object) and the consequence for the functioning of the object/component. Here we see a difference between the current practice and the framework approach. E.g. a poor functioning of drainage system can have consequences for the service (too much water on the road), the life span of other components of the bridge (water seepage in cracks, leading to corrosion) and/or consequences for the future repair measures and costs. These consequences should be known and implemented in the framework. The same goes for the measures. This is necessary as the prioritization of measures in the framework will be done on network and EUSL level, not on structure and structure functioning level.

For road equipment in most countries the basic and essential information for implementing the ASCAM ideas is (partly) available: the inventory of road equipment, location and performance indicator(s). This information is sufficient for implementation of the framework ideas.

Degradation curves

To be able to use the principles of the framework the decrease of the condition of the assets (objects, components) is essential. Only with predictions of future condition of the assets, the assessment of future measures and future EUSL’s can be done. First part of the condition prediction is the (deterministic) degradation curve. The second important part is the uncertainty. Predictions can be seen as a mean value with an uncertainty. This uncertainty is important in the framework, because it is the cause of risk, the probability of unplanned maintenance, increase in number of accidents, queues, etc. And necessary to implement the advantages of inspections (to reduce the uncertainty). For more information on the risk issue in the framework, we refer to the WP 1 report.

Most countries are using predictions of the future degradation of pavement. Mostly a combination of degradation curves and inspection, monitoring or measurement results is used to predict. In some countries (e.g. Austria) the curves are related to the individual performance indicators like rutting, skid resistance, etc. In other countries (Slovenia) in the (visual) condition assessment of the pavement the relevant performance indicators are included (cracking, raveling, patching and deformation). The result is expressed in the Modified Swiss Index (MSI), which can reach values from 0 to 9. Severity (0-3) and affected area (0-3) and specific weigh of the distress is taken into account. These practices can be used together with the framework principles: degradation is shown in time, the results of the actual condition assessment is taken into account, only uncertainty has to be added for a full implementation of the framework principles.

In circa 50% of the Bridge Management Systems deterioration predictions are implemented. Deterioration prediction is an important aspect of the framework, because the prediction of the costs and value (EUSL) is based on the expected deterioration and the related development of the EUSL's (decrease of service level, increase of "EUSL costs"). Four categories of deterioration models can be divided: mechanistic models, deterministic models, stochastic models and artificial intelligence models. In principle for the framework implementation all models can be used, as long as a condition – time graph can be produced.

In the Austrian BMS for example the prediction of bridge ageing takes place on a probabilistic basis. Ageing is described through a hazard function, which defines the probability that the condition of a bridge migrates from one class to another. With these models a condition – time graph can be produced as well as a (time dependent) uncertainty level.

Degradation curves for road equipment are hardly available. Nevertheless in most countries life span expectations are available and used to plan maintenance (replacement). Furthermore cleaning, replacement of bulbs etc. is planned on basis of actual performance and service life expectations. With this information the basics for degradations curves are available. Information about uncertainty is more difficult. The question is, if this information is necessary for road equipment, as the amount of money spend on road equipment is relatively low.

Measures

In current PMS and BMS and road equipment data concerning measures are available. The influence of measures on the condition of asset, objects, components is available or can be guessed (as been shown in ASCAM WP2, 3 and 4 reports). Costs can be assessed, although the costs can be very situation dependent. Degradation curves of repaired components are less evident. Nevertheless the ASCAM WP 2, 3 and 4 reports show the necessary information about measures.

4.1.2 Top Down

EUSL

The framework is based on the End User Service Levels, theoretically translated in the amount of money end users are willing to pay for a service level. To be able to asses the EUSL's the stakeholders (or end users) involved, have to be defined. Furthermore the relevant issues the stakeholders demand from the road operator have to be clear. In other ERANET projects in this asset management program, research to clarify the stakeholders requirements is carried out (SABARIS, EXPECT), which can be used for this part of the framework. In the framework the requirements will have to be defined as a quantitative parameter (this will be assessed in part B and C of the program: "Understanding asset Performance" and "development of suitable Key Performance Indicators", HEROAD, SBAKPI and EVITA). For some EUSL's we can show a way to quantify these as examples or ideas for NRA's.

For the ASCAM project we have chosen (in the Description of Work) to focus on some important EUSL. As the project is about a "proof of concept" the choice for safety, availability, risk and noise can be considered as sufficient. A spectrum of stakeholders (driver, operator, neighbourhood) is represented and the issues are relevant in current practice of most (all) countries. Extension to other EUSLs of course is possible.

The first step in connecting the existing practice in road management and the framework principles is finding the relevant unity for the abstract issues, like “safety”, “availability”, “noise hindrance”, etc. To our opinion the “key performance indictor” projects in the program should deal with this issue, but looking at the timeframe of the program, ASCAM was not able to wait for the results of the projects dealing with this. So we have chosen our own way, just to proof the concept.

