Maintenance Backlog Estimation and Use

Final Report

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Swedish Road Administration (SRA)

Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT),

Danish Road Directorate (DRD)

Norwegian Public Roads Administration (NPRA)

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MAINTENANCE BACKLOG – ESTIMATION AND USE

Final Report

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Summary

The objective of ERA-NET ROAD (ENR) is to coordinate and mutually open up road research in Europe and to implement a trans-national road research program that is strategically planned and trans-nationally funded. Within this framework of ERA-NET ROAD the trans-national project entitled "Maintenance Backlog – Estimation and Use" was initiated. The countries funding the project were Austria, Denmark, Finland, Norway, Sweden, Switzerland and the UK. These participating countries formed a project team (Project Executive Board - PEB) for coordination of the project led by the Swedish Road Administration (SRA). Following an invited bidding and selection procedure an international consortium led by PMS-Consult (Austria) and the Institute for Transport Planning and Systems (ETH Zurich, Switzerland) was charged to conduct the study.

Maintenance backlog can be used as a common and comparable denominator of road maintenance results for different types of road sub-assets and for different management tasks. The objective of the project was to prepare recommendations for the comprehensive implementation and use of maintenance backlog indicators ("best practice").

The project covers the following sub-assets of the road infrastructure:

- Pavements (trafficked and non-trafficked areas)
- Engineering structures (bridges, tunnels, walls and other engineering structures)
- Road furniture (signs, guardrails, lights, etc.)

To achieve the objectives of the project the work was based on structured interviews with the participating agencies preceded by the necessary preparation based on existing documents and background information. These interviews were performed at visits at the participating agencies by the same two persons from the consortium.

The aim of the interviews was to produce an inventory of maintenance backlog issues, underlying information and most relevant input parameters, taking into account different sub-assets of the road infrastructure. In order to obtain the data the technical approach to this work was to perform the interviews with the following partners:

- PEB-countries (Austria, Denmark, Finland, Norway, Sweden, Switzerland, United Kingdom)
- Countries where a partner of the consortium was coming from but not being a PEB-country (Germany, Slovenia)
- 2 concessionaires with concessions in Europe

The results of the interviews were summarized (see chapter 4) and finally implemented into a database. The investigations were limited to the type of road network within the responsibility of the respective central road administration. Thus a big variety of road categories is covered by the interviews, with a main focus on high level roads. In parallel to the interviews related information was collected and analysed from a limited investigation from literature, current projects, experiences within the team and a generalized international recherché on the basis of a questionnaire. It could be seen, that the calculation and estimation of maintenance

backlog is widely used in the Scandinavian countries, while in the other investigated countries various approaches are used without directly assessing a maintenance backlog in the same way. However, the need for expressing the necessity for improved road maintenance and additional funds is recognized in any case.

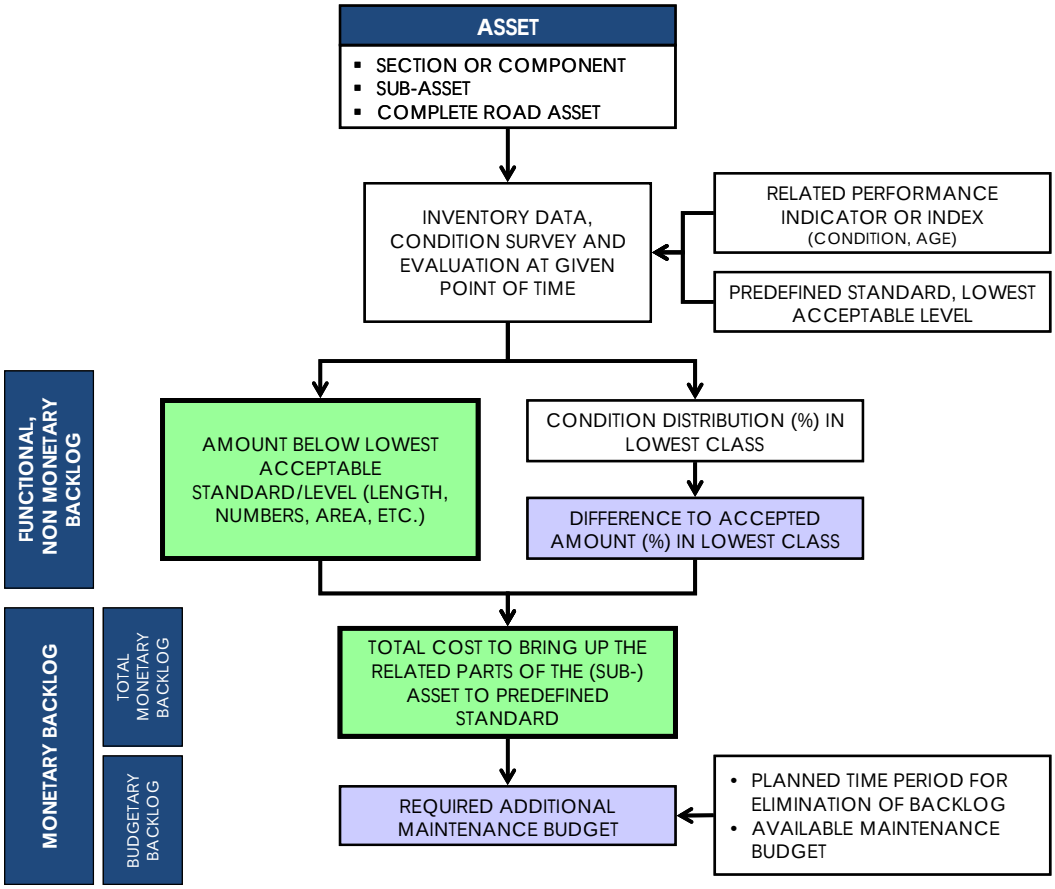
The results of the evaluation of the interviews and investigations are summarized under the following basic topics (see chapter 5):

- Maintenance and maintenance objectives: three groups of maintenance are widely distinguished:
  - Routine Maintenance (also called road operations), not planned and therefore not taken into account for assessing maintenance backlog.
  - Planned (major) maintenance: maintenance measures with long lasting improving effect. The need for such measures provides the basis for the calculation of a maintenance backlog.
  - Upgrading and extension: measures which upgrade the sub-asset to a higher level than the original new condition (additional lane, higher requirements for retention systems etc.) These measures are not fully included into the calculation of maintenance backlog; the upgrading costs are covered by the budget for investments.
- Condition and performance indicators:
  A general recommendation of performance indicators (single and combined indicators or indices) is given for all sub-assets (pavements, structures and road furniture). While performance indicators are widely used in the respective countries for pavements and structures, a lack of performance indicators for the various parts of the road furniture could be found. This should be improved in future.
- Data acquisition:
  The data acquisition is the basis for the condition evaluation. For pavements measurements of user specific indicators as well as visual inspections for structural indicators, and for structures visual inspections of sub-components are recommended (and already widely in use). For road furniture visual inspection and functional testing should generally be implemented to a bigger extent. Maximum intervals for the measurements and the visual inspections are recommended as well (max. 5 yrs for pavements, max. 6 yrs for structures and max 1 yr for the functional testing of road furniture)
- Maintenance standards and maintenance strategy
  - In accordance with the performance indicators the respective standards (levels of quality) must be defined. These threshold values are defining the border line between fulfilled and unfulfilled demands (generally in form of a condition related value or a maximum deterioration rate). Also the target values to be reached after maintenance measures have to be defined for each performance indicator. It was not the scope of this project to analyse the condition indicators and the related threshold values used in the various countries in detail.
  - The calculation of the maintenance backlog is based on the optimum maintenance strategy. Based on LCC-calculations the optimum solution can be found either by minimizing the costs of the treatment strategies for keeping the predefined standards or by maximizing the benefits of the treatment strategies under given monetary constraints (budgetary limits).

The main part of chapter 5 deals with the topic maintenance backlog. Based on the collected and analyzed information the following general definition is recommended:

> ***Maintenance backlog of the road infrastructure is the amount of unfulfilled demands at a given point of time in explicit reference to the predefined standards to be achieved. Maintenance backlog can be expressed in functional (non-monetary) or monetary terms and it refers to single components, sub-assets or to the whole road infrastructure asset of a given road network.***

From the flowchart below it can be seen, how this backlog can be assessed in a stepwise procedure and it could be shown that almost all the procedures and definitions in use today can be covered by this approach. Nevertheless the application of the maintenance backlog expressed in monetary terms is generally recommended, be it for expression of the total monetary backlog at a given point of time or for the need of additional annual funds (budgetary backlog) to eliminate the maintenance backlog within a given time period.



Procedures for the calculation of the maintenance backlog – for the maintenance backlog expressed in non-monetary terms as well as for the maintenance backlog expressed in monetary terms - are proposed and recommendations for the practical application of the algorithms are given in addition.

As an important topic also the consequences of maintenance backlog as

- Effects to the road users (accidents, loss of time, disturbance, etc.)
- Effects to the road operators/administrations (monetary/budgetary effects, effect on responsibility etc.)
- Economic and socio-economic effects (strengthening of construction industry, preservation of jobs, etc.)
- Environmental effects (increase of emissions and pollution)

were mentioned. The calculation and the evaluation of these effects were not covered by the scope of this project, but they should be applied widely to present the consequences of maintenance backlog especially to the public in a clear and understandable way.

The final part of this chapter is dedicated to the use of maintenance backlog.

- Use for different sub-assets: it was found, that in all the investigated countries for pavements and structures (especially for bridges) a clear procedure exists to assess the maintenance backlog. For the road furniture part the situation is less developed. Therefore it is recommended to develop deterioration functions for these parts to allow the calculation of maintenance backlog related to condition. However, as a first step it is necessary to establish a complete inventory of this sub-asset and its components.
- For the practical use a distinction between internal and external use has to be made.
  - The internal use within the road administration can comprise among others the allocation of grants to different regions and/or sub-assets, benchmarking between different regions and departments and the assessment of the internal effectiveness of the road administration.
  - The external use is attributed to the argumentation against the related money providing ministry or government, the politicians and the public as well. It is also important for a successful competition with other public sectors (e.g. health sector) for the necessary budget.
- Some reservations against the application and use of maintenance backlog calculation have to be faced as well. Therefore a clear transparent approach including all levels of administration is recommended during the implementation, in order to convince all partners of the advantage of this procedure. Where the implementation of maintenance backlog calculation is started, a stepwise approach – for the selection of indicators, the condition assessment, the detailed calculation etc. – is highly recommended.

The output and results of this project should encourage general use of maintenance backlog including benchmarking between different road administrations on the national as well as on the international level.

Kurzfassung

Das Ziel von ERA-NET ROAD (ENR) ist die Koordination und gegenseitige Öffnung der Straßenforschung in Europa und die Implementierung eines transnationalen Straßenforschungsprogramms, das strategisch geplant und transnational finanziert wird. Im Rahmen von ERA-NET ROAD wurde neben anderen auch das transnationale Projekt „Erhaltungs-Nachholbedarf – Abschätzung und Anwendung“ initiiert. Das Projekt wurde von den Ländern Österreich, Dänemark, Finnland, Norwegen, Schweden, Schweiz und dem Vereinigten Königreich finanziert. Die teilnehmenden Länder bildeten ein Projektteam (Project Executive Board – PEB) unter der Führung der Schwedischen Straßenverwaltung zur Projektkoordination. Auf Basis einer beschränkten Ausschreibung und eines nachfolgenden Auswahlverfahrens wurde ein internationales Konsortium unter Führung von PMS-Consult (Österreich) und dem Institut für Verkehrsplanung und Transportsysteme der ETH Zürich (Schweiz) mit der Durchführung der Studie beauftragt.

Erhaltungs-Nachholbedarf kann als eine allgemeine und vergleichbare Bestimmungsgröße für Ergebnisse der Straßenerhaltung für verschiedene Arten von Straßen-Teilassets und verschiedene Managementaufgaben verwendet werden. Das Ziel des Projektes war es, Empfehlungen für die umfassende Implementierung und Anwendung von Indikatoren für den Erhaltungs-Nachholbedarf („best practice“) zu erarbeiten.

Das Projekt umfasst die folgenden Teilassets der Straßeninfrastruktur.

- Straßenoberbau (befahrene und nicht befahrene Flächen)
- Bauwerke (Brücken, Tunnel, Wände und andere Ingenieur-Bauwerke)
- Straßenausstattung (Verkehrszeichen, Leitschienen, Beleuchtung etc.)

Um dieses Ziel zu erreichen, baute die Bearbeitung auf strukturierten Interviews mit den teilnehmenden Straßenverwaltungen auf, denen die notwendige Vorbereitung über verfügbare Unterlagen und Hintergrundinformationen voranging. Diese Interviews wurden im Zuge von Besuchen bei den teilnehmenden Verwaltungen stets von denselben zwei Personen des Konsortiums durchgeführt.

Das Ziel der Interviews war die Erstellung einer Bestandsaufnahme von Aspekten des Erhaltungs-Nachholbedarfes mit grundlegenden Informationen und den häufigsten Einflussgrößen für die verschiedenen Teilassets der Straßeninfrastruktur. Um diese Daten zu erhalten, wurden Interviews mit folgenden Partnerländern durchgeführt:

- PEB-Länder (Österreich, Dänemark, Finnland, Norwegen, Schweden, Schweiz, Vereinigtes Königreich)
- Länder, aus denen ein Partner des Konsortiums kommt, die aber kein PEB-Land sind (Deutschland, Slowenien)
- 2 Konzessionäre mit Konzessionen in Europa

Die Ergebnisse der Interviews wurden zusammengefasst (sh. Kap. 4) und schließlich in eine Datenbank implementiert. Die Untersuchungen beschränkten sich auf das Straßennetz, das in der Verantwortung der betreffenden zentralen Straßenadministration liegt. Damit wurde eine große Vielfalt von Straßenkategorien abgedeckt, mit dem Schwerpunkt auf hochrangige Straßen. Parallel zu den Interviews wurden auch Informationen aus einer im Umfang begrenzten Literaturrecherche, laufenden Projekten, den Erfahrungen innerhalb des Bearbeiterteams und einer internationalen, generalisierten Recherche mittels Fragebogen

gesammelt und analysiert. Es war zu sehen, dass die Abschätzung und Berechnung des Erhaltungs-Nachholbedarfes in den skandinavischen Ländern weite Anwendung findet, während in den anderen untersuchten Ländern unterschiedliche Vorgangsweisen in Verwendung sind, ohne den Erhaltungs-Nachholbedarf direkt in derselben Art und Weise zu bestimmen. Es wird jedoch in allen Fällen der Bedarf erkannt, die Notwendigkeit einer verbesserten Straßenerhaltung und zusätzlicher finanzieller Mittel zum Ausdruck zu bringen.