To describe the utilization, we have explored the “safety” issue and found the following solution. Safety could be related to the number of accidents. With accidents extra costs (negative values) are involved: direct material damage, human suffering (wounded, deceased), rescuers, indirect costs (delay of other travelers) and maybe other costs. Categorizing accidents in severity and defining the “negative values” of the “representative” accident in each category will result in a workable definition of the EUSL of accidents. Only the resulting cost should be calculated out of the defined “accident category”.

For the “availability” issue, we explored a description of the number of hours lost by traffic (per car) due to queues. For example the measure “speed limit” will cost a little bit of extra time for each passing car. Summing up these extra minutes for all cars and the length of the speed limit, will result in a amount of extra travel time. For measures the same kind of calculations can be made. E.g. repavement will cause extra travel time, due to queues and speed limits.

For noise hindrance, the amount of people suffering from the noise and the amount of noise (dB) can be used to clearly define the hindrance.

EUSL and costs.

In the previous paragraph we explored ways to define EUSL in measurable unities, like number of deceased, wounded, material damage, number of extra travel hours due to delays, etc. These unities should be converted into costs (Euro). The cost can be seen as the amount of Euros we (society) are willing to pay for preventing this to happen. The extra accidents, traffic time, noise, caused by not taking a measure

By prizing the cost of an accident (e.g. mean value, or values per category) the yearly expected number of accidents on a corridor can be converted to a value in euros. The last part: the prizing of the accidents) is a policy issue. In the end it always turns out to be a discussion about the amount of money we (society) want to spend to save a human life.

This part of the EUSL utilization is not part of the ASCAM scope. Partly, figures from Dutch practice are used in the demonstrator. Each NRA can decide what to use for this.

Performance indicators and EUSL

The last and most unknown part of the framework is about the relation between the EUSL and the performance indicators. For example the abstract requirement “safety” in Pavement Maintenance Management Systems is normally utilized by defining critical values for skid resistance, rutting, etc. or a combination of these parameters (a combined performance index). The direct relation between number of accidents and e.g. skid resistance is a rather unknown aspect. From experience, research and/or a pragmatic perspective, these critical values are chosen. In WP 2, 3 and 4 we have searched for pragmatic ways to find relations between these performance indicators and the EUSL. But unfortunately only some relations could be found, that have been used in a societal cost benefit tool for maintenance. For instance, in WP 3 (structures) reference is made to the work of Elbehairy, 2007, investigating life cycle cost optimizations in bridge managements systems. In his work, a user cost model for bridge related accident counts is reported as developed by Thompson, 2000, in which a relation is stated between (among others) the annual accident count and the deck condition.

In WP2 (pavement) relations between skid resistance and accidents are reported and discussed.

A preliminary model for the increase in noise production due to raveling of open asphalt was developed in the Netherlands and can be used in the framework. Though few relations are found so far, it shows that first steps are being made and found feasible. It is expected that with the ongoing focus on functionality and end user perspective in the asset management practice and the increase of data gathered through monitoring systems, registration and the accessibility of such data, more research efforts in this field will take place and that additional and well found relations will eventually become available.

4.2 ASCAM assessment from other ERANET ROAD projects

4.2.1 ASCAM versus SABARIS

SABARIS and ASCAM are both projects in the ENR SR04 program "Effective asset management meeting future challenges". SABARIS is related to topic A, meeting stakeholders requirements, where ASCAM is in topic D, Framework for optimized asset management. One of the important factors in the ASCAM framework is the End User orientation. Topic A is focused on the stakeholders requirements and expectations. The question is how the results of SABARIS and the framework of ASCAM can be related. For that reason contact between the two projects is established.

The SABARIS project has focused on two items: stakeholder expectations and a maintenance optimization tool. Stakeholder expectations are measured by asking the stakeholders before and after maintenance activities in two cases about their expectations, experience and satisfaction. The results can be used to improve maintenance activities to improve stakeholder satisfaction. The tool is based on societal cost – benefit optimization. The cost of maintenance strategies as well as the societal benefits (or costs) are included and an optimization algorithm is used to find the optimum solution.

In the ASCAM project a framework for cross asset maintenance strategies is developed from an end user perspective. In ASCAM we made an inventory of current maintenance practices and the available information and relations for pavement, structures and road equipment. ASCAM also explored the possibilities to use the available information in the framework.

Both projects have encountered the information deficiencies. For the time being, that will be a barrier for the full implementation of the developed principals. Especially the missing relations between condition and the end user service levels are show stoppers. On the other hand in both projects with practical assumptions the principal could be shown. Both concluded that it's a NRA responsibility to find the necessary information for the specific application in the NRA asset management practice.

The knowledge developed in both projects can be seen as complementary. SABARIS has resulted in a detailed perspective on end user requirements and satisfaction aspects. This can be used to optimize maintenance strategies for relatively small parts of the highway. ASCAM has put emphasis on the technical information available and on the framework. The ASCAM framework can be seen as a principle that can be used to compare maintenance strategies on network or corridor level or even for small parts of the highway. It can be used in rough estimations (information necessary is less detailed), but also in a very detailed analysis (as long as the information for such a level of detail is available).

As ASCAM will be finished the end of March 2012 and SABARIS is still in progress, the merge of the knowledge of both projects can only be done afterwards. TNO and UTwente are willing to cooperate in this matter.

4.2.2 ASCAM versus EXPECT

EXPECT and ASCAM are both projects in the ENR SR04 program "Effective asset management meeting future challenges". EXPECT is related to topic A, meeting stakeholders requirements, where ASCAM is in topic D, Framework for optimized asset management. One of the important factors in the ASCAM framework is the End User orientation, the End User Service Levels (EUSL). Topic A is focused on the stakeholders requirements and expectations. The question is how the results of EXPECT and the framework of ASCAM can be related. For that reason contact between the two projects is established.

In EXPECT the aim is to develop a methodology to enable national highway authorities to define service levels for highway asset maintenance using road user perceptions. EXPECT has investigated or trialed a number of different methods (questionnaires, interviews, focus groups and accompanied journeys) that may be used to gather information and have developed a multi-criteria analysis framework to make use of information so gathered. Furthermore EXPECT will perform a case study to demonstrate how this process may be integrated into an asset management program of a national road authority.

There is a distinction between the service levels ASCAM refers to (highway availability and performance service levels) and those that EXPECT is considering (highway asset condition service levels).

The main difference (and complementary issue) between ASCAM and is that EXPECT is offering a method to define service levels on asset condition level using road user perception and ASCAM is offering a method to assess the cost value ratio of maintenance scenarios. The service levels from a user perspective (EXPECT) can help to define the missing relation between some "End User Service Level" and asset condition and in the perspective add EUSL aspects to the ASCAM framework for some issues.

As the ASCAM project is finished half a year earlier then the EXPECT project thoughts about further integration of the results of both projects will have to wait until after finishing the “effective asset management meeting future challenges” program. Both consortia are willing to discuss about the integration of the results in future activities.

4.2.3 The ASCAM concept from PROCROSS viewpoint

Under the same topic (D) of the Asset management Call as ASCAM also the PROCROSS project is executed. The goal of PROCROSS is the development of optimized procedures for cross-asset management of the total road infrastructure, while finding out if there is actually a benefit in moving towards cross-asset management, given an operator’s organizational structure, the type of network and the form of funding. This process requires knowledge about the different stakeholders’ objectives of cross-asset management e.g. is the aim a minimization of costs, the maximization of performance (or both), avoiding multiple road interventions/closures, increasing availability, reducing user costs, or reducing negative effects on neighbors? Therefore it seems valuable to have an assessment of the appropriateness of the ASCAM concepts, in which cross asset management is intrinsically captured, from the viewpoint of the knowledge and insights developed within PROCROSS. PROCROSS is still underway and the final results are as yet not known. However a preliminary assessment is given in the following paragraph.

Within PROCROSS six stakeholder groups were identified: operators, users, neighbours, society, financing body and owners, each with their respective interests. Altogether, the stakeholder objectives could be clustered into the following groups: safety, costs, environment, availability and customer satisfaction (comfort). These correspond to the five end user service levels (EUSLs) worked with in ASCAM as example EUSL: safety, noise, emission, accessibility and comfort. From a PROCROSS viewpoint this set could be adequate and complete. PROCROSS’s term “costs” is a generic term including the total cost/value of infrastructure itself and the cost/value of maintaining the infrastructure. While ASCAM compares the EUSLs to each other on the same scale by converting them into a mutual unit [€], PROCROSS leaves each NRA to weight the objectives according to their strategic interests i.e. the absolute costs of an objective such as environment are not dealt with in PROCROSS but only the relative value. If an NRA is able to compute the actual costs [€] using one of the relationships that are currently defined as hypothetical functions in ASCAM (e.g. the quantitative link between rutting & noise, road stud visibility & comfort etc.), then PROCROSS simply refers to such an existing relationship but does not develop a new function in the course of the project.

The first step in PROCROSS was to analyze existing structures/frameworks as well as existing cross-asset management procedures in different NRAs (= identification of good practice). This revealed that the organizational structure, the network type and how maintenance is funded played a crucial role in the type of cross-asset management employed (= strategic level procedures i.e. top-down approach). The second step was to identify monitoring requirements and existing intervention levels (= relationships between monitoring parameters and key performance indicators. Monitoring asset condition to reveal maintenance needs = bottom-up approach). PROCROSS looked into top-down and bottom-up approaches, as well as their respective (dis)advantages and decided to focus on an approach that combines the two: top-down (strategic objectives) meets bottom-up (performance indicators and measures).