Die Ergebnisse der Auswertung der Interviews und Untersuchungen wurden zusammengefasst und behandeln die folgenden Punkte (siehe Kapitel 5):

- Erhaltung und Erhaltungsziele: drei Gruppen der Straßenerhaltung werden unterschieden
  - Routinemäßige Erhaltung (Instandhaltung, oft auch als Teil des Straßenbetriebs gesehen), nicht geplant und deshalb bei der Ermittlung des Erhaltungs-Nachholbedarfs nicht berücksichtigt
  - Geplante, umfassende Erhaltung (Instandsetzung): Maßnahmen mit einem länger wirksamen Verbesserungseffekt. Die Notwendigkeit dieser Maßnahmen bildet die Basis für die Berechnung des Erhaltungs-Nachholbedarfs
  - Höherstufung und Erweiterung: Maßnahmen, die das Teilasset (Teilobjekt) auf einen höheren Standard bringen, als er ursprünglich gegebenen war (zusätzlicher Fahrstreifen, höhere Anforderungen an die Rückhaltesysteme etc.). Diese Maßnahmen fließen nicht zur Gänze in die Berechnung des Erhaltungs-Nachholbedarfs ein, die Zusatzkosten werden in der Regel aus dem Budget für Investitionen gedeckt.
- Zustand und Zustandsindikatoren:
  Für alle Teilassets (Oberbau, Bauwerke, Straßenausrüstung) wird eine generelle Empfehlung von Zustandsindikatoren (Einzel- und kombinierte Indikatoren oder Indices) gegeben. Während für den Straßenoberbau und die Bauwerke Zustandindikatoren in den jeweiligen Ländern bereits weite Anwendung finden, konnte das allgemeine Fehlen solcher Indikatoren für die Straßenausrüstung festgestellt werden. Dies sollte zukünftig behoben werden.
- Datenerfassung:
  Die Datenerfassung ist die Grundlage für die Zustandsbewertung. Für die Straßenbefestigung werden Messungen der nutzerspezifischen Indikatoren und visuelle Inspektionen für die strukturellen Indikatoren und für Bauwerke visuelle Inspektionen der einzelnen Komponenten empfohlen, die auch bereits weitgehend in Anwendung sind. Für die Straßenausrüstung sollte eine visuelle Inspektion und eine funktionelle Beurteilung umfassend eingeführt werden. Empfehlungen werden auch für die maximalen Intervalle zwischen den Messungen bzw. den visuellen Inspektionen gegeben (max. 5 Jahre für die Straßenbefestigung, max. 6 Jahre für die Bauwerke und max. 1 Jahr für die funktionelle Prüfung der Straßenausrüstung)
- Erhaltungsstandards und Erhaltungsstrategien
  - Für die verwendeten Zustandsindikatoren müssen die entsprechenden (Mindest-)Standards (Qualitätsanforderungen) definiert werden. Diese Werte definieren die Grenze zwischen Erfüllung und Nichterfüllung der Anforderungen (meist in Form eines zustandsbezogenen Wertes oder einer maximal zulässigen Schadensrate). Ebenso sind für jeden Zustandsindikator die Zielwerte zu definieren, die nach der Durchführung der Erhaltungsmaßnahme erreicht werden müssen. Die detaillierte Analyse

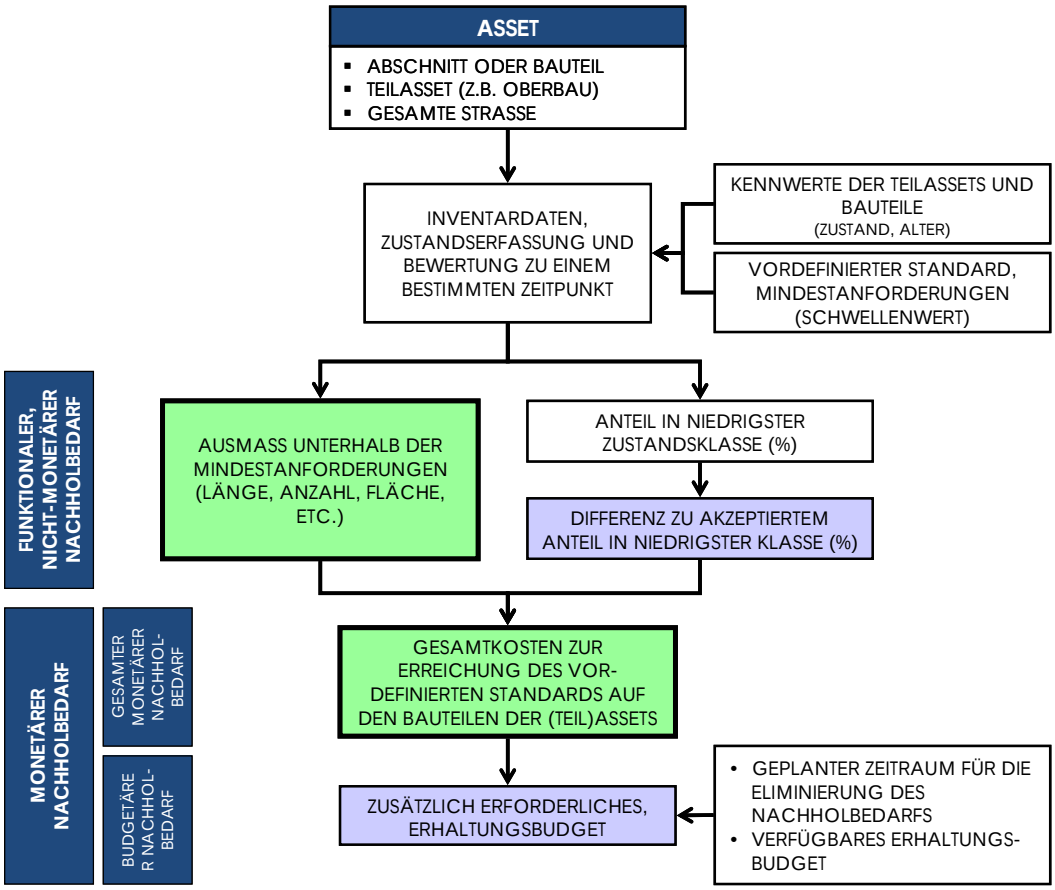
der in den verschiedenen Ländern verwendeten Zustandsindikatoren und der Grenzwerte war nicht die Aufgabe der vorliegenden Studie.

- Die Berechnung des Erhaltungs-Nachholbedarfs bezieht sich auf die optimale Erhaltungsstrategie. Durch eine Lebenszyklusanalyse kann die optimale Lösung entweder für eine Kostenminimierung unter Beibehaltung eines vorgegebenen Standards oder für die Nutzenmaximierung unter gegebenen budgetären Beschränkungen (Budgetlimits) gefunden werden.

Der Hauptteil dieses Kapitels behandelt den Begriff „Erhaltungs-Nachholbedarf“. Auf der Grundlage der gesammelten und analysierten Informationen wird die nachfolgende generelle Definition vorgeschlagen:

Der Erhaltungs-Nachholbedarf der Straßeninfrastruktur ist das Ausmaß nicht erfüllter Anforderungen in direktem Bezug zu den zu erreichenden definierten Standards zu einem gegebenen Zeitpunkt. Der Erhaltungs-Nachholbedarf kann als funktioneller (nicht monetärer) Wert oder als monetärer Wert ausgedrückt werden und er bezieht sich entweder auf eine einzelne Komponente, ein Teilasset oder auf die gesamte Straßen-infrastruktur des betrachteten Netzes.

Aus der nachfolgenden Abbildung ist ersichtlich, wie der Nachholbedarf in einer stufen-weisen Prozedur ermittelt werden kann.



Es konnte gezeigt werden, dass fast alle Prozeduren und Definitionen, die heute in Gebrauch sind, durch diesen Ansatz abgedeckt werden. Nichtsdestoweniger wird die monetäre Form des Erhaltungs-Nachholbedarfs zur generellen Anwendung empfohlen, sei es als gesamter monetärer Nachholbedarf zu einem bestimmten Zeitpunkt oder als Ausdruck für die erforderlichen zusätzlichen jährlichen Mittel (budgetärer Nachholbedarf), um den Erhaltungs-Nachholbedarf innerhalb einer gewählten Zeitspanne zu eliminieren.

Prozeduren für die Berechnung des Erhaltungs-Nachholbedarfes – sowohl für den funktionellen, nicht monetären als auch für den monetären Erhaltungs-Nachholbedarf - werden vorgeschlagen und Empfehlungen für deren praktische Anwendung werden zusätzlich gegeben.

Als wichtige Aspekte werden auch die Folgen eines Erhaltungs-Nachholbedarfes erwähnt, wie

- Auswirkungen auf den Straßennutzer (Unfälle, Zeitverluste, Störungen etc.)
- Auswirkungen auf den Straßenbetreiber/die Straßenverwaltung (monetäre Effekte, Auswirkung auf die Verantwortlichkeit etc.)
- Ökonomische und sozio-ökonomische Effekte (Stärkung der Bauwirtschaft, Sicherung von Arbeitsplätzen etc.)
- Umweltauswirkungen (Zunahme der Emissionen und Schadstoffe)

Die Berechnung und Bewertung dieser Effekte lag nicht in der Aufgabenstellung dieses Projektes, aber diese Darstellung sollte breite Anwendung finden, um die Auswirkungen eines Erhaltungs-Nachholbedarfes der Öffentlichkeit in klarer und verständlicher Form zu präsentieren.

Der Schlussteil dieses Kapitels ist der Anwendung des Erhaltungs-Nachholbedarfes gewidmet:

- Verwendung für verschiedene Teilassets: es wurde festgestellt, dass in allen untersuchten Ländern für die Straßenbefestigung und die Bauwerke (besonders für Brücken) eine klare Prozedur für die Ermittlung des Erhaltungs-Nachholbedarfs existiert. Für die Straßenausrüstung ist dies weniger zutreffend. Deshalb wird empfohlen, entsprechende Schadensfunktionen für diese Teile zu entwickeln, um die Kalkulation eines zustandsbezogenen Erhaltungs-Nachholbedarfs zu ermöglichen. Zunächst ist es als erster Schritt jedoch notwendig, eine vollständige Bestandsaufnahme aller Komponenten dieses Teilassets vorzunehmen.
- Für die Praxis kann weiters zwischen interner und externer Anwendung unterschieden werden.
  - Die interne Anwendung innerhalb der Straßenverwaltung kann neben anderem die Zuteilung von Mitteln an die verschiedenen Regionen bzw. zu verschiedenen Teilassets, das Benchmarking zwischen verschiedenen Regionen und Abteilungen sowie die Ermittlung der internen Effizienz der Straßenverwaltung umfassen.
  - Die externe Anwendung umfasst die Argumentation gegenüber dem geldgebenden Ministerium bzw. der Regierung, den Politikern und der der Öffentlichkeit. Sie ist ebenso wichtig für einen erfolgreichen Wettbewerb

um das nötige Budget gegenüber anderen öffentlichen Bereichen (wie z.B. Gesundheitssektor)

- Allerdings muss auch einigen Vorbehalten gegen die Ermittlung und die Anwendung des Erhaltungs-Nachholbedarfes entgegengesehen werden. Deshalb wird eine klare transparente Vorgangsweise bei der Einführung empfohlen, die alle Ebenen der Verwaltung umfasst, um alle Beteiligten von den Vorteilen dieser Prozedur zu überzeugen. Wird die Einführung der Kalkulation des Erhaltungs-Nachholbedarfes erst gestartet, wird eine stufenweise Vorgangsweise – für die Auswahl der Indikatoren, die Zustandserfassung, die Detailkalkulation etc. – wärmstens empfohlen.

Das Ergebnis und die Resultate dieses Projektes sollten zur generellen Anwendung der Ermittlung des Erhaltungs-Nachholbedarfs ermutigen, einschließlich Benchmarking zwischen den verschiedenen Straßenverwaltungen auf nationaler und auch auf internationaler Ebene.

Résumé

L'objectif d'ERA-NET ROAD (ENR) est de coordonner et de développer une recherche routière mutuelle en Europe, ainsi que de mettre en œuvre un programme transnational de recherche routière stratégiquement planifié et financé au niveau transnational. Dans le cadre d'ERA-NET ROAD, le présent projet intitulé "Maintenance Backlog – Estimation and Use" a été initié. L'Autriche, le Danemark, la Finlande, la Norvège, la Suède, la Suisse et le Royaume-Uni ont financé ce projet. Les pays participants ont formé le groupe de coordination PEB (Project Executive Board) mené par l'Administration Routière Suédoise (SRA). Un appel d'offre et un processus de sélection a octroyé le pilotage du projet au consortium international, mené par PMS-Consult (Autriche) et l'Institut de planification des systèmes de transport (EPF Zürich, Suisse).

Le retard de maintenance (travaux de maintenance restants et non effectués par manque de budget) peut être utilisé comme dénominateur commun dans la comparaison des résultats de maintenance des divers éléments composant le patrimoine routier et des diverses tâches de gestion. L'objectif du projet était de donner des recommandations pour la mise en œuvre complète et l'utilisation d'indicateurs de retard de maintenance selon un code de bonne pratique.

Le projet couvre les éléments suivants du patrimoine routier:

- Chaussées (surfaces circulées et non circulées)
- Ouvrages d'art (ponts, tunnels, murs et autres structures)
- Equipement routier (panneaux, glissières de sécurité, éclairage, etc.)

Pour atteindre les objectifs du projet, le travail a été basé sur un questionnaire structuré envoyé aux diverses entités du projet et préparé en tenant compte des informations existantes. Le questionnaire et les entrevues qui ont suivi ont toujours été faits par les deux mêmes personnes du consortium.

Le but des entrevues était de produire un inventaire concernant le retard de maintenance, en soulignant les informations nécessaires et les paramètres les plus importants, et en tenant compte des différents éléments du patrimoine routier. Les entrevues ont été menées avec les partenaires suivants:

- Pays composant le PEB (Autriche, Danemark, Finlande, Norvège, Suède, Suisse, Royaume-Uni)
- Pays d'où un partenaire du consortium était issu mais ne faisant pas partie du PEB (Allemagne, Slovénie)
- 2 concessionnaires européens

Les réponses des entrevues ont été résumées au chapitre 4 et introduites dans une base de données. Les recherches ont été limitées aux types de réseaux routiers gérés par les administrations routières centrales respectives, de telle manière à couvrir une grande variété de catégories de routes, avec une focalisation sur les routes de plus haut niveau.

Parallèlement aux entrevues, l'information relative a été récoltée dans la littérature, sur la base des expériences au sein du groupe de travail et recherche internationale au moyen d'un questionnaire généralisé. Cette information a ensuite été analysée et a montré que le calcul et l'estimation du retard de maintenance est largement utilisé dans les pays scandinaves, tandis que d'autres pays utilisent plusieurs approches sans directement évaluer le retard de maintenance. Cependant, dans tous les cas, ils reconnaissent le besoin d'exprimer la nécessité d'une maintenance routière améliorée et de financements accrus.

Les résultats de l'évaluation des entrevues et des recherches sont résumées par les points suivants (voir chapitre 5):

- Maintenance et objectifs de maintenance: trois groupes de maintenance sont couramment distingués:
  - Maintenance de routine (appelées aussi opérations routières), non planifiées et de ce fait non prises en compte dans l'évaluation du retard de maintenance.
  - Maintenance planifiée (lourde): mesures de maintenance avec une amélioration à long terme. Le besoin de telles mesures forme la base pour le calcul du retard de maintenance.
  - Amélioration et aménagement: mesures qui améliorent le patrimoine routier jusqu'à un niveau plus élevé que l'état neuf initial (voies additionnelles, exigences plus grandes pour les systèmes de rétention, etc.) Ces mesures ne sont pas totalement incluses dans le calcul du retard de maintenance, les coûts d'amélioration sont couverts par les investissements.
- Indicateurs d'état et de performance:
  Une recommandation générale concernant les indicateurs ou indices de performance (simples et combinés) est donnée pour différents éléments du patrimoine routier (chaussées, ouvrages d'art et équipement). Les pays analysés utilisent largement les indicateurs de performance pour les chaussées et les ouvrages d'art, mais ces indicateurs ne sont par contre pas utilisés pour tous les autres équipements. Ceci devrait être amélioré dans le futur.
- Acquisition de données:
  Des indicateurs spécifiques et des inspections visuelles pour les chaussées et des indicateurs structurels ainsi que des inspections visuelles pour les composantes principales des ouvrages d'art sont recommandés (et déjà largement utilisés) pour l'acquisition de données en tant que base pour l'évaluation de leur état. L'inspection visuelle et les évaluations fonctionnelles devraient être étendues au domaine des équipements.