Different procedures of cross-asset management optimization will be elaborated in the course of PROCROSS in the context of the given settings in a country: the NRA's organizational structure, the technical requirements of cross-asset interdependencies and the stakeholders' expectations. PROCROSS aims to recommend prioritization strategies and cross-asset management optimization procedures, taking into account whatever is feasible within an NRA given the abovementioned boundary conditions (organizational structure, budget source, objectives). The same applies to ASCAM, as the developed tool can be used as for single asset maintenance or cross-asset maintenance by entering the respective objects into the tool, providing a flexible structure that can be used by different departments within an NRA.

4.3 Feedback of NRA's representatives

The results of the ASCAM projects were presented to the NRA of the partners countries, which resulted in sometimes more and sometimes lesser feedback which is given here. IGH tried to do so, but due to reorganization of the Croatian NRA and the fact that Croatia is not a PEB member, this seems ill timed and not likely at the moment. VTI had to cancel the presentation, scheduled 21th of March, due to personal circumstances of the presenter.

BRRC, AIT, ZAG, IGH and TNO presented the project and the demonstrator to their NRA. The feedback on the presentations, in short, is presented below. For ASFINAG and RWS a more extensive feedback was obtained. All reports from the partners on the feedback are presented in the appendix to this report.

Summarising the following can be said. All NRA recognize the importance of the gap between top/down and bottom/up asset management. All NRA's also recognize that ASCAM aims to bridge this gap. Coupling of methods and tooling and their numerical implementations to existing databases is seen as essential. Finding the relationships between asset condition and EUSL was recognised as an important research issue for the near future. One NRA (ASFINAG) uses safety as a dominant EUSL and recognized that the framework was broader, due to the opportunity to incorporate a large set of EUSL's. The Dutch NRA saw a relation between the use of the ASCAM principle and a Life Cycle Cost project, related to the RWS Service Level Agreements (SLA). The Ministry and Rijkswaterstaat negotiate a SLA for 4 years, in which service levels and budgets are being agreed. In the coming years the SLA agreement will be developing to a more "functional level" from an end user perspective. In this development the ASCAM principle is appropriate.

4.4 ASCAM implementation

Road authorities have defined their goals for the network, mostly in political terms like a safe and available network, reliable and predictable travel time, etc. and of course in financial targets (budget). Tooling based on the ASCAM principles is a not such a goal. Its unique feature is that it enables to predict consequences of maintenance scenarios in the political terms. With the ASCAM principles effects of maintenance schemes on maintenance policy and on the political level of network operation (and vice versa), can be made explicit and transparent. This is certainly not common practice in NRA's and its introduction needs a NRA wide effort to spread the awareness of the benefits. This is the reason that our preferred strategy for implementation of the framework starts with pilot projects. These pilot projects concern real issues and the ASCAM principles will provide solutions, which demonstrate the beneficial effects of working with the ASCAM principles. In this chapter we will suggest issues and indicate the added value of the ASCAM principal for decision making in these issues.

Using the ASCAM principle demands an open mind as to be able to drop current practices, rules and regulations. For example the principles demand the acceptance of not meeting the prescribed minimum values (criteria) for performance indicators, or the acceptance of the traffic density as a relevant parameter in maintenance decisions. It means that a "safe" decision (the performance indicator is below its threshold, so maintenance activity is mandatory) is not available anymore.

We are convinced that such changes can only be adopted by demonstrating the logic of it, show the added value and, in the end, external pressure to strive to deliver optimal value for money. The demonstrator and the description of the framework in this ASCAM project has shown the possibilities, but not the concrete win by using it. The pilot projects should show the (quick) win of using the framework and help to find the necessary (reliable) information for using the framework principles in the NRA-specific circumstances. Note that real benefits of EUSL driven maintenance shows only after a long period of time, which makes demonstration of them in pilot projects somewhat difficult.

In the ASCAM project we have made an inventory of existing information and practices available to combine with the ASCAM framework ideas. We are well aware of the need to adjust the information and relations to the framework and to search for relations between performance indicators and EUSL's. In pilot projects concrete activities can be planned for specific cases. The experience and results will help the development of the implementation of ASCAM principles.

As a last generic remark we are convinced that implementation should start with limited complexity; limited to a small part of the road (a corridor) and to one asset (pavement, because PMS is best compatible with the ASCAM principles).

We think that the following issues could be used as ''low hanging fruits'' for implementation of the ASCAM philosophy:

- Using the ASCAM principal to analyze historical data about measures, condition decrease and consequences for end users. By using different data sources and combining data from these sources, we could be able to find better relations between performance indicators and EUSL's. The ideal result should be a transparent calculation of budgets used to increase the EUSL's in several cases with different circumstances. And in this respect it could help to get a better idea about what we are willing to spend for EUSL's (values), because it will explicitly show what we implicitly decided on this.
- Using historical data about the problems with severe winter conditions and combining this with alternative preventive maintenance scenarios using the risk based approach with an end user perspective (the ASCAM principal). This approach should be able to

compare the cost and value of alternative scenarios and optimize the robustness of the network form a EUSL perspective. The risk and EUSL perspective should show that traffic density is a very relevant parameter in this issue.

- Night work. ASCAM principles can be used to find “objective” information about the benefits of night work. It will help to find a solution for the calculation of indirect cost caused by traffic hindrance (queues, delay), that can be used in a generic way in the framework.
- Landslides. An objective assessment of the risk of slides from a EUSL perspective could be helpful to find decision supporting information. This is a problem in most European countries. The ASCAM approach includes the valuation of risk.
- Using the ASCAM principal to predict the consequences in EUSL terms of political budget restraints. NRA’s budgets are being cut down while no consequences for the network performance are being accepted.

Such a pilot project will at first show short comings in the information and relations. Using realistic assumptions, being transparent about this and showing the sensitivity will show the most important trends and will show the most important short comings. These should get priority in the development. Prioritization of these implementation projects is among others NRA dependent.

5 Conclusion on the appropriateness

These conclusions are divided according to the key challenge set out to tackle in the ASCAM project; ‘*Can we show that a framework, to connect existing asset management practices into a holistic, integrated cross asset and pro-active approach, is* ***feasible*** *and of (practical)* ***added value*** *for NRA’s.’*

Is it feasible to build an end user value framework?

The demonstrator of the framework has shown that it is possible to build a tool which in theory can connect technical measures to end-user services levels (EUSL’s). The information gathered in the WP’s 2, 3 and 4 has shown that in most countries relevant data for the framework can be found. The information available in maintenance management systems, used in European countries, can be used in the framework. The weak link in the framework is the limited information available on the relationship between (technical) condition (skid resistance, evenness, etc.) and EUSL’s (safety, etc.).

In the demonstrator uncertainty of (predictions of) the technical condition can be taken into account. Also risk (the possibility that a certain unplanned measure has to be taken, causing extra hindrance and unreliable traffic time) has been added as a EUSL. This enables the possibility to show the added value of inspection and monitoring.

The demonstrator was built in such a way that the results in terms of EUSL of three maintenance scenarios could be compared. The demonstrator included safety, traffic delay (mobility), risk, cost and noise (in the vicinity of the road) as EUSL. Because of the open character of the framework other EUSL, such as the effects of climate change, can be added.

The work with the demonstrator showed that ASCAM concepts and implementation is best suited for assessing sub networks, though in principle it can be applied to an entire network. This would however lead to a very complex system, which requires a complex data input system and of which the results are hard to interpret by maintenance managers. Instead for an entire network, multiple implementations of different sub networks could be used.

From an implementation point of view differences between the three asset types considered are not significant. From an ‘availability of input data’ point of view, comparison of the results on existing information of the three asset types shows that for pavements the most information is available. Therefore for NRA's it is easiest to start working with ASCAM methods for pavements. For structures the step from the commonly used ranking systems of the condition (e.g. from 1-5), to describing the asset condition with EUSL relevant aspects, is a major one. In the same sense for road equipment basically the aspect 'visibility' is important and hard to quantify. Also for road equipment the amount of maintenance budgets spent are low, and optimization against EUSL will therefore not lead to much benefit.

The conclusion is that building the framework is feasible, but attention and development is needed for:

- The relationships between condition and EUSL for pavement and foundations, structures and road equipment.
- Assessment of quality of input data with respect to practical decision support.

Can such a framework be implemented and does it have added value?

In the ASCAM concept a vertical cross section is made in the asset management Top-Down and Bottom-UP approaches which link the high level strategic and low level technical aims in asset management. This is of added value for the NRA's. Such concepts are not easily adopted within most road infrastructure communities, however such breakthrough thinking is necessary to realize the transition to a more market driven approach to infrastructure maintenance.

So from a past and present perspective ASCAM concept appropriateness seems limited because of an ill-fit with available thinking, processes, routines, methods, organization and data. On the other hand, from a viewpoint of envisaged future maintenance practice ASCAM concepts appropriateness seems spot on, because of the intrinsic characteristics (cross asset, holistic and the user perspective as the leading principal), the risk adopted approached and the quantitative nature of tooling based on the framework.

Introducing ASCAM concepts now seems well timed. At the moment methods and means are emerging which can help to resolve the huge challenges which road maintenance management are facing the coming decades, e.g. ageing infrastructure, high demand on availability safety. Such methods comprise e.g. life cycle costing or condition monitoring. Benefits of such methods, especially in risk reduction, though well accepted, can hardly be substantiated using present day maintenance systems. This is extremely well facilitated using ASCAM principles and concepts.

From this perspective, the gap between current practice and the ASCAM framework is rather limited. For practical framework implementation, input from available MMS systems can be used. Immediate benefit would be that a well-founded cross national information exchange on ''good practices'' will become possible.

Implementation of the principle behind the framework will need a change of mind set. In current practises the EUSL is translated in criteria and the mind set in maintenance practise is mostly "meeting technical criteria". Using the full principle behind ASCAM the mind-set is changed to "negotiable decision support information". Differentiation in minimal road condition requirements is possible, because the decision is based on an optimal combination of End User Service Levels.