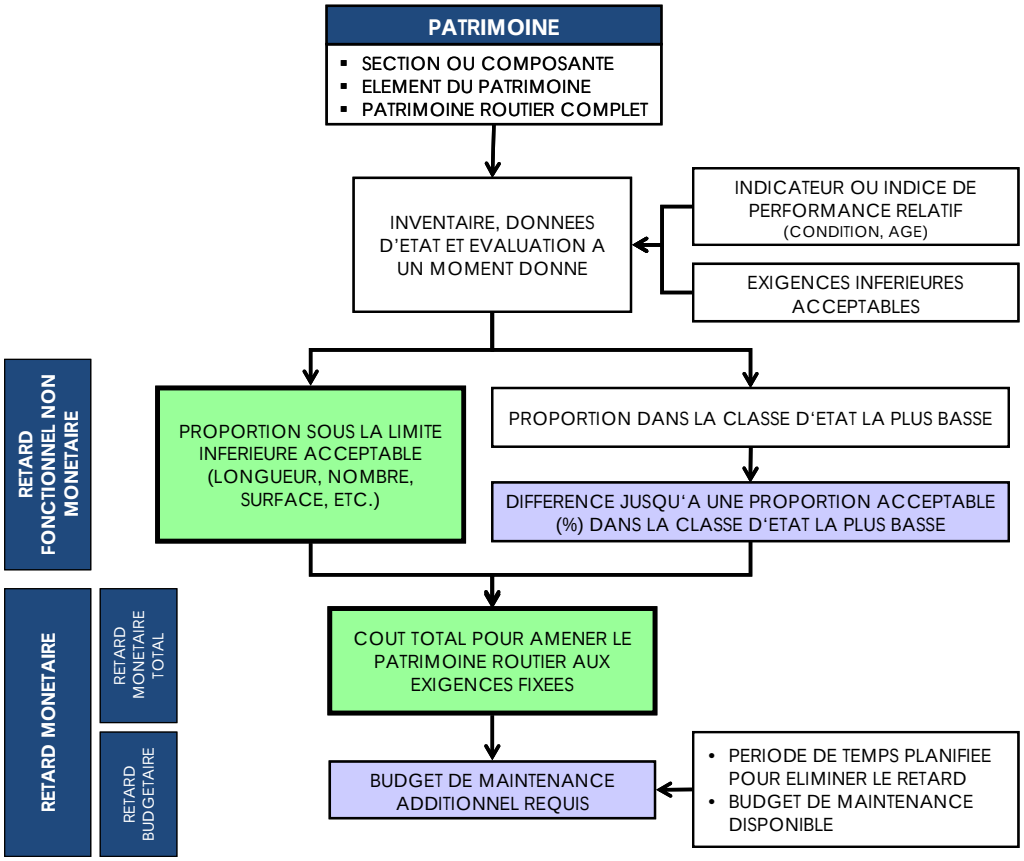
  L'intervalle maximum recommandé pour les mesures et les inspections visuelles devrait être de 5 ans pour les chaussées, 6 ans pour les ouvrages d'art et 1 an pour l'évaluation fonctionnelle des équipements.
- Normes et stratégie de maintenance
  - Il convient de définir les règles d'évaluation pour les différents indicateurs de performance utilisés (niveaux de qualité). Ces valeurs limites définissent le point à partir duquel les exigences ne sont plus remplies. Les valeurs cibles à atteindre après des opérations de maintenance doivent être définies pour chaque indicateur de performance. Le but de ce projet n'était pas d'analyser en détail ces indicateurs d'état et les valeurs limites relatives.
  - Le calcul du retard de maintenance est basé sur la stratégie de maintenance optimale. En utilisant la méthode LCC (Life Cycle Cost), une

solution optimale peut être trouvée en minimisant les coûts ou en maximisant les bénéfices des traitements par rapport aux contraintes de budget.

Sur la base de l'information collectée et analysée, il est possible d'extraire la définition générale suivante pour le retard de maintenance:

Le retard de maintenance d'une infrastructure routière représente l'ampleur du besoin de maintenance à combler, à un moment donné, selon les exigences prédéfinies. Il peut être exprimé en termes fonctionnels (non monétaires) ou monétaires et il se réfère aussi bien à des composants individuels qu'à une partie ou à l'ensemble du patrimoine routier.

L'organigramme ci-dessous montre une approche par étapes couvrant la plupart des procédures et définitions utilisées aujourd'hui, et permet de déterminer ce retard de maintenance. Néanmoins l'expression du retard de maintenance en termes monétaires est généralement recommandé, que ce soit pour l'expression du retard monétaire total à un moment donné, ou pour la détermination du besoin budgétaire additionnel (retard budgétaire) pour éliminer le retard de maintenance.



Des procédures pour le calcul du retard de maintenance – aussi bien non monétaire que monétaire – sont proposées et des recommandations sont données pour l'application pratique des algorithmes.

Les conséquences importantes suivantes d'un retard de maintenance ont été citées:

- Effets sur les usagers de la route (accidents, perte de temps, dérangements, etc.)
- Effets sur les opérateurs/administrateurs de la route (effets monétaires/budgétaires, responsabilités, etc.)
- Effets économiques et socio-économiques (renforcement de l'industrie de la construction, préservation des emplois, etc.)
- Effets environnementaux (augmentation des émissions polluantes)

Le calcul et l'évaluation de ces effets n'entraient pas dans le cadre de ce projet mais ils devraient être évalués dans le futur pour pouvoir présenter en particulier à l'opinion publique les conséquences d'un retard de maintenance de façon claire et compréhensible.

La partie finale de ce chapitre est dédiée à l'utilisation du retard de maintenance:

- Utilisation pour différents éléments du patrimoine: dans les pays ayant participé, il existe des procédures claires pour évaluer le retard de maintenance dans les chaussées et les ouvrages d'art (spécialement les ponts). Ce développement n'est pas aussi avancé pour le l'équipement routier. C'est pourquoi il est recommandé de développer des modèles de comportement pour permettre l'évaluation du retard de maintenance. Néanmoins, il est nécessaire, dans une première étape, d'établir un inventaire complet de cette partie du patrimoine routier.
- Il est possible de distinguer l'usage interne de l'usage externe:
  - L'usage interne dans l'administration routière peut aider à l'attribution de budgets aux différentes régions et/ou éléments du patrimoine, à une analyse comparative entre différentes régions et départements, et à l'évaluation de l'efficacité interne de l'administration routière.
  - L'usage externe peut aider à l'argumentation vis-à-vis des ministères ou gouvernements – mais aussi des politiciens et de l'opinion publique - pour l'obtention des budgets gouvernementaux, notamment dans la compétition budgétaire avec d'autres secteurs publics (comme par exemple le secteur de la santé).
- Quelques réserves sont à mentionner en ce qui concerne l'application et l'utilisation du retard de maintenance. Il est recommandé d'adopter une approche transparente faisant appel à tous les niveaux administratifs et de convaincre tous les partenaires de l'avantage d'une telle procédure. Dans la procédure de mise en œuvre du retard de maintenance, il est hautement recommandé d'utiliser une procédure par étapes pour la sélection des indicateurs, l'évaluation de l'état du patrimoine, le calcul, etc.

Les résultats de ce projet devraient encourager l'utilisation générale du retard de maintenance en incluant les analyses comparatives entre les différentes administrations routières, au niveau national et international.

Table of content

1 Introduction

The objective of ERA-NET ROAD (ENR) is to coordinate and mutually open up road research in Europe and to implement a trans-national road research program that is strategically planned and trans-nationally funded. ERA-NET ROAD initiates trans-national research activities like this.

This trans-national project is entitled "Maintenance Backlog – estimation and use". The countries funding the project were Austria, Denmark, Finland, Norway, Sweden, Switzerland and the UK. The participating countries have formed a project team called Project Executive Board (PEB) for coordination of the project. The project was led by the Swedish Road Administration (SRA) and followed the Swedish laws and contracting rules.

1.1 Objectives of the Project

The maintenance of road network has become a highly important part of the road management in industrialized countries. The road network is quite well developed, and preservation of the asset must be secured. The objectives of maintenance are upkeep and restoration of road network condition to counterbalance its deterioration due to weather, traffic, aging etc. The results of the maintenance effort must be measured to assess to what degree the objectives are achieved and also to assess the effectiveness of maintenance (doing the right things in the right way).

Road network condition is the measured output of the maintenance and the basis for estimation of its outcome (road user effects etc). The large number of road condition variables attributed to different road network components makes it necessary to find a common denominator. The term “maintenance backlog” has become such a common denominator opening vast possibilities to improve effectiveness through performance monitoring and performance management.

The purpose of the trans-national research project “Maintenance Backlog – estimation and use” is to help road owners and road managers to implement and/or further develop maintenance backlog indicators for different assets of the road infrastructure. Maintenance backlog can be used as a common and comparable denominator of road maintenance results for different types of road sub-assets and for different management tasks.

The objective of the project was to prepare recommendations for the comprehensive implementation and use of maintenance backlog indicators (“best practice”). Those are based on analysis of experience in studied countries, available recent research reports, and the experiences of the involved parties.

Furthermore, the recommendations include principles for specification as follows:

- Maintenance objectives
- Maintenance standards
- Selection of required data and their acquisition
- Calculation of maintenance backlog

- Assessment of its short- and long-term consequences for different stakeholders;
- Recommendations for the presentation and use of maintenance backlog in practice (both in- and outside of road administrations)

The output and results of this project should encourage general use of maintenance backlog including benchmarking between different road administrations on the national as well as on the international level. The project covers the following sub-assets of the road infrastructure:

- Pavements (trafficked and non-trafficked areas)
- Engineering structures (bridges, tunnels, walls, and other engineering structures)
- Road furniture (signs, guardrails, lights, etc.)

The results given in the final report will be presented at a special seminar. The seminar's main objective is to present a common maintenance backlog assessment framework recommended for the road administrations of CEDR (Conference of European Directors of Roads) based on the agreed recommendations of the project.

1.2 Project Organization

At the ERA-NET Asset Management workshop the participants have unanimously selected a project proposal dealing with the objectives described above and road agencies from several countries decided to contribute to the project. These road agencies have then formed a project team called Project Executive Board (PEB) for the coordination of the project. This PEB was led by the Swedish Road Administration and consisted of the following representatives:

- **Dr. Christian Pecharda** representing
  Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT),

  AUSTRIA (AT)
- **Mr. Jan M. Jansen**
  Danish Road Directorate (DRD),

  DENMARK (DK)
- **Mr. Tuomas Toivonen and Mr. Vesa Mannistö**
  Finnish Road Administration (FinnRA),

  FINLAND (FI)
- **Dr. Even Sund**
  Norwegian Public Roads Administration (NPRA),

  NORWAY (NO)
- **Mr. Jaro Potucek and Mr. Johan Lang**
  Swedish Road Administration (SRA), Vägverket

  SWEDEN (SE)

- **Dr. Ali Rafi** representing
  Swiss Federal Roads Authority (ASTRA),

  SWITZERLAND (CH)
- **Mrs. Annette Pass / Mr. Roger Fairclough**
  Department for Transport – Highways Agency (HA),

  UNITED KINGDOM (UK)

To fulfil these objectives and comprehensive tasks following an invited bidding and selection procedure an international Consortium was charged by the Swedish Road Administration. The following partners formed this Consortium:

- **PMS-Consult**, Dr. A. Weninger-Vycudil, Engineering Office for Traffic and Infrastructure, in cooperation with Prof. J. Litzka, Vienna, Austria (project leader)
- **Institute for Transport Planning and Systems** (IVT), Swiss Federal Institute of Technology (ETHZ), Zurich, Switzerland (co-project leader)
- **DDC Consulting and Engineering Ltd.**, Ljubljana, Slovenia
- **Heller Engineering Ltd.**, Darmstadt, Germany
- **Viagroup Ltd.Co.**, Winterthur, Switzerland

The leading partner of this trans-national Consortium and thus its official representative was PMS-Consult in cooperation with IVT.

2 Methodology and Working Program

2.1 General

To achieve the objectives of the project it was necessary to develop a methodology for collecting the existing knowledge and practice as a basis for the analysis and the recommendations to be developed. The work was based on structured interviews with the participating agencies preceded by the necessary preparation based on existing documents and background information. These interviews were performed at visits at the participating agencies by the same two persons from the consortium with experience in the subject. The PEB supported the interviewers during the preparation of the visits and by providing the relevant interview partners.

To reach the objectives of this project, 4 Work Packages have been carried out, each covering a number of tasks and providing the basis for the reports, the planned meetings, and finally the recommendations. The four Work Packages are the following:

Work Package 1: Questionnaire and Interviews

The main objective of Work Package 1 was to provide the Questionnaire and to carry out the planned Interviews.

Work Package 2: Investigation on Literature, current Projects and Experiences

The main objective of Work Package 2 was the collection of additional information about maintenance backlog indicators based on existing literature, international expertise and own experience of the Project Team. Due to the time and budget restrictions the effort had to be limited.

Work Package 3: Database and Evaluation

An electronic database was setup to store and evaluate the collected information.

Work Package 4: Conclusions and Recommendations

The main objective of the Work Package 4 was the preparation of recommendations and a practical procedure for the use of backlog subjects in the different fields of application (=result of the project)

2.2 Interviews

2.2.1 Interview Partner

The aim of the interviews was to produce an inventory of maintenance backlog issues, underlying information, and most relevant input parameters, taking into account different assets of the road infrastructure. In order to obtain the data the technical approach to this work was to perform the interviews with the following partners:

- PEB-countries:
  - Austria
  - Denmark
  - Finland
  - Norway
  - Sweden
  - Switzerland
  - United Kingdom
- Countries where a partner of the consortium was coming from but not being a PEB-country:
  - Germany
  - Slovenia
- 2 concessionaires with concessions in Europe

The following Table 1 gives an overview of the interviews which have been carried out. The selection of the interview partners was in the responsibility of the PEB-members.

Table 1 List of interview-partners

Organization / Institution	Date
BMVIT - Federal Ministry of Transportation, Innovation and Technology, ASFiNAG - Austrian Motorway Company (AT)	25.11.2008 and 1.12.2008
DRD - Danish Road Directorate (DK)	28.11.2008
FINNRA - Finnish Road Administration – Tiehallinto (FI)	3.-4.12.2008
NPRA - Norwegian Public Road Administration - SVV (NO)	27.11.2008
SRA - Swedish Road Administration - Vägverket (SE)	8.-9.10.2008
ASTRA – Swiss Federal Road Administration (CH)	26.1.2009
HA - Highways Agency (UK)	18.-19.11.2008
BMVBS – German Federal Ministry of Transport, Building and Urban Affairs (DE)	17.2.2009
DARS – Slovenian Motorway Company (SI)	10.2.2009
DirectRoute (Concessionaire, Ireland)	19.2.2009
M6 Duna (Concessionaire, Hungary)	15.1.2009

2.2.2 Interview Teams

According to the commitments given by the Consortium the interviews were carried out by interview teams as follows:

- Primary interview team for PEB-countries:
  - Dr. A. Weninger-Vycudil
  - Prof. J. Litzka
- Secondary interview team for additional countries and concessionaires:
  - 1 person of the primary interview team
  - Local interview team (composed of local consortium partner)

2.2.3 Documents for the Interviews

In accordance with the DoW (description of work) and the recommended Working Program a questionnaire was produced as a basis for the interviews. The primary aim of this questionnaire was the collection of existing available information about maintenance backlog for different assets of the road infrastructure. The questionnaire dealt exclusively with information, which was related to the road infrastructure and not to other infrastructures (e.g. water supply). The questionnaire was designed for data collection in order to prepare the database. The output of the questionnaire or the database respectively can be distributed to all participating experts and non-experts, policy makers, research institutes, etc.

The complexity of the information required and demanded the use of an electronic questionnaire based on the commercial software product MS Excel©, because this is available in almost every road administration.

The questionnaire was structured in accordance of the interview milestones, which can be taken from the following chapter. The questionnaire consisted of the following main parts:

- Information about pavements
- Information about engineering structures
- Information about road furniture
- Information about cross asset assessment of the whole road infrastructure

During the interviews the questionnaire was used as an essential basis. It helped the partners and the interviewers on the one hand to prepare the interviews and on the other hand to support both parties during the interviews in asking and answering the most important questions.