A roadmap was drafted in which further development of ASCAM principles into NRA's asset management systems is described. This showed that a substantial effort is required, which can be divided in multiple steps each of them bringing added value for NRA's.

6 Recommendations

The recommendations are twofold: recommendations for implementation and recommendations for further development.

Implementation

Implementation of the ASCAM principles should be done by the NRA itself. Research institutes and consultants can help, but cannot implement the principle.

Pilot projects will help to find the necessary (reliable) information for using the framework principles in the NRA-specific circumstances. Due to practical reasons (availability of data) the ASCAM team recommends to use past performance for the pilot projects. Furthermore we think that implementation should start with examples with limited complexity; limited to a small part of the road (a corridor) and to one asset (pavement, because PMS is best compatible with ASCAM principles).

In the pilot projects specific problems could be assessed with the framework principle. These pilot project should show the quick wins of using the framework in a specific NRA perspective. Evaluating the projects will lead to an understanding of the added value of the principle, the link with the current practices and the issues blocking further implementation. NRA specific and generic projects for further development can be specified. From the ASCAM team the following ideas for such projects are suggested:

Severe winter conditions: comparison of information of the results of maintenance practices used in the past with predicted results of alternative scenarios, in terms of cost and value for End Users (more specific: probability of unplanned maintenance and congestion). Quick win of such a project is is the demonstration in stakeholder communication of the cost and risks effects of taking preventive maintenance measures against the consequences of severe winter conditions.

Night work: comparison of the congestion and cost of day and night work scenario for maintenance for specific corridors, to find an objective figure of the results in terms of EUSL and cost.

Quick win of such a project is the quantification and objective demonstration of the cost benefit effects of night work, especially the effects on the availability of the (piece of the) network. The investment in direct cost of night work can be justified (or not) by quantifying the gain in reduction of traffic delays.

Landslides: using the valuation of risk from an End User perspective as a way to find decision support information on the necessity of measures. Again quick win here is quantification of cost and risk reduction.

Budget restraints: Using the ASCAM principle to predict the short (1 to 4 years), middle (4 to 8 years) and long term (Life Cycle Costs) effects for End Users of scenarios to meet the (short term) budget restraints for a (for example) corridor. Quick win is the public acceptance of consequences on short or long term and help to find alternative solutions.

Further development

As stated in the conclusions the demonstration of the feasibility to build the ASCAM framework has shown that some issues need to be further developed. If the NRA want to make the transition to a more market driven (i.e. End User Value driven) approach, this work showed that an effort obtaining the data and the relationships between asset condition and these End User Service Levels need to be defined. This actually is a well-accepted in asset management in other field, e.g. process industry were relationships between throughput of an installation and asset condition is of high importance.

The implementation aimed pilot projects will help to find solutions to some of these issues, but a more fundamental applied research on this short comings is strongly recommended. Such information can be obtained by combinations of large scale monitoring programs, expert systems, advanced data mining techniques of existing databases (e.g. pavement conditions, like skid resistance and EUSL), an etc.

From the roadmap drafted in the ASCAM project follows that the next step in further development is the development of NRA specific prototypes of (adapted) tooling based on the ASCAM principle. Most readily implemented at the moment would be a new risk based decomposition of the network form an EUSL perspective. However this is already a major development, for which NRA broad support is needed. Therefore small scale implementation project, showing the added value of applying ASCAM principles are more important at the moment.

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Appendix 1. Utilization from a NRA perspective

The results of the ASCAM projects were presented to the NRA of the partners countries, which resulted in sometimes more and sometimes lesser feedback which is given here. IGH tried to do so, but due to reorganization of the Croatian NRA and the fact that Croatia is not a PEB member, this seems ill timed and not likely at the moment. VTI had to cancel the presentation, scheduled 21th of March, due to personal circumstances of the presenter.

BRRC, AIT, ZAG, IGH and TNO presented the project and the demonstrator to their NRA. The feedback on the presentations, in short, is presented below. For ASFINAG and RWS a more extensive feedback is reported subsequently.

BRRC-AWW

Margo Briessinck, Senior Advisor, Vlaamse Overheid, Agentschap Wegen en Verkeer, Mobiliteit en Openbare Werken - Afdeling Wegenbouwkunde,

Erik De Bisschop, Verkeerskundig Ingenieur, Vlaamse overheid, Agentschap Wegen en Verkeer, Expertise Verkeer en Telematica

Framework and demonstrator well received. NRA was open to deliver input. In all, the ASCAM project turned out to be more conceptual as anticipated at the beginning of the project. NRA had questions whether the framework (and demonstrator) can be coupled to their own tools and databases. BRRC explained that this is the case, but requires a substantial effort.

ZAG.

The ASCAM presentation was shown on the 8 March to Vlado Ostir (DRSC) Andrej Zajec (DARS) Jana Jamnik (DRI) and my co-workers Bine Pengal (ZAG) Bojan Leben (ZAG)

Reaction in short:

NRA showed interest in trying to work with the framework. Especially the demonstrator drew their attention. NRA identified the relationships between asset condition and EUSL as a point of attention and further research. NRA well received the openness of the framework.

AIT - ASFINAG

Karl Gragger (Department Asset-Management). ASFINAG SERVICE GMBH.

NRA well received the presentation and demo. For them safety is the dominant EUSL which limits the functionality of the framework which is interesting for them. See also appendix end report

TNO-RWS

Jaap Bakker Senior Specialist at DI at Rijkswaterstaat, Ministry of Transport, Public Works and Water Management.

Jasper Schravemaker, Senior Advisor Asset Management DVS at Rijkswaterstaat, Ministry of Transport, Public Works and Water Management

ASCAM was presented in relationship to the LCC thinking and initiatives within Rijkswaterstaat and is promising in this respect. See also appendix end report.

Complete report of comments from ASFINAG(Jaap Bakker and Jasper Schravemaker).

ASFiNAG's current approach on cross-asset management is built around the condition development of pavements, which are considered the core asset of road infrastructure. The degradation prediction is assessed using the software viaPMSTM which involves the degradation curves and methods described in Austria's feedback to the questionnaire for WP 2. Bridges are incorporated into the viaPMSTM system by checking the bridges along certain stretches of road to see if their condition is approaching a state where major maintenance will be necessary. On the whole, bridges degrade more slowly than pavements, allowing their maintenance to be planned/foreseen over a longer term. This can mean that maintenance, for example, constitutes the "extension" of the lifetime of the pavement across a bridge, or along a stretch of road containing a bridge, through smaller repair measures until a point in time when both the pavement and the bridge can undergo major repairs simultaneously.

Bridges themselves are assessed using a database called "BAUT". This initially started out as a bridge management system (based on probabilistic condition development) and has gradually been expanded over the last 15 years to include tunnels and other engineering structures along Austria's major road network. However, the maintenance management of tunnels is not so much affected by the natural degradation of the structure with age, but due to incidents in the last couple of decades such as the fire in the Mont Blanc tunnel (1999, 39 deaths) and the Tauern Tunnel (1999, 12 deaths) a rethinking took place concerning the installation of safety equipment. The initiative that was kicked off shortly afterwards saw the refurbishment of all tunnels with high-tech equipment and warning systems. While this sometimes had the side effect of taking structural measures such as renewing the tunnel lining or the drainage systems at the same time as performing the technological upgrade, the structure itself was and is usually of secondary importance because it is the warning equipment that needs to be kept at the state-of-the-art. Hence the trigger for taking maintenance measures in tunnels is usually not the structural degradation, but the need to e.g. replace a camera system after 5 years or make sure the number of safety tunnels/shafts is adequate. Issues concerning the safety of road users in tunnels are of utmost importance, as several laws and norms have been introduced since the incidents, hence the required budgets can always be justified to the stakeholder. Prediction models for the condition of tunnels and noise barriers do not exist yet e.g. natural degradation of tunnels has in a way been interrupted due to the introduction of a new generation of safety equipment (too little experience on a full life cycle?).

An important aspect in bridge maintenance has also arisen since the introduction of the Eurocodes. Given a bridge that is approaching a state where major repair is necessary and knowing figures for traffic forecast on that stretch of road, one needs to consider whether an expansion (lane widening or additional lanes) is actually feasible on the existing structure or whether – due to the rules in the Eurocode – a new bridge would actually be needed, hence it would be more sensible to just sustain the structure in a state of usability until the complete renewal is economically sensible, rather than investing in the old structure's refurbishment.

In terms of ranking the stakeholder priority according to which maintenance measures are taken, ASFiNAG's approach would be road users > stakeholders (Austrian state) > residents in the vicinity of roads.

- Safety (for road users) is the utmost priority, hence the maintenance program is condition-based i.e. when an asset is in a condition state 5 (very bad) measures must be taken immediately.

- It is in the interest of stakeholders (owners, state) to maintain a high as possible quality of the infrastructure as a whole. Several negative examples have occurred in the past where privatisation (e.g. railways in the UK) has led to poor standards.

- The interests of local residents are usually a means of getting media attention when it comes to noise and emissions, yet on a global (or possibly even national) scale it may be questionable whether a speed limit of 100 km/h instead of 130 km/h on motorways near a town is going to have a significant effect on CO_2 emissions.

Regarding the EUSLs and work packages used by ASCAM, the following comments were made.

Safety – clearly a good measure, as it is the only concrete way of arguing the need for a certain budget to the funding body (state). However, studies in Austria have indicated that if maintenance measures to upkeep a certain standard of road infrastructure aim for a minimum number of accidents, the asset quality would be strongly skewed towards urban areas. It would ultimately lead to large investments around cities and densely populated areas, whereas rural areas with fewer road users would in the long-term suffer from neglect, resulting in a strategy that could promote urbanisation.