Beside the questionnaire an additional document was prepared after the interview testing phase. It supported the interview partners and interview team and included some general statements and questions which were the basis for the discussions during the interviews. It was used during the interview and aimed together with the questionnaire to collect the most important information for this project.

Both documents were sent out to the interview partners in advance of all interviews.

2.2.4 Execution of the Interviews

As already mentioned all interviews were held by the same project team members. The interviews were the main basis for the following up work in the different work packages. To guarantee a high quality of the answers during the interviews a test interview was carried out with the Swedish road administration in order to assess the planned structure of the interview. During the first interviews it could be seen that the recommended approach brought good results and was sufficient for the following analysis of the information.

The interviews were implemented finally into the database. Furthermore it was decided by the interview team in accordance with the interview partner to prepare short minutes of the interviews and to send these minutes to the interview partner for review and correction if necessary before further assessment and analysis.

2.3 Investigation on Literature, current Projects and Experiences

In parallel to the interviews the investigation on literature, current project and experiences started. This activity aimed to collect additional information about maintenance backlog and how the maintenance need is expressed. In accordance with task 2 of the Working Program this investigation focused on

- National and International Literature
  - Recent European and other international conferences on managing assets (EPAM3, ICMPA2008, SURF2008, and TRA2008)
  - National research reports
  - National and European standards
  - Publications of COST-actions
  - Other literature
- International Expertise
  Email discussion with selected international experts practically working with maintenance backlog indicator.
- Experiences of Project Team

3 Definition of Main Terms

Throughout the whole project the following definitions of main terms have been used. However, this is not intended to be a complete list of terms used in road infrastructure maintenance and in some cases differences to definitions from literature and national papers can exist. The definitions refer especially to the road infrastructure asset.

Asset

The asset considered in this report is the road infrastructure which can be divided into different sub-assets (e.g. pavements, structures, road furniture) each consisting of several components.

Asset Management of Road Infrastructure

An administrative process for the purposes of financial accounting and maintenance of the road infrastructure assets

Pavement Management

Management of trafficked and non-trafficked pavement constructions of the road infrastructure

Engineering Structures Management

Management of engineering structures of the road infrastructure like bridges, tunnels and galleries, walls and others.

Road Furniture Management

Management of road furniture of the road infrastructure like traffic signs, protection systems, markings and others

Maintenance

All types of activities on the road infrastructure aiming at upkeep or restoration of condition of road components (assets), from routine maintenance over periodic maintenance (minor maintenance treatments) to rehabilitation / reconstruction (major maintenance treatments).

Maintenance activities

Routine Maintenance:

Small measures with short life time executed on actual demand to avoid progressive deterioration and operational activities (e.g. winter maintenance / winter operation)

Planned (major) maintenance

Maintenance measure with a long lasting effect to the condition of the sub-asset or component including preventive maintenance

Upgrade and extension

Measures which upgrade the existing asset or component or extend the infrastructure to a higher level than the original new condition (e.g. additional lane, higher requirements for retention systems)

Maintenance Backlog

Maintenance backlog of the road infrastructure is the amount of unfulfilled demands at a given point of time in explicit reference to predefined standards to be achieved. Maintenance backlog can be expressed in functional (non-monetary) or monetary terms and it refers to single components, sub-assets or to the whole road infrastructure asset (details see chapter 6.6).

Maintenance standard

A (predefined) quality level to be achieved by means of maintenance activities.

Performance Indicator

A superior term of a technical road asset characteristic that indicates its condition. It can be expressed in the form of a Technical Parameter (dimensional) and/or in the form of a dimensionless Index [1].

Technical Parameter (TP)

A physical characteristic of the road asset condition, derived from various measurements, or collected by other forms of investigation [1]. In some cases a distinction between functional (user related) and structural (construction related) parameters can be made.

Performance Index (PI)

An assessed Technical Parameter of the road pavement, dimensionless number or letter on a scale that evaluates the Technical Parameter involved [1].

Single Performance Indicator

A dimensional or dimensionless number related to only one technical characteristic of an asset, indicating the condition of that characteristic [1].

Combined Performance Indicator

A dimensional or dimensionless number related to two or more different characteristics of an asset, that indicates the condition of all the characteristics involved (e.g. PCI- Pavement Condition Index) [1].

General Performance Indicator (GPI)

A mathematical combination of single and/or combined indicators which describe the condition concerning different aspects like safety, structure, riding comfort and environment (also called Global Performance Indicator) [1].

Threshold Value

A value, which defines the limit between fulfilled and unfulfilled demands (due to given maintenance standards and requirements) related to the condition of an element or component of a sub-asset, a single sub-asset or the total road infrastructure asset. It generally defines the lowest acceptable standard.

Trigger Value

A value used for determining the feasibility of maintenance measures or treatments.

4 State of the Art

The state of the art was evaluated by interviews and an investigation of the existing literature. It has to be stated, that the interviews are providing a clear picture of the applied practice in the different countries, while from the literature normally no clear information is available, whether the described procedures are really used in practice or are proposals and ideas only.

4.1 Interviews

As already mentioned, the primary aim of the interviews was to produce an inventory of maintenance backlog issues, underlying information, and most relevant input parameters, taking into account different sub-assets of the road infrastructure. For each single road administration or concessionaire the information are listed as follows:

- General
  - Description of the network
  - Organisation
  - Definition of road maintenance activities
  - Management Systems
- Maintenance backlog in general
  - Definition of maintenance backlog in general
  - Use of maintenance backlog
- Sub-asset Pavement
  - Condition surveys of pavements
  - Performance indicators for road pavements
  - Assessment of pavements
  - Definition of maintenance backlog for pavements
- Sub-asset Structures
  - Categorisation of structures
  - Condition inspection of structures
  - Performance indicators for structures
  - Assessment of structures
  - Definition of maintenance backlog for structures
- Sub-asset Road Furniture
  - Categorisation of road furniture
  - Condition inspection of structures
  - Performance indicators for road furniture
  - Assessment of road furniture
  - Definition of maintenance backlog for road furniture
- Cross Asset Management and Budget Allocation

The following sub-chapters are showing a summary of the interviews in the different countries according to this structure. The complete minutes of the interviews can be seen in Annex A.

It has to be stressed again, that only these roads were included in the interviews and results which are in the direct responsibility of the respective road administration, resulting in the main focus on high-level road network.

4.1.1 Austria

The interview in Austria was carried out with the Austrian Motorway Company (ASFINAG) and the Federal Ministry of Traffic, Innovation and Technology (BMVIT).

4.1.1.1 General (AT)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	2'100	subdivided into motorways and expressways
Other primary roads[2)]	NO	-	
Other roads[3)]	NO	-	
Gravel roads	NO	-	
	Total:	2'100	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	ASFINAG is a company under private law in the ownership of the Austrian state; BMVIT is the controlling authority and proprietor's representative
Regional offices	4	service companies: maintenance measures with a total amount of less than €500'000,-
Other units	1	construction management company: maintenance measures with a total amount of more than €500'000,-

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	small maintenance measures in the context of operation	NO	
Planned (major) maintenance	planned maintenance activities: repair and reconstruction	YES	
Improvement and extension	extension of existing road: increase of capacity (additional lane); split of budget (new construction and maintenance)	YES	

1).....Execution of activity but not planning!

Management Systems

System	in use	Description
Pavement Management System	YES	• VIAPMS™ analytical pavement management software (Canadian origin) is used net-wide since 1998 including all maintenance relevant data (inventory, condition data, pavement construction data, traffic data, climate data, etc.) • system uses LCC-analysis with deterministic performance prediction of single indicators and optimization with budgetary constraints
Structure Management Systems	YES	• BAUT system is used for all types of structures according to guideline RVS 13.04; web-based solution includes the information (inventory, organization data, inspection data) • planning of maintenance activities based on BAUT system: o definition of maintenance measures for each single component o calculation of maintenance needs on network level: cohort model; applied every year using actual data from inspections
Management System for Road furniture	NO	
Asset Management System	NO	

4.1.1.2 Maintenance Backlog in General (AT)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	• percentage of network in condition class 5 (very poor) • maintenance backlog for pavements could be expressed by %-length in very poor condition and for bridges/structures in %-area in very poor condition • no monetary definition of backlog because of high variation of prices (especially for structures); only possible on project level with detailed cost estimation

Use of maintenance backlog

Use	Description
General	only comparable approach used; budget for maintenance activities is directly coming from toll (trucks and buses) and vignette (personal cars)
External use	• no need because the budget for maintenance activities is directly coming from the income of toll and vignette • not necessary because there is no need for argumentation to public • exception: argumentation of head with respect to necessary increase of prices for toll or vignette
Internal use	• for argumentation to get more budget for maintenance activities; competition to new construction • for argumentation to audit court and proprietor's representative (BMVIT): minimum collateral of network and effective maintenance; coordination of maintenance activities • information to the head • initiation of projects • information to BMVIT which defines objectives of maintenance in general • basis for the definition of the construction program (distribution to new construction and maintenance) • displaying the history

4.1.1.3 Sub-asset Pavement (AT)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	5	
Measurement	network	5	
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	• rut depth • water depth	
Longitudinal evenness	IRI	
Friction (skid resistance)	• friction coefficient (Stuttgarter Reibungsmesser) • texture (MPD)	
Surface defects	surface defects: defect rate	combination of different surface defects, e.g. ravelling, bleeding, patching, etc.
Cracking	cracking: defect rate	combination of different cracking types
Bearing capacity	-	
Road geometry	-	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	thresholds for each single indicator available and used especially in PMS
Indices	YES	each technical parameter is transformed to an index (normalization)
Classification scale	YES	index scale from 1 (very good) to 5 (very poor)
Combined Indices	YES	• combined indicators o functional index (comfort and safety) o structural index o total condition index • complex combination algorithm based on brake-down rule and weights

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	maintenance backlog for pavements could be expressed by %-length in very poor condition

4.1.1.4 Sub-asset Structures (AT)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges • troughs	
Tunnels	• galleries and open constructed tunnels • mined tunnels	
Walls	• retaining walls • noise barriers	
Others	• gantries • protections structures (stone falls, avalanches)	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	6 (10)	every 6 years (structures with non-moving elements every 10 years)
Interim inspection	2	control inspection
Other inspections	-	special inspections in case of special problem or because of security reasons

Performance indicators for structures

Category	in use	Description
Single indicators	YES	assessment of single components based on the collected distresses during inspection
Combined indicators	YES	damages on each inspection element is collected → rating score for each single component given by the inspector (individual assessment by inspector)
Other indicators	NO	

Assessment of structures

Assessment	in use	Description
Indices	YES	
Classification scale	YES	rating scale from 1 (very good) to 5 (very poor) [guideline RVS 13.04; assessment scheme]
Combined indices	YES	total condition index: given by the inspector of the structure, no combination procedure in use

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	• maintenance backlog for bridges/structures in %-area in very poor condition • backlog could be defined for tunnels: improvement of tunnels for safety reasons because of new EU-regulation

4.1.1.5 Sub-asset Road Furniture (AT)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• guard rails • concrete barriers • crash cushions	
Equipment	• markings • traffic signs • lightning	
Others	• animal fences • IT-equipment • guidance systems	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	during safety inspections function of road furniture is checked

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	only reflectivity of traffic signs and markings is checked (but not periodically)
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.1.6 Cross Asset Management and Budget Allocation (AT)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	definition of budget is based on network level assessment in combination with detailed investigations on project level (mixture of network and project level assessment)
Allocation to components	• no existing procedure for the distribution of maintenance budget between the different components or assets • measures will be combined to get minimum disturbance for the road user (main objective of maintenance on ASFINAG network) • assessment of sections where all necessary maintenance activities will be combined → reduction of disturbance • thus no fixed distribution key for the different components • service companies are defining “projects”; execution of “projects” by construction management company of ASFINAG
Allocation to regions	-

4.1.2 Denmark

The interview in Denmark was carried out with the Danish Road Directorate (DRD).

4.1.2.1 General (DK)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	1'000	subdivided into motorways and expressways
Other primary roads[2)]	YES	2'800	
Other roads[3)]	NO	-	
Gravel roads	NO	-	
	Total:	3'800	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	strategic level
Regional offices	6	operation and maintenance
Other units		

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	small maintenance measures in the context of operation	YES	
Planned (major) maintenance	repair: raising to original level of condition	YES	
Improvement and extension	improvement / upgrading: raising to advanced or extended level; because of new or higher requirements or extension of functional demands	YES	financed partly by maintenance and investment budget

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• software: BELMAN, in house made system developed by DRD; recently upgraded system implemented which can be used by municipalities as well; includes VIS database (storage of all PMS data) • deterioration model based on existing long term monitoring data • LCC-analysis • for calculation of maintenance strategies / needs VOC taken into account (savings in VOC), based on world bank models, HDM, and mainly IRI
Structure Management Systems	YES	in-house system DANBRO includes: • inventory of bridges • inspection results • budget calculation
Management System for Road furniture	YES	• Separate database including o drainage system o traffic sign (registered in detail) o guard rails (summation of annual costs for repairs) • video data base: video recording of all roads including images of the traffic signs; every 20m a picture; updated every 3 years
Asset Management System	NO	

4.1.2.2 Maintenance Backlog in General (DK)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• maintenance backlog expresses the need in form of a monetary value to bring the assets from a condition below or at the lowest acceptable up to an agreed, better level (normally equal to the original condition) • backlog originally expressed in technical terms but finally transformed to monetary terms
If NO, comparable approach	-

Use of maintenance backlog

Use	Description
General	could be used for expressing the benefit of maintenance versus VOC/User costs
External use	• the main objective of the backlog is to express the development/trends of needs for optimal maintenance within o budget negotiation o discussion with politicians o discussion with ministry o easier comparison of arguments with other competing areas (health care, etc.) • benchmarking between other countries (external); sometimes problems with the comparability (different basis)
Internal use	• the backlog shall (ideally) perform the basis for allocating of grants for maintenance of sub assets • could be used for benchmarking between regions

4.1.2.3 Sub-asset Pavement (DK)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	1	
Measurement	network	1 (2)	every year on the slow lane and every 2nd on the other lane additionally
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	rut depth	
Longitudinal evenness	IRI	
Friction (skid resistance)	• Friction coefficient (ROAR) • Texture (MPD)	
Surface defects	surface damages	
Cracking	cracking	
Bearing capacity	deflection: FWD	not on the motorways, only on specific sections
Road geometry	-	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	• evaluation and assessment is based on single indicators • assessment based on “road regulations”: on section level IRI higher than 2.5 not excepted
Indices	NO	
Classification scale	NO	
Combined Indices	NO	

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• based on average life time of bituminous surface (wearing) courses: 12 years (output of PMS data) • simple calculation o total network length divided by 12 = theoretical renewal per annual o compared to executed renewals o difference expresses the maintenance backlog in length then multiplied with unit costs (per km) is backlog in monetary value • this approach focuses on surface only but based on estimations bearing capacity part is added • backlog expressed by length and monetary value
If NO, comparable approach	-

4.1.2.4 Sub-asset Structures (DK)

Categorisation of structures

Group	Type	Comments
Bridges	• major bridges (> 200 m) • minor bridges	
Tunnels	tunnels	
Walls	• retaining walls • Noise barriers	
Others	gantries	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	1 - 6	principle / general inspection of all bridges and other structures every 1 to 6 year - depending of the condition and the traffic on the structure
Interim inspection	-	
Other inspections	-	special inspection: at all major repair works (> 15.000 €)

Performance indicators for structures

Category	in use	Description
Single indicators	YES	note is given to different components and then extended to the whole bridge
Combined indicators	YES	total condition index is used; combination procedure subject to importance of components
Other indicators	NO	

Assessment of structures

Assessment	in use	Description
Indices	YES	note is given to different components and then extended to the whole bridge
Classification scale	YES	all structures are given a condition mark between 0 and 5 • 0 indicates: no problems • 5 indicates: alarm/immediately repair
Combined indices	YES	total condition index is used; combination procedure subject to importance of components

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	every year, at the 1st of September, the total costs of all repairs indicated to be carried out during the following year - plus not carried out repairs during previous years - are calculated. This figure is defined as the backlog and includes all “matured” repair works independent from the money available or expected for the following year.
If NO, comparable approach	-

4.1.2.5 Sub-asset Road Furniture (DK)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• guard rails • concrete barriers • safety fences (rope barriers)	
Equipment	• traffic signs • lightning • fences • Km-posts	
Others	• drainage and verges • sidewalks • curbs • side areas • plantation	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	3	video recording of all roads including images of the traffic signs; video data base; every 20m a picture

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	only single technical parameter for some components/assets
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• based on definition of “normal” condition • backlog calculated only for drainage systems, lightning (only on some spots, urban areas, built up areas), crash fences and guard rails o draining system: backlog calculation is based on inspection in 2003; randomly detailed video system inspection; extrapolation for the whole network; repetition planned for 2009 to 2011 o lightning: backlog calculation is based on the need for upgrading due to new standards o guard rails and fences: backlog calculation is based on average lifetime and number of damages
If NO, comparable approach	-

4.1.2.6 Cross Asset Management and Budget Allocation (DK)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	• summation of the backlog of each component • included in Annual report
Allocation to components	• chief engineer in DRD (maintenance department) distributes the budget between the sub assets taking into account special requirements (last years distribution, strong arguments), not necessarily based on original backlog request • discussion about the use of output from management system with combined optimization procedure for distribution (common optimization of investments based on NPV, rate of return, VOC); more money went to the pavements but not all bridges were included, many of them were pre-decided; system was originally looking promising but operation only if enough money, method under development
Allocation to regions	• routine maintenance taken out of overall maintenance budget • rest distributed for “hard” maintenance works based on PMS (centrally), but also on internal balance between the regions; 1 year and 10 year prioritization

4.1.3 Finland

The interview in Finland was carried out with the Finnish Road Administration (FINNRA).

4.1.3.1 General (FI)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	700	
Other primary roads[2)]	YES		included in length of other roads
Other roads[3)]	YES	77'500	
Gravel roads	YES	(27'000)	included in other roads
	Total:	78'200	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	strategic place; split in 2 parts: head office and expert services
Regional offices	9	
Other units	-	

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	small measures, maintenance on gravel roads, winter maintenance, operational maintenance	YES	
Planned (major) maintenance	major maintenance activities and repairs	YES	
Improvement and extension	improving (functional) and widening	YES	

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• no network level pavement management system currently available • database is existing, including condition data and historical data (since 1994); oracle based (KURRE) • PMSpro: programming level PMS is available (similar to 2nd level of HDM)
Structure Management Systems	YES	module based system: Hanke-Siha (programming level system)
Management System for Road furniture	NO	
Asset Management System	NO	

4.1.3.2 Maintenance Backlog in General (FI)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• maintenance backlog is referred to assets / components which are in bad condition = class 1 or 2 (based on a classification scale from 5 = very good to 1= very bad) • maintenance backlog expressed in o monetary terms: costs of maintenance measures to bring up to “good” (normal) level; calculated annually; accumulation over time including not fulfilled needs from former years o non monetary backlog: length or number of assets (e.g. bridges) in class 1 and 2 • detailed investigation about the calculation of maintenance backlog [see paper Vesa Männistö at TRA 2006]
If NO, comparable approach	-

Use of maintenance backlog

Use	Description
General	• actual way of expressing the maintenance backlog is not efficient enough, should focus more on o user effects o economic effects o environmental effects • better marketing to compete with other sectors, big backlog in the whole public sector • not really successful at the moment (way today is too soft) • problem: connection of investments with effects (to users)
External use	• use for arguments against politicians and media • show the consequences of reduced budget (problem of understanding by public as long as condition is obviously good) o road user effects: higher transport costs, economic consequences, environmental consequences (noise, fuel consumption, air pollution, etc.); heavy tool: speed reduction; evaluate road user satisfaction o economic effects: increased depreciation if shorter life-cycle → financial consequence on budget; real estate definition (depending on the willingness of users to pay) versus technical definition (relation investment – maintenance) → more connections to users • general idea: road administration should not act as owner, has no influence • report from Finnish government to public to show the consequences (business accounting in administration, balance sheet, relation to asset value [e.g. asset value 15 billions €, backlog 1,4 billions €]) • show that maintenance creates local jobs • for explanation of maintenance needs to politician and media • studies and reporting all the time • must be done in connection with the question “what will happen if the money will not be spent into the assets?” • financing outside of the budget could be one effect • to display better the effect to close a road • more and more public of reporting • public conversation • comparison on international level: calculation process must be equal (problem) • monetary value has a limit in expressing maintenance backlog • improve the marketing
Internal use	• support • better marketing to compete internally with other sectors (assets) • to get reliable data • internal quality assessment

4.1.3.3 Sub-asset Pavement (FI)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection[1)]	network	3-4	automatic surface defect measurements: every 3-4 years on all single carriageway roads
Measurement	network	1 (3)	on main roads every year (high traffic) and on the other roads every 3 years
Other	-	-	

1).....includes inspection methods by using video/picture systems

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	rut depth	
Longitudinal evenness	• IRI • wavelength	
Friction (skid resistance)	texture	
Surface defects	-	under development
Cracking	cracking rate	under development
Bearing capacity	deflection	not measured routinously
Road geometry	• crossfall • curvature • radiant	
Other		

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	• assessment for different types of pavements o asphalt pavements o soft asphalt pavements (roads typically < 1000 AADT) o concrete pavements (only 10km of motorways) o gravel roads • lowest acceptable level (threshold) is between class 1 and 2
Indices	YES	transformation matrix for the transformation of the technical parameter into index based on o measurement specifications o traffic load (AADT) o speed (km/h)
Classification scale	YES	scale from 5 (very good) to 1 (very poor): very good – good – satisfactory – poor – very poor
Combined Indices	YES	combined indicator: minimum of the single (for each 100m section) = total condition index

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• based on general definition (backlog = sections in condition class 1 and 2) • calculated annually (if money available for backlog calculation) • beside condition indicators two additional values are taken into consideration o crossfall o fast deterioration • monetary value will be calculated as the sum of o maintenance need calculated in PMSpro o roads with bad crossfall and fast deterioration • backlog expressed in length (paved road in bad condition) and monetary terms • backlog not intended to go to 0 (a given percentage is accepted, because of deterioration additional sections reach backlog area)
If NO, comparable approach	-

4.1.3.4 Sub-asset Structures (FI)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges (span width from 2 up) • culverts (span width > 2 m, under 2 m it is drainage) • road on piles, covered (buried) bridges	
Tunnels	• constructed tunnels • mined tunnels	
Walls	retaining walls	
Others	piers and quays	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	5	defines also when the next inspection will be
Interim inspection	1	annual inspection
Other inspections	-	• basic inspection: more than general; on special bridges (125 reference bridge groups and large bridges), also for age-behaviour modelling • special inspection: if problems are detected or before repair planning • underwater inspection • intensified monitoring: bridge with weak bearing capacity, bridge close to the limit (every month); for postponement of renovation or reconstruction of bridges on main routes which cannot be closed; repeated every month

Performance indicators for structures

Category	in use	Description
Single indicators	YES	9 different sub-components (superstructure, pavement, edge beam, extensions joints, etc); sub-components are assessed
Combined indicators	YES	damage index: based on condition, 9 structural components, total condition index: complex function; calculated; every damage gets points and summarized (sum of damage points)
Other indicators	YES	• calculated overall condition distribution • condition class distribution (5=very good to 1=very bad)

Assessment of structures

Assessment	in use	Description
Indices	YES	sub-components are assessed
Classification scale	YES	• new scale: 5=very good to 1=very bad • old scale: 0=new to 4=very bad)
Combined indices	YES	• damage index • calculated overall condition distribution • condition class distribution

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• based on general definition (backlog = bridges in condition class 1 and 2) • sum of damage points = damage index • average of condition classes will be calculated (scale from 5 to 1) • number of bridges in bad condition are basis of maintenance backlog o maintenance backlog is referred to bridges which are in bad condition = class 1 or 2 (or 2.26 to 4.00; classification from 0 to 4) = bridges which do not fulfil the demands o expressed in monetary terms, calculated annually, also including not fulfilled needs from former years o non monetary backlog: number of bridges in poor or very poor condition
If NO, comparable approach	-

4.1.3.5 Sub-asset Road Furniture (FI)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• safety barriers • other protection systems	
Equipment	• traffic signs and signals • gantries • markings • lightning • fences (elk-fences)	
Others	• noise barriers • sidewalks, pedestrian ways (urban and extra urban) • rest and parking areas	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	in theory, no extensive inspection in practical use • traffic signs: visual inspection • guard rails: visual inspection • gantries

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	specific performance indicators defined for some components
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	YES	in theory
Classification scale	YES	assessment based on 5 to 1 scale
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• study in 2007 for road furniture (excl. road lightning, sep. study): backlog based either on performance requirements including cost effectiveness calculation (barriers) or on the service life • no regular calculation of backlog of equipment (esp. guardrails, noise barriers, fences) at the moment, but now urgent needs to plan for these renewals and repairs • in the general calculation of the total sum of maintenance backlog this backlog is not included at the moment • basis for future calculation will be the scaling from 5 to 1 as well (after collection of all the data)
If NO, comparable approach	-

4.1.3.6 Cross Asset Management and Budget Allocation (FI)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	sum of backlog of components (main is pavement and bridges)
Allocation to components	based on experiences; increase of maintenance importance of bridges
Allocation to regions	distribution to regions of maintenance and repair budget is based on the length, condition and the traffic volume

4.1.4 Norway

The interview in Norway was carried out with the Norwegian Public Roads Administration (NPRA – statens vegvesen SVV).

4.1.4.1 General (NO)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	300	main roads
Other primary roads[2)]	YES	8'600	main roads
Other roads[3)]	YES	18'400	secondary national roads
Gravel roads	NO	-	approx. 5'600 km of gravel roads (= county roads), not in the responsibility of SVV
	Total:	27'300	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	
Regional offices	5	
Other units	30	districts

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	routine maintenance and winter maintenance (main part)	YES	• area specific contracting; • 107 contracts (local district contracts)
Planned (major) maintenance	planned, systematic maintenance activities	YES	
Improvement and extension	new construction and rehabilitation (funded either by investment budget or maintenance budget, primarily from investment budget)	YES	

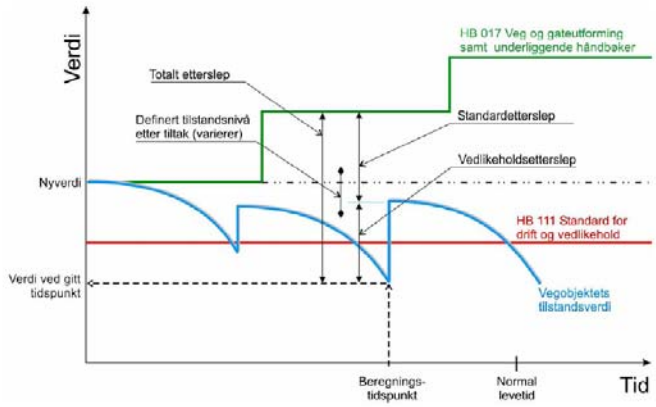
1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• PMS project level system (in house system) • network level management system (out-house-system, not used since 2007, replaced by simpler in-house procedure) • new centralized ORACLE-database to be finished in 2009 (PMS 2008)
Structure Management Systems	YES	database BRUTUS (for bridges) • 4 main parts: • separate military part • centralized database with online-connection to the regions (bridge inspector) • system “PLANIA” used for tunnels (mainly management of tunnel equipment)
Management System for Road furniture	YES	inventory in central national database
Asset Management System	NO	

4.1.4.2 Maintenance Backlog in General (NO)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	 • [Beregning av vedlikeholdsetterslep for riksvengettet (for national roads), 2003] = document which includes backlog definition • maintenance backlog for a road infrastructure component is the cost of bringing the condition of the component from its current condition to a defined condition level in such a way that it will fulfil its intended purpose for a normal life cycle period" (translated from Norwegian) • maintenance backlog has also been referred to as "neglected maintenance" (i.e. maintenance that should have been done for technical/economical reasons but that has been deferred) • maintenance backlog comprises more than upgrading to the minimum level; but to a “normal” standard, as referred to in the definition used. In practice this will vary between different objects. (It can be up to almost new condition equal to full service live, but not including any new demands or increased standard levels) • maintenance backlog is defined on monetary terms, represented by these section (components) which are below the lowest acceptable standard (sections which are above the minimum level are not taken into account) • standards: o definition of minimum requirements: official maintenance standard [Standard for drift og vedlikehold” (available www.vegvesen.no under handböker, number 111, from 2003)] o definition of normal level: basis for contracts for acceptance tests • maintenance backlog is objective measure for accumulated neglected maintenance that is comparable across asset types (when measured in monetary value) • in theory the calculated maintenance backlog represents the estimated accumulated need for funds to bring the road network up to a condition level that satisfies our defined Maintenance Standard levels
If NO, comparable approach	-

Use of maintenance backlog

Use	Description
General	used as arguments for budget levels (money). One disadvantage is that condition change can be masked by increased prices (Maintenance backlog calculated in monetary terms is a function of both condition and price level).
External use	• reporting and communication to policy level o department of transportation / ministry of transport: comparison of backlog from year to year (increase, same price level) o annual report, detailed to different assets updated on [Vegkapital 2003] o department of transportation in principle satisfied with using the term maintenance backlog, but have requested a review of the calculation procedures. • communication to interested public and press • National Transportation Plan: information to parliament, long term planning • media strategy • transfer of responsibility for main part of state roads to the counties has increased the political focus on maintenance backlog
Internal use	• limited internal use • not really used for benchmarking, only for general comparison • indirect use for change of distribution of money between investment and maintenance because of increasing maintenance budget (shown by the trend)

4.1.4.3 Sub-asset Pavement (NO)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	-	-	videos only for support / documentation, no evaluation of condition data (cracking, ravelling, etc.)
Measurement	network	1	
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	• rut depth • cross fall	
Longitudinal evenness	IRI	
Friction (skid resistance)	friction coefficient	not measured on a regular basis, but when suspected slippery conditions. Also for research purposes.
Surface defects	-	
Cracking	-	
Bearing capacity	deflection	just measurements on project level; not used for backlog definition
Road geometry	cross fall	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	• thresholds available and based on o measurement specifications o traffic (AADT) o road class (main or secondary) • if one single is under minimum level then the whole road is in "very poor" condition • indicators which are used and assessed for the definition of maintenance backlog: o Rutting o IRI
Indices	NO	
Classification scale	YES	• classification of single indicators based on 5 classes: very good, good, acceptable, poor, very poor • limits of classes defined subject to the indicator o rutting: class limits are 7 – 12 – 18 – 25 mm o IRI: class limits are 1,0 – 2,2 – 3,1 – 4,5 mm/m
Combined Indices	NO	

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• definition of maintenance backlog of pavements is based on general definition; but especially for pavements divided into two situations: 1. all pavement sections that have a condition level that is outside the defined threshold values in the Maintenance Standard is defined as having backlog; defined procedure for calculation [formulated as part of the "Vegkapital"-project (2003)] 2. for pavement sections with un-normally short expected pavement life: definition of a "road base"-related backlog which is calculated using specific procedures • generally only IRI and rutting are used for the calculation of maintenance backlog • backlog is sum of costs for all sections on network level which are below minimum level to be upgraded to “normal standard” • backlog calculated in detail only once: and the difference between the actual investments and the calculated maintenance needs has been added to the backlog for the following year(s) (accumulation)
If NO, comparable approach	-

4.1.4.4 Sub-asset Structures (NO)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges • culverts (> 2.4 m)	
Tunnels	• concrete tunnels and entrance sections (including submerged tunnels) • mined tunnels	
Walls	walls (> 4 m)	
Others		

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	5 (10)	every 10th year for smaller bridges (<10m)
Interim inspection	1 (2)	general inspection: 1 year interval (visual); every 2nd year for smaller bridges (<10m)
Other inspections	-	special inspections and cable inspections: if necessary from general inspections; detailed inspection up to re-calculation of bearing capacity

Performance indicators for structures

Category	in use	Description
Single indicators	YES	assessment of single components
Combined indicators	YES	combination for each part / component: combination of severity with consequence → 16 combinations subject to the type of bridge and the type of component described in the handbook
Other indicators	NO	

Assessment of structures

Assessment	in use	Description
Indices	YES	assessment for each single component • type of damage • severity from 1 to 4 (1 is small damage → do nothing); referred to time frame when something must be done • consequences (4 categories)
Classification scale	NO	
Combined indices	YES	overall / combined evaluation by complicated algorithm to one figure (indicator); defined for the whole construction; used only for general reports and overviews

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• the results of inspections, expressed by a number, which is related to a time frame for treatments (e.g. 3M = 1 to 3 years) forms the basis for the calculation of maintenance backlog • to calculate the costs (= maintenance backlog), unit prices are combined with the inspection number • philosophy of repair is the same as for pavements: repair to almost new condition, costs = backlog • replacement of bridge is investment and not a part of maintenance backlog
If NO, comparable approach	-

4.1.4.5 Sub-asset Road Furniture (NO)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• speed bumps • guard rails • crush cushions (buffers) • rope barriers	
Equipment	• traffic signs • guide posts • markings and reflectors • signalling systems and traffic signals • traffic mirrors • mile markers • lightning • marking lights • snow poles • animal fences	
Others	• height controls • management and monitoring systems • wind socks • cattle grids • noise barriers • shelters at bus stops • garbage cans • bicycle parking stands • indicators for handicapped persons	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	safety (visual) inspections are done by contractors, but no detailed condition inspection; functionality will be checked mainly

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	only single technical parameter for some components/assets (e.g. reflectivity)
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	no detailed backlog calculation, only general estimation: difference between estimated need for maintenance and real cost over some years (lifetime)
If NO, comparable approach	-

4.1.4.6 Cross Asset Management and Budget Allocation (NO)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	• overall backlog = sum of backlogs of single road components /assets [see report: “Beregning av vedlikeholdsetterslep for riksvegnettet, 2003”]; will not be repeated / updated before 2010/11 • model steering: including all different parts of assets; overall model = overall budget → contract between central department and regions
Allocation to components	region decides how much on each component should be spent; based on the experience in the last year plus a certain percentage
Allocation to regions	distribution of total budget according to “management by objectives”, based on requests from regions together with top down distribution

4.1.5 Sweden

The interview in Sweden was carried out with the Swedish Road Administration (SRA)

4.1.5.1 General (SE)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	1'700	
Other primary roads[2)]	YES	13'700	
Other roads[3)]	YES	82'900	
Gravel roads	YES	(20'000)	as a part of total network
	Total:	98'300	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	head office provides support for the Director-General in managing, prioritizing and following-up activities.
Regional offices	7	regions are responsible for road management on the state road network and have a sectoral responsibility for the road transport system in the regions
Other units	8	2 support and development divisions; 3 profit centres; 3 business divisions

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	routine maintenance, locally, measures with lifetime < 1 year	YES	
Planned (major) maintenance	maintenance measures with lifetime > 1 year	YES	
Improvement and extension	improved function = new road or improved road (improved geometry, width, bearing capacity, road equipment etc.)	YES	

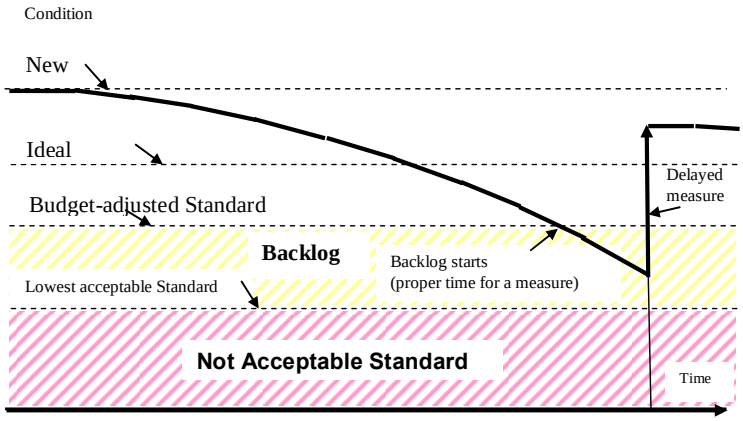
1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• database with all data of network level condition measurement available • PMS available, used for the calculation of maintenance backlog
Structure Management Systems	YES	• BATMAN system with centralized database • covers bridges, walls and noise barriers • tunnel with equipment: MAXIMO system, operational costs, work on daily level
Management System for Road furniture	NO	
Asset Management System	NO	

4.1.5.2 Maintenance Backlog in General (SE)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	if a threshold value of the standard is passed but no works are performed a backlog occurs. The value of the backlog is the cost of the optimal maintenance measure at the moment. The optimal maintenance measure is the first measure of the optimal maintenance strategy respecting the maintenance standard during the analysed time period and giving the lowest cost during the period.  maintenance Backlog for a road network can be expressed as • cost for all delayed maintenance at the moment • volume or percentage of the net below the threshold values (length, area)
If NO, comparable approach:	

Use of maintenance backlog

Use	Description
General	maintenance backlog is used for goal achievement based on actual value, estimation of annual cost of keeping status-quo and available budget. Then the result is compared to the goal and analysis is performed to explain the difference. In the same way, the internal effectiveness is calculated (special method available).
External use	• national network level management – external (in relation to the road owner and other stakeholders) o volumes and explanations of maintenance backlog are required/expected o consequences of maintenance backlog required/expected more and more o compare theoretical (objective, measured) condition with subjective impressions of road users o in relation to road owner, government and users o explain procedure or better explain the consequences to politicians and users, (describe the consequences of increased backlog to road users)
Internal use	• national network level management – internal (in relation between the Director General and regional units) o benchmarking of condition and internal effectiveness between regions, sub-networks, etc. o strong belief to use the sub-network condition for goal achievement and budget allocation o link to regional network level management, also based on benchmarking • regional network level management (in relation between the regional managers and their staff responsible for maintenance) [see national level] • project level (selection and prioritisation of projects and maintenance methods): maintenance backlog not relevant • functional contracts (in relation to the contractors, not implemented): o new road: no backlog allowed o existing road: no increase of backlog allowed o basis for penalties o in all cases a good description of the standard and the measurements necessary ! • benchmarking between different road administrations: level of backlog for financing discussions

4.1.5.3 Sub-asset Pavement (SE)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	-	
Measurement	network	1 - 5	according to the strategy 5 years on minor roads and each year on major roads. The regions added more measurements, average interval 2-3 years. One lane is considered to be representative for the full road width (except at motorways)
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	• rut depth • theoretical waterarea • edge drop • support shoulder (gravel outside pavement edge)	functional indicators
Longitudinal evenness	• IRI • local unevenness • longitudinal profile	functional indicators
Friction (skid resistance)	• friction coefficient • texture (MPD)	measured on demand if needed • Special measurement vehicle (high speed) • SRT, smaller areas (pedestrian areas, cycle paths, road markings)
Surface defects	megatexture	technical indicator
Cracking	-	
Bearing capacity	• rut area • yearly increase of longitudinal evenness • yearly increase of long. unevenness	technical indicators
Road geometry	cross fall	functional indicator
Other	drainage o ditches along o ditches from o culverts o side culverts o inner slope	technical indicators

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	requirements for functional and technical indicators defined subject to o characteristic (property) o measurement specifications o traffic (AADT) o speed (km/h)
Indices	NO	
Classification scale	NO	
Combined Indices	NO	

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• definition is based on general definition • maintenance backlog is estimated once a year, at the end of the year, using measurements and visual inspections performed during the year; routine maintenance is excluded • maintenance backlog is estimated for each condition variable; then it is summarized for the whole network, but there are rules to avoid duplication.
If NO, comparable approach:	

4.1.5.4 Sub-asset Structures (SE)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges	
Tunnels	• tunnels	
Walls	• retaining walls • noise barriers	
Others	-	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	6	inspection at least each 6th year, inspector decides about the time for the next inspection (max. 6 yrs), and for minor inspections
Interim inspection	1	
Other inspections	1/4	if condition = 3, detailed investigation within 3 months on necessary measure

Performance indicators for structures

Category	in use	Description
Single indicators	YES	assessment of single components (extension and severity); condition rating: scale from 0 to 3 o 0 measures > 10 years, structure in good condition o 2 = warning level o 3 = does not fulfil the requirements → detailed inspection → measures
Combined indicators	NO	
Other indicators	YES	Lack of Capital Value (LCV): o difference between expected and current economic condition of the bridge o expressed by the costs of those theoretical remedial measures necessary to restore the bridge to the expected economic condition (standardised appraisal of the defects) o LCV corresponds with backlog

Assessment of structures

Assessment	in use	Description
Indices	NO	
Classification scale	YES	0 = measures > 10 years, structure in good condition 2 = warning level 3 = does not fulfil the requirements → detailed inspection → measures
Combined indices	NO	

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• definition is based on general definition • maintenance backlog is estimated once a year, at the end of the year, using results of inspections performed during the year; routine maintenance is excluded • maintenance backlog is estimated for each condition variable; then it is summarized for each component type, but there are rules to avoid duplication.
If NO, comparable approach:	

4.1.5.5 Sub-asset Road Furniture (SE)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• guardrails • rope barriers	
Equipment	• road signs • lighting • road markings	
Others	• side area • rest areas • noise protection • animal fences	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	reflection measurements made in the test phase only

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	only single technical parameter for some components/assets (e.g. reflectivity)
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	YES
Application in practice	YES
Definition	• estimations of annual costs and backlog were made by a local engineer and a central engineer (each made twice) • backlog is rough estimation, no exact calculation like for pavements and structures • main problem: no clear standard available, thus exact calculation of backlog not possible
If NO, comparable approach	

4.1.5.6 Cross Asset Management and Budget Allocation (SE)

Monetary issues	Description and comments
Total budget	• information necessary and available of all 3 sectors (pavements, structures, furniture) → combination possible • normally a sum of all backlogs is taken
Allocation to components	• distribution of budget between bridges and roads: according to a special fixed key • if not enough money is available, internal prioritization rules are used (1. operations, 2. bridges and tunnels 3.road furniture, 4. pavements)
Allocation to regions	distribution of budget between regions: according existing key (based on volumes)

4.1.6 Switzerland

The interview in Switzerland was carried out with the Swiss Federal Roads Office (ASTRA).

4.1.6.1 General (CH)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	1'400	
Other primary roads[2)]	YES	300	
Other roads[3)]	YES	100	
Gravel roads	NO	-	
	Total:	1'800	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	
Regional offices	5	branches
Other units	-	

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	small maintenance measures	YES	winter maintenance; repairs (e.g. after accidents); grass cutting; etc. are operational activities
Planned (major) maintenance	planned maintenance activities, reconstructions	YES	defined in form of individual projects; in the responsibility of branches
Improvement and extension	• new construction (planning in central office) • extension: additional paved area	YES	

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• MISTRA = central information management system (under development) • will include PMS-module; prioritization based on manual assessment and evaluation; no optimization tool and no real LCC-analysis at the moment → next step (only on Canton level, VIAPMS™ in use)
Structure Management Systems	YES	• KUBA system for structures (centralized data base as a part of MISTRA) • different access-levels for different users • management module for bridges especially implemented • tunnels: EU-regulation applied; implementation into KUBA system at the moment
Management System for Road furniture	NO	planned: implementation of road furniture inventory into MISTRA system
Asset Management System	NO	

4.1.6.2 Maintenance Backlog in General (CH)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	• backlog could be based on maintenance targets (performance requirements) which are related to the condition distribution of the network: o certain percentage of road sections in very poor condition allowed, but also fixed percentages of road condition for other condition classes o could be basis for definition of maintenance backlog; if percentage is higher than fixed targets (performance requirements) → maintenance backlog • no monetary definition

Use of maintenance backlog

Use	Description
General	-
External use	• reporting and communication to ministry of transportation and parliament • performance contract between ASTRA and ministry of transportation / parliament: representation of actual condition
Internal use	benchmarking between branches

4.1.6.3 Sub-asset Pavement (CH)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	4	
Measurement	network	4	
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	rut depth	
Longitudinal evenness	slope variance	
Friction (skid resistance)	friction coefficient	SRM, Skiddometer, SCRIM
Surface defects	surface defects and repairs	individual indicators for different "families" of surface defects including patches and combination of all surface defects in a combined indicator
Cracking	cracking	see surface defects
Bearing capacity	deflection	no systematic measurement of bearing capacity
Road geometry	-	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	thresholds available and based on • measurement specifications • road category (transverse and longitudinal evenness) • measurement speed in km/h (friction) • design traffic category (bearing capacity)
Indices	YES	calculation of indices by using transformation functions
Classification scale	YES	scale from 0 (very good) to 5 (very poor)
Combined Indices	YES	combined index for surface defects, proposals for global indicators

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	theoretically: could be based on performance requirements (maintenance objectives); max. 5% in condition class 4 (poor); if more → maintenance backlog

4.1.6.4 Sub-asset Structures (CH)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges • culverts	
Tunnels	• constructed tunnels and galleries • mined tunnels	
Walls	• retaining walls • noise barriers	
Others		

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	5	
Interim inspection	2	
Other inspections	-	special inspections: after event or problem was detected during other inspection

Performance indicators for structures

Category	in use	Description
Single indicators	YES	assessment for each single component
Combined indicators	YES	total condition index; not calculated but given by the inspector
Other indicators	NO	

Assessment of structures

Assessment	in use	Description
Indices	YES	assessment for each single component
Classification scale	YES	scale from 1 to 5 (1 = good, 5 = very poor)
Combined indices	YES	total condition index; not calculated but given by the inspector

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	theoretically: could be based of performance requirements (maintenance objectives); max. 5% in condition class 4 (poor); if more → maintenance backlog

4.1.6.5 Sub-asset Road Furniture (CH)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• guard rails • other protection systems	
Equipment	• traffic signs • markings • lightning • fences	
Others	• monitoring systems • IT-equipment • noise barriers (height < 3 m)	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	

Performance indicators for road furniture

Category	in use	Description
Single indicators	NO	
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.6.6 Cross Asset Management and Budget Allocation (CH)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	the long term need of cross-asset optimisation is recognised; so far, however, the problem of distribution of budget to different assets / components has not been faced: • investments are based on fixed sections according to so called U-plan (including all aspects and components); distribution to components not necessary; no different pots for different assets • problems of U-plan o everything will be done at once, could be uneconomically o fixed sectioning
Allocation to components	-
Allocation to regions	-

4.1.7 United Kingdom

The interview in United Kingdom was carried out with Highways Agency (HA).

4.1.7.1 General (UK)

Description of the network (only in England, excluded Scotland, Northern Ireland and Wales)

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	3'000	
Other primary roads[2)]	YES	4'000	
Other roads[3)]	NO		
Gravel roads	NO		
	Total:	7'000	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	2	• network operation directorate: responsible for operation and for distribution of budget to regional offices, and controlling the MACs (managing agent contractor) • network services directorate (Netserve): setting the rules and standards, helps and provides advice to the network operation directorate
Regional offices	7	1 for 2 regions (14 regions in total)
Other units	-	

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	operational and cyclic maintenance	YES	
Planned (major) maintenance	planned maintenance; bigger repair and renewal	YES	
Improvement and extension	reconstruction and upgrading of existing roads	YES	

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• centralized database where all information is stored • PMS available; whole life cost model; “minimize cost analysis” to hold condition of road network above the “not acceptable” condition
Structure Management Systems	YES	• SMIS (Structures Management Information System) with centralized database • all types of structures included in the element list of SMIS • at the moment no deterioration model in use for structures, but the development of a corresponding procedure and software is planned; a related project is running [Highway Structures: Optimum Maintenance Strategies and Network Model] but no results yet available
Management System for Road furniture	NO	
Asset Management System	NO	

4.1.7.2 Maintenance Backlog in General (UK)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	• agency does not accept sections below “not acceptable” standard -> no backlog exists (see also standards) • only if below “not acceptable” than theoretical backlog

Use of maintenance backlog

Use	Description
General	-
External use	-
Internal use	-

4.1.7.3 Sub-asset Pavement (UK)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	1	
Measurement	network	1	
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	rut depth	
Longitudinal evenness	IRI	
Friction (skid resistance)	• friction coefficient (SCRIM) • texture: MPD	
Surface defects	fretting (ravelling)	
Cracking	cracking rate	
Bearing capacity	-	
Road geometry	-	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	• thresholds available and based on o function o traffic volume o etc. • only the percentage of sections below thresholds will be used to report the condition of the network
Indices	NO	
Classification scale	NO	
Combined Indices	NO	

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.7.4 Sub-asset Structures (UK)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges • large culverts • small structures / culverts(> 900 mm diameter))	culverts < 900 mm belong to drainage
Tunnels	tunnels	
Walls	retaining walls	
Others	• high masts • gantries	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	6	principal inspection every 6 years, touching distance
Interim inspection	2	general inspection every 2 years, visual
Other inspections	-	• special inspection if earlier inspections showed problems or if a structural assessment is necessary (severe deterioration, increase of loads, change of use, etc.) • additional inspections for specific problems (e.g. ASR, suspension corrosion, local hit of bridge by a lorry etc.)

Performance indicators for structures

Category	in use	Description
Single indicators	YES	assessment of components; list of 40 components in database (for all structures) and assessed as relevant as condition indicators on network level
Combined indicators	YES	then combined to overall condition index within a scale from 0 – 100 (network level); based on complex algorithm
Other indicators	NO	

Assessment of structures

Assessment	in use	Description
Indices	YES	• assessment for each single component • allocation of defects according to o severity 1 – 5 o extent A -E o cause of defect
Classification scale	YES	scale from 0 – 100 (network level)
Combined indices	YES	overall condition index with a scale from 0 – 100 (network level); based on complex algorithm

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.7.5 Sub-asset Road Furniture (UK)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• guard rails • concrete barriers	
Equipment	• lightning • traffic signs • ITS equipments	
Others	• earthworks/geotechniques • drainage • noise barriers • retaining systems • tree planting	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	control by MACs in the context of routine maintenance

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	traffic signs: reflectivity measured or estimated by MACs
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	YES	requirements stated in maintenance contracts
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.7.6 Cross Asset Management and Budget Allocation (UK)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	request for budget at government made by HA based on annual bids from regions for 2-3 years
Allocation to components	• extra budget for roads and structures • no fixed distribution-key between different assets/components
Allocation to regions	distribution to different budgets and the regions by value management guidance (scores for different options of schemes), top down approach taking into account bottom up requests as well

4.1.8 Germany

The interview in Germany was carried out with the German Federal Ministry of Transport, Building and Urban Affairs (BMVBS).

4.1.8.1 General (DE)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	12'600	
Other primary roads[2)]	YES	41'000	federal highways
Other roads[3)]	NO	-	
Gravel roads	NO	-	
	Total:	53'600	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	BMVBS: responsibility for financing and maintenance
Regional offices	16	16 federal states are partners in the context of maintenance of federal trunk road network; 3 administrative levels: • state ministry • intermediate authority (state authority) • building authority
Other units	-	

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	small maintenance measures in the context of operation	NO	
Planned (major) maintenance	planned maintenance activities	YES	
Improvement and extension	• extension: increase of capacity (+1 addition lane); new construction budget with portion of maintenance budget • improvement: without increase of capacity; distribution of costs between new construction and maintenance budget	YES	

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• VIAPMS™ analytical pavement management software in pilot phase for more than 10 years • OKSTRA database holds all the maintenance relevant data
Structure Management Systems	YES	• SIB-Bauwerke: database for all type of structures which includes: o inventory o condition data of inspections • BMS: bridge management system under development o allocation of measures to the different component groups o complex algorithm for the combination of different treatments on different components o includes performance prediction models o assessment of different strategies
Management System for Road furniture	NO	
Asset Management System	NO	

4.1.8.2 Maintenance Backlog in General (DE)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• according to "Federal Transport Infrastructure Plan 2003" maintenance backlog is the money to be invested over a longer time period to reach the maintenance objectives: o improvement of condition o stable network o uniform condition level over the whole network (at the moment no homogeneous condition over the whole network because of history) • comparison of target and actual results is the basis for the calculation of the maintenance backlog; to reach the objectives an increase of investments is necessary → amount to be increased = maintenance backlog • maintenance backlog calculation is based on calculation of different sub-assets: o pavement: PMS-analysis with VIAPMS™, including performance prediction and LCC-analysis; basis was year 2000 with the condition distribution of functional and structural index in different classes; objective is based on improvement of condition o structures: statistical analysis of life span of different bridges and/or bridge components o road furniture: engineering judgement and experiences
If NO, comparable approach	-

Use of maintenance backlog

Use	Description
General	-
External use	• acquisition of additional budget for maintenance • justification financial resources required; basis for “Federal Transport Infrastructure Plan 2003”
Internal use	• argumentation towards new construction • distribution of maintenance budget between federal states; at the moment “Brandenburg key” which is based mainly on length and traffic volume

4.1.8.3 Sub-asset Pavement (DE)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	4	video system and manual assessment afterwards
Measurement	network	4	
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	• rut depth • water depth	
Longitudinal evenness	AUN-value based on wave-spectrum	
Friction (skid resistance)	friction coefficient (SCRIM/SKM)	
Surface defects	• patching on asphalt pavements: images/videos → defect rate • corner breaks and joint damages on rigid pavements: images/videos → severity and frequency of distressed concrete slabs	
Cracking	images/videos → defect rate	
Bearing capacity	-	
Road geometry	-	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	thresholds for each single indicator available and based on the functionality of the road (function class) or on the measuring speed (skid resistance)
Indices	YES	each technical parameter is transformed to an index
Classification scale	YES	index scale from 1 (very good) to 5 (very poor)
Combined Indices	YES	• combined indicators o functional index (comfort and safety) o structural index o total condition index • complex combination algorithm based on brake-down rule and weights

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	maintenance backlog is defined as additional investments to reach objectives in form of a better condition distribution over a certain time period
If NO, comparable approach	-

4.1.8.4 Sub-asset Structures (DE)

Categorisation of structures

Group	Type	Comments
Bridges	bridges	
Tunnels	• tunnel • troughs	
Walls	• retaining structures • noise barriers	
Others	gantries	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	6	
Interim inspection	2	
Other inspections	-	special inspections in case of special problem or because of security reasons

Performance indicators for structures

Category	in use	Description
Single indicators	YES	• assessment of single components based on the collected distresses during inspection • 3 characteristics are used for assessment: o stability o safety o durability
Combined indicators	YES	• component groups: the assessment of single components is summarized to component group; number of damages and the type of damages on each single component is taken into consideration • total condition index: complex algorithm; result is note from 1 (very good) to 4 (closure of bridge)
Other indicators	NO	-

Assessment of structures

Assessment	in use	Description
Indices	YES	for each single component the characteristics will be combined with an index from 0 (no damage, very good) to 4 (very poor)
Classification scale	YES	index from 0 (no damage, very good) to 4 (very poor)
Combined indices	YES	• component groups: the assessment of single components will be summarized to component group • total condition index: complex algorithm; result is note from 1 (very good) to 4 (closure of bridge)

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	YES
Application in practice	YES
If YES, definition	• maintenance backlog is defined as additional investments to reach objectives in form of a better condition distribution over a certain time period • basis is statistical evaluation of service life of different structures (components)
If NO, comparable approach	-

4.1.8.5 Sub-asset Road Furniture (DE)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• guard rails • concrete barriers • etc.	
Equipment	• traffic signs • lightning • etc.	
Others	• drainage • soil and subbase • planting • culverts • others	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	during safety inspections function of road furniture is checked

Performance indicators for road furniture

Category	in use	Description
Single indicators	NO	
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.8.6 Cross Asset Management and Budget Allocation (DE)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	sum of all assets
Allocation to components	distribution of maintenance budget between different components • pavement : structures : road furniture = 60 : 30 : 10 • no fixed key, only rough estimation
Allocation to regions	distribution of budget between federal states: • Brandenburg key • based mainly on length and traffic volume

4.1.9 Slovenia

The interview in Slovenia was carried out with the Slovenian Motorway Company (DARS).

4.1.9.1 General (SI)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	500	
Other primary roads[2)]	NO	-	
Other roads[3)]	NO	-	
Gravel roads	NO	-	
	Total:	500	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	
Regional offices	8	regional offices for routine maintenance activities
Other units	-	

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	routine maintenance (small measures) and winter maintenance by regional offices	NO	
Planned (major) maintenance	planned, systematic maintenance activities	YES	
Improvement and extension	• improvement financed from the maintenance budget: activities on motorways which already exists (new noise barriers, ventilation in tunnel, etc.) • new construction budget: for new roads only	YES	

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	• state database o inventory o online application o updated annually • VIAPMS™ = PMS o analytical pavement management software o LCC-analysis with performance prediction and optimization (best condition under given budgetary constraints)
Structure Management Systems	YES	State database • inventory of all structures • inspection reports not in the database, only hardcopies available • no database or managing system available
Management System for Road furniture	YES	inventory available in state database (traffic signs, animal fences, safety barriers) but no condition
Asset Management System	NO	

4.1.9.2 Maintenance Backlog in General (SI)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	• possible definition from DARS: amount of money which would be needed in a certain time period to ensure that the condition of network is out of poor and very poor condition • maintenance backlog could be expressed by o length or areas or components in poor and very poor condition o the needed budget to execute the maintenance activities to bring the condition to a “normal level” in a certain time frame • additional backlog definition: additional investments because of an increase of requirements according new or higher EU-regulations (safety barriers, tunnels, etc.)

Use of maintenance backlog

Use	Description
General	-
External use	• to get more money from the ministry • not used for public affairs: negative consequences because of vignette
Internal use	• no use because of no competition in the organisation (1 central office) → no benchmarking • only for distribution of budget to different assets/components

4.1.9.3 Sub-asset Pavement (SI)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	2	
Measurement	network	2	
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	rut depth	
Longitudinal evenness	IRI	
Friction (skid resistance)	• friction coefficient (SCRIM) • texture (MPD)	
Surface defects	• ravelling • potholes • patching • deformation	
Cracking	cracks	
Bearing capacity	-	
Road geometry	-	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	• thresholds (technical specifications) available for the following performance indicators: o rutting: rut depth under 2m straight edge o longitudinal evenness: IRI o skid resistance: SCRIM o texture o bearing capacity: no measurements available at the moment, but assessment possible • thresholds available and based on o traffic (rutting, MSI – Modified Swiss Index) o speed (only texture)
Indices	YES	calculation of indices by using transformation functions
Classification scale	YES	assessment scale from 0 to 5: 0 to 1 (very good),…4 to 5 (very poor)
Combined Indices	YES	• combined indicators o functional index (comfort and safety index) o structural index o total condition index • complex combination algorithm based on brake-down rule and weights

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	• theoretical definition of maintenance backlog in PMS (VIAPMS^{TM}): length of sections in poor and very poor condition; expressed as physical value • possible definition: amount of money which would be needed in a certain time period to ensure that the condition of network is out of poor and very poor condition

4.1.9.4 Sub-asset Structures (SI)

Categorisation of structures

Group	Type	Comments
Bridges	bridges (3 categories)	
Tunnels	• tunnels • galleries	
Walls	retaining walls	
Others		

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	6	
Interim inspection	2	Regular inspection: every 3rd regular inspection is main inspection
Other inspections	-	• seasonal inspection: twice a year (by routine maintenance staff) • special inspections: accidents, problems, etc.

Performance indicators for structures

Category	in use	Description
Single indicators	YES	assessment based on 4 main components
Combined indicators	YES	total condition value: sum of 4 components
Other indicators	NO	

Assessment of structures

Assessment	in use	Description
Indices	YES	point system: from 0 to “unlimited”; assessment of single distresses and product of distresses on single component gives a certain amount of points -> summarized to the 4 main components
Classification scale	NO	
Combined indices	YES	total condition value: sum of 4 components

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.9.5 Sub-asset Road Furniture (SI)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	safety barriers	
Equipment	• traffic signs • lightning • markings • tunnel equipment • SOS-system	
Others	• noise barriers • monitoring system • animal fences	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	safety inspections (3 times per day)

Performance indicators for road furniture

Category	in use	Description
Single indicators	NO	
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	NO	
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.9.6 Cross Asset Management and Budget Allocation (SI)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	-
Allocation to components	• no universal distribution key in use • each year individual decision according to the condition of the different assets • each year every asset/component gets an certain amount of money • quite small network → individual decision every year
Allocation to regions	-

4.1.10 Concession Motorway DirectRoute (Fermoy) Ltd.

The interview for this concession (C1) was carried out with DirectRoute managing director.

4.1.10.1 General (C1)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	17.5	concession
Other primary roads[2)]	NO	-	
Other roads[3)]	NO	-	
Gravel roads	NO	-	
	Total:	17.5	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	Concessionaire: DirectRoute (Fermoy) Ltd (STRABAG is partner of DirectRoute)
Regional offices	1	Responsibility for operation and maintenance: Lagan Maintenance Ltd.
Other units	-	

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	small maintenance measures (crack sealing, filling of potholes, etc.), winter maintenance	NO	exact definition by the contract
Planned (major) maintenance	planned maintenance activities, by order of DirectRoute	YES	exact definition by the contract
Improvement and extension	-	-	no improvement or reconstruction during concession phase planned,

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	PMS application is obligatory for the concessionaire
Structure Management Systems	YES	Structure management system is obligatory for the concessionaire: EIRSPAN system and regulations
Management System for Road furniture	NO	
Asset Management System	YES	cost centre accounting of all activities; RMMS (road maintenance management system)

4.1.10.2 Maintenance Backlog in General (C1)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

Use of maintenance backlog

Use	Description
General	-
External use	-
Internal use	-

4.1.10.3 Sub-asset Pavement (C1)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	network	4	
Measurement	network	1 - 4	interval subject to indicator and lane
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	Rut depth	
Longitudinal evenness	IRI	
Friction (skid resistance)	• Skid resistance: SCRIM • Texture: MPD	
Surface defects	Spalling: defect rate	
Cracking	Cracking rate	
Bearing capacity	Deflection: FWD	
Road geometry	Cross fall	
Other	-	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	• assessment of each single indicator • thresholds are stated in the contract o requirements during concession phase o handback requirements; stronger than requirements during concession phase
Indices	NO	
Classification scale	NO	
Combined Indices	NO	

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.10.4 Sub-asset Structures (C1)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges • viaduct (450 m) • culverts (> 2.4 m)	
Tunnels	-	no tunnels
Walls	protection fences against rock fall	
Others	-	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	6	principal inspection: every six years
Interim inspection	1/52	routine inspections: weekly
Other inspections	-	special inspection: after event or problem was detected during other inspection

Performance indicators for structures

Category	in use	Description
Single indicators	YES	• assessment of single components • EIRSPAN defect/damage ranking is basis for the condition assessment
Combined indicators	NO	-
Other indicators	NO	-

Assessment of structures

Assessment	in use	Description
Indices	YES	• assessment for each single component • EIRSPAN defect/damage ranking is basis for the condition assessment
Classification scale	YES	Ranking rate from 0 (as new) to 5 (= highly serious) → action with given time frame for the completion of repair
Combined indices	NO	-

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.10.5 Sub-asset Road Furniture (C1)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• guardrails	
Equipment	• lightning: interchanges and toll plaza • cat eyes and markings • traffic signs • Gantries	
Others	• border fences • noise barriers • IT-equipments	only absorbing types

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	• during safety inspections (safety patrol) condition and/or function of road furniture is checked • no periodical condition survey

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	reflectivity of markings and traffic signs
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	YES	• functionality defined • performance requirement fixed in contract
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.10.6 Cross Asset Management and Budget Allocation (C1)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	• monthly maintenance plan: description of all maintenance works which were carried out during the last month and forecast for the next month • annual maintenance plan: includes all maintenance activities for the coming year for all assets and components • 5 years maintenance concept for major maintenance activities must be provided to the client • neither annual maintenance plan nor 5 years maintenance concept must include cost and cost distribution to the components or assets
Allocation to components	-
Allocation to regions	-

4.1.11 Concession motorway M6-Duna

The interview for this concession (C2) was carried out with M6-Duna partner PORR Construction Company.

4.1.11.1 General (C2)

Description of the network

Road type	Responsibility	Length [km]	Comment
Motorways[1)]	YES	60	concession
Other primary roads[2)]	NO	-	
Other roads[3)]	NO	-	
Gravel roads	NO	-	
	Total:	60	

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

Organisation

Unit	# of units	Comment
Head (central) office	1	concessionaire: M6-Duna (PORR is partner of M6-Duna)
Regional offices	1	responsibility for operation and maintenance: Intertoll operation company
Other units	-	

Definition of road maintenance activities

Category	Description	Outsourced[1)]	Comment
Routine maintenance	small maintenance measures in the context of operation	NO	exact definition by the contract
Planned (major) maintenance	planned maintenance activities	YES	exact definition by the contract
Improvement and extension	-	-	no improvement or reconstruction during concession phase planned,

1).....Execution of activity but not planning!

Management Systems

Assessment	in use	Description
Pavement Management System	YES	PMS application is obligatory for the concessionaire
Structure Management Systems	YES	structure management system is obligatory for the concessionaire
Management System for Road furniture	NO	
Asset Management System	NO	

4.1.11.2 Maintenance Backlog in General (C2)

Definition of maintenance backlog in general

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	backlog could be based on the fixed requirements (performance standards) in the contract: • expressed by time: time period from knowledge that one or more performance standards are not fulfilled until maintenance measure; reaction time is fixed in the contract • expressed by unfulfilled demands (contract point of view): concessionaire does not fulfil the requirements → consequences are penalty points = backlog; if concessionaire exceeds certain amount of penalty points (for the whole concession, not limited to single asset) → reduction of payment (availability fee); catalogue of penalty points in combination with monetary losses for the whole infrastructure is basis

Use of maintenance backlog

Use	Description
General	
External use	
Internal use	• assessment of the most economical way of maintenance • comparison of different concessions (benchmarking) • basis for internal back calculation

4.1.11.3 Sub-asset Pavement (C2)

Condition surveys of pavements

Type of survey	Level	Interval [years]	Comments
Visual inspection	-	-	
Measurement	network	1 - 5	interval depending on indicator
Other	-	-	

Performance indicators for road pavements

Indicator	Technical Parameter	Comments
Transverse evenness	rut depth	
Longitudinal evenness	IRI	
Friction (skid resistance)	friction coefficient (SCRIM)	
Surface defects	-	
Cracking	-	
Bearing capacity	deflection (FWD)	
Road geometry	-	
Other	cross fall	

Assessment of pavements

Assessment	in use	Description
Thresholds of indicators	YES	• assessment of each single indicator • thresholds are stated in the contract o requirements during concession phase o handback requirements; stronger than requirements during concession phase (e.g. age of wearing course not higher than 3 years)
Indices	NO	
Classification scale	NO	
Combined Indices	NO	

Definition of maintenance backlog for pavements

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.11.4 Sub-asset Structures (C2)

Categorisation of structures

Group	Type	Comments
Bridges	• bridges • culverts (> 2.4 m)	
Tunnels	-	no tunnels
Walls	-	no walls
Others	• drainage systems • operation base	

Condition inspection of structures

Type of inspection	Interval [years]	Comments
Main inspection	1	defined in the contract
Interim inspection	-	
Other inspections	-	special inspection: after event or problem was detected during other inspection

Performance indicators for structures

Category	in use	Description
Single indicators	YES	assessment of single components
Combined indicators	NO	-
Other indicators	NO	-

Assessment of structures

Assessment	in use	Description
Indices	YES	assessment for each single component
Classification scale	NO	scale from 0 to 5 (1 = good, 5 = very poor) and urgency class in 3 levels (V = immediately, S = urgent; H = during the next 2 years)
Combined indices	NO	-

Definition of maintenance backlog for structures

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.11.5 Sub-asset Road Furniture (C2)

Categorisation of road furniture

Group	Types included	Comments
Protection systems	• safety barriers • crush cushions (buffers)	
Equipment	• lightning: on rest areas and operation basis only • markings • traffic signs • mile posts • handrails	
Others	• border fences • IT-equipments	

Condition inspection of road furniture

Type of inspection	Interval [years]	Comments
Main inspection	-	
Interim inspection	-	
Other inspections	-	• during safety inspections (safety patrol) condition and/or function of road furniture is checked • no periodical condition survey

Performance indicators for road furniture

Category	in use	Description
Single indicators	YES	reflectivity of markings and traffic signs
Combined indicators	NO	
Other indicators	NO	

Assessment of road furniture

Assessment	in use	Description
Thresholds	YES	• functionality defined (e.g. 95% of lamps must work) • performance requirement fixed in contract
Indices	NO	
Classification scale	NO	
Combined indices	NO	

Definition of maintenance backlog for road furniture

Information	Description and comments
Definition available	NO
Application in practice	NO
If YES, definition	-
If NO, comparable approach	-

4.1.11.6 Cross Asset Management and Budget Allocation (C2)

Monetary issues and budget allocation

Monetary issues	Description and comments
Total budget	• Annual maintenance plan: includes all maintenance activities for the coming year for all assets and components • 5 years maintenance concept for major maintenance activities must be provided to the client • Neither annual maintenance plan nor 5 years maintenance concept must include cost and cost distribution to the components or assets
Allocation to components	-
Allocation to regions	-

4.2 Investigation on Literature and Projects

4.2.1 General Investigation

The following chapter describes the limited analysis of literature and projects available in terms of given definitions and state of the art of the use of maintenance backlog. It was agreed from the beginning of the project to restrict this research on the most recognised conferences for experts in pavement and asset management:

- TRA 2006, Göteborg, Sweden
- EPAM3 2008, Coimbra, Portugal
- TRA 2008, Ljubljana, Slovenia
- ICMPA 2008, Calgary, Canada

There have been contributions from Sweden [2], Denmark [3], Norway [4] and Finland [5] in one of the conferences listed above that focused on the term “maintenance backlog”. But unfortunately, a discussion about this topic could not be found in many other publications Therefore it was decided to check also the annual TRB meetings (Transportation Research Board of the National Academy - Washington D.C., USA) of the years 2004 to 2009 to get additional information.

Table 2 Conference papers dealing with the term of maintenance backlog

Conference	No. of analysed papers	Papers concerning maintenance	Papers concerning the term of backlog	
			Use of the term in the paper	definition available for maintenance backlog
TRA 2006 (Europe)	203	71	2	1
TRA 2008 (Europe)	350	119	2	0
EPAM3 2008 (Europe)	80	58	6	3
ICMPA 2008 (Canada)	104	95	13	3
TRB 2004 (US)	1507	542	7	1
TRB 2005 (US)	1620	522	17	2
TRB 2006 (US)	1713	506	12	0
TRB 2007 (US)	1861	587	11	2
TRB 2008 (US)	1765	527	10	3
TRB 2009 (US)	2011	564	10	1
TOTAL	11214	3591	90	16

In the table 2 above, it can be seen that out of the 90 papers referencing to ‘maintenance backlog’ only 16 are giving a definition of this term. Many authors used it only to emphasize the monetary value but did not go in more details on this.

Besides all those contributions on international conferences in Europe and North-America, additional information published on the web pages of the different road authorities (national and some provincial authorities) were checked. In table 3 below, a few of their references, standards or recommendations were listed. Regarding the information collected from UK or Swiss authorities, this is gathered from different sources than interviewed for the report (see chapter 4.1). This information is from county respectively cantonal web pages. Unsurprisingly, their use of the term maintenance backlog is different from the information

which were collected during the interviews at the central road administrations.

Table 3 Road network information (type, length) of other evaluated sources

Country	Road network information	
	Road network type	**Length** [km]
Mississippi (MDOT) [1)]	Interstates	1176
	Principal Arterials	4039
	Other	12345
Nevada (NDOT) [2)]	National Highway System	3421
	Surface Transportation Program	4847
	Other Improved	570
City of Portland [3)]	Local	1931
UK Counties	Various levels, no national highway	not specified
Canton Graubünden Switzerland [4)]	Main roads	597
	Collectors	835
Standard for cities and towns in Switzerland	Main roads	Not specified
	Collectors	Not specified
	Estate roads	Not specified

1)…Mississippi's Unified Long-range Transportation Infrastructure Plan, 2007
2)...State of Nevada Transportation Facts and Figures, 1999
3)…http://www.portlandonline.com/transportation/index.cfm?&a=83397&c=35714, am 30.03.2009
4)…http://www.tiefbauamt.gr.ch/strassennetz/index.htm, am 30.03.2009

4.2.2 Overview of Application

Generally, it could be recognised that the use of the term "maintenance backlog" and its importance are increasing over the last years.

In the maintenance of road infrastructure asset of communities [6], on regional or even on state level [7] (Departments of Transportation, DoT) the implementation of asset management process is an ongoing activity in North America and in Europe as well.

Maintenance backlog is used on budged level to assess the effects of different budget scenarios on the changes of the maintenance backlog over time [4]: Was the budget sufficient to maintain the current condition of the road network or will the backlog being larger? Is there any need to increase the budget for the next periods to avoid such an increase of the maintenance backlog?

The term "maintenance backlog" was already used in the 1980s in Northern America for pavement management reasons and thus implemented in different management software products for example such as dTIMS [8] or HDM 4 [9]. n 2001 the American Association of State Highway and Transportation Officials (AASTHO) published a "Pavement Management Guide" [10] for the US Department of Transportations (DOTs), which was an extract of basics, methods and terms used in the context of managing pavements. In this guide the term maintenance backlog is used several times but there is no exact definition. The term refers mainly to the condition of the pavement (below a certain defined level) and not to monetary values. The budget required to increase the overall condition of the road network is primarily described as "fund needs" or "maintenance needs".

With the idea of total asset management, additional road assets such as bridges, tunnels or road furniture were added to the pavement management processes or systems to give the responsible managers multi-asset based network information.

One of the most recent activities to define the term of "maintenance backlog" come from Scandinavia, particularly from Sweden (see [40] and [41]). Although some of the literature

was only available in a draft version the most recent information is included in the conclusions and recommendations (see chapter 6).

In summary, a common definition of the term “maintenance backlog” could not be found in the investigated literature. However, the following chapter gives an overview of possible definitions and approaches which are available. To which extent this definitions are used in practice or in theory was not investigated in detail.

4.2.3 Expression of Maintenance Backlog

Generally there are two different ways to express the maintenance backlog:

1. Physical (non-monetary) value
2. Monetary value

DARS, the motorway company of Slovenia, who is responsible for building and maintaining the motorway network decided in 2002 to implement a Road Management System (RMS) for their motorway network. With the implementation of the management software VIAPMS™ the backlog is expressed by the physical value length [km] by summing road segments in condition classes “poor” and “very poor” into length of backlog [11].

On the other hand it is also possible to use the length of roads in backlog for each funding scenario for a number of different time periods to show the cumulative investment and the resulting in a Remaining Work Report [12].

A similar approach to express backlog for maintenance management reasons is found at the City of Portland in Oregon (USA). The local road engineers are cumulating the length of all known sections in fair, poor, or very poor condition, through rating done visually [13].

In the maintenance management of structures there are different tools available as well. In Hungary the American PONTIS system was adapted to set up a bridge management system based on mathematical optimisation. The decisive parameters for the optimum, cost-effective bridge maintenance-rehabilitation were analysed on the Hungarian highway bridge stock. With an optimisation method considering the condition distribution, deterioration process and intervention cost need of bridge elements defined in this bridge management system (PONTIS-H) it is possible to define a specific backlog. In this case the deviation from the optimal condition distribution describes the backlog in the bridge network [14].

These examples show that it is necessary to define certain thresholds of indicators for the different condition classes or a minimum condition standard. For this reason internationally accepted performance indicators [1] have to be defined for the road network and its assets.

Of course the maintenance backlog expressed by a physical value is not a monetary term. But it can be preliminarily calculated to get a monetary value in a next step. This is already expressed in some of the following definitions.

In 1987 in the US the Pavement Management Forecasting Model [15] was used to calculate maintenance backlog as the $- amount which would improve all roads to excellent condition in a given time. This very basic use of the term includes the input of pavement conditions as well as the costs for road maintenance and construction.

Another approach is to define a certain service level for the road network. The Department of Transportation of the state Nevada (US) determines its backlog computing the costs to

improve the defined assets to good condition (roads, bridges) [16]. However, if there is no common definition of a specified service level and the assets included of the network it will not be possible to compare the calculated backlogs [17].

Strategic management by road owners requires a limited number of representative measures. In the SRA, two aggregated measures are presently used for the road maintenance. Development ("performance") of the road network condition is monitored using the measure "Maintenance backlog" expressed in monetary terms. Development of the maintenance itself is monitored using the measure "Effectiveness" [2] (see chapter 4.1.7).

The Norfolk County in the UK defines backlog as the cost of maintenance work required to bring the condition of the asset up to the agreed service level. Any negative movement against the service level will be considered a backlog and this is demonstrated by the difference in the cost of carrying out the UKPMS treatments [18]. To address this service level agreement (SLA) or level of service (LOS) for each road asset of the network different thresholds have to be defined. Another way is to define LOS classes in combination with performance indicators, which was carried in North Carolina [19].

However the service level to be agreed is depending on available influences to be considered. These can be agency requirements as well as road user needs or environmental influences. In Denmark maintenance backlog is calculated as the difference between the present condition level of the road network and the financial resources required to restore it to standard condition defined by the Danish Road Directorate [20] (see chapter 4.1.3). The same could be realized in Stirling Council calculating backlog, based on returning the network to a Scottish average condition [21].

Compared to the use of LOS there are other possibilities to define backlog. Two additional definitions mentioned in the Audit Scotland Report [22] for road maintenance backlog should be shortly described. Backlog can be defined as:

- the cost of improving the condition of the roads network to a 'steady state' where a fixed percentage of the network (around 8%) requires maintenance each year (no complete backlog clearing)
- applying an average unit cost to the length of the road network needing repair (rough approximation for linking conditions to maintenance costs)

The different maintenance backlog definitions also include items other than the pavements (e.g. footways, street lighting, drainage, bridges and traffic signals). The simplest method of taking into account these items is by multiplying the road maintenance backlog by a factor representing the relative weight of these items compared to that of the road pavement.

Different methods of calculating the backlog can lead to widely differing results. This means it is important that the methodology adopted is widely accepted and provides a consistent measure of the backlog" [22].

In 2005 in the United Kingdom a slightly different definition was added: Backlog is the work needed to arrest deterioration and restore the network to a pre-defined condition, which is then maintained at a steady state [23]. In comparison with chapter 4.1.6 the different counties in the UK are already using this definition of backlog for the UK wide county benchmarks and management reasons. But as mentioned this is not valid for the national highway agencies.

Another more sophisticated way is the calculation of measures to clear the existing backlog