Comfort – Factors that are considered to contribute towards the comfort of road users (besides bumpy road surfaces) are the upkeep of a continuous speed level (i.e. as few as possible stretches with speed limits or varying speed limits), the lane width, and having a lane still available even when there is a construction site.

Emission – Difficult to treat as an objective measure, as it tends to be used in a rather political fashion. Probably an unsuitable stand-alone parameter when it comes to justifying funding needs or calculating the life-cycle costs of the network. Besides, emission and noise usually go hand in hand with the factor safety, as improvements to the pavement to raise the safety standard generally have a positive effect on noise and emission as well.

Accessibility – probably better termed "availability" to avoid confusion.

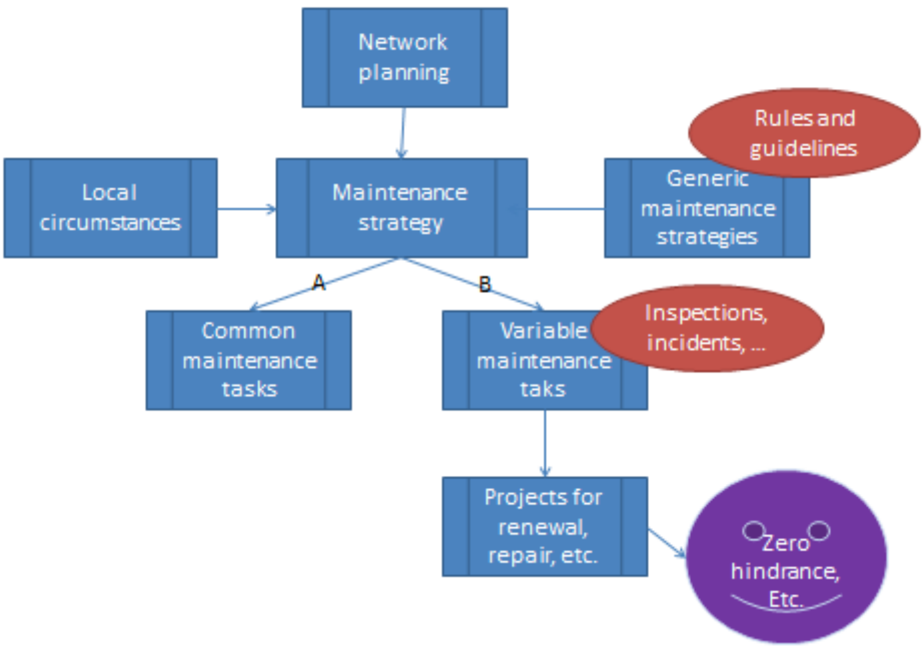
WP 4 Equipment – Seeing as the overall costs for maintaining road studs, road markings, post delineators etc. are comparably small, they are generally maintained during routine inspections and not even considered by the "ASFiNAG Service" department who are responsible for maintenance planning of pavements and structures. Monitoring the condition development of roadside equipment or performing measurements such as reflectivity tests is usually a greater effort and more expensive than just renewing them at fixed intervals.

On the whole, ASFiNAG thinks the way ASCAM functions would probably be an interesting tool for NRAs to illustrate the effect of what happens when a certain budget is not available, but currently the budget is justified from the viewpoint of safety, which is something the stakeholder cannot argue against. Noise and emission play a lesser role or are indirectly already covered by the safety EUSL, while accessibility is partly covered by the aspect of comfort (maintaining lanes and speed limits) and the field of construction site management.

Complete report of comments from Rijkswaterstaat (Jaap Bakker and Jasper Schravemaker).

The discussion was related to the use of the ASCAM principle as a basis for a Life Cycle Cost project, related to the RWS Service Level Agreements (SLA). The Ministry and Rijkswaterstaat negotiate a SLA for 4 years, in which service levels and budgets are being agreed. In the coming years the SLA agreement will be developing to a more "functional level" from an end user perspective. In this development the ASCAM principle is appropriate.

The use of the ASCAM idea in the maintenance planning process and the added value to existing documents, methods, etc. should be clear, to get a valuable tool. A rough sketch of the process leading to maintenance contracts for the common maintenance tasks (A) and projects for variable maintenance tasks (B) can be seen in the figure below.



The SLA deals with the budget and the performance of the network in the SLA period (4 years). The consequences of this agreement for budget and/or performance in the next period is not part of the SLA. Due to insufficient information the significance of the consequences on the long run is underestimated during the negotiations.

A more explicit and quantified (sound) assessment of the consequences for the next period and the Life Cycle Costs could help to give these consequences the appropriate importance. Hence further development of the ASCAM framework in relation with the above mentioned process could lead to a better understanding and sound data for the SLA negotiation. This will be a tough process, because of the lack of understanding of the relations between technical condition and functional requirements. However integration of the current practice and an “ideal world” could result in a clear picture of the development needed on short term and the usefulness of the ASCAM principal in this development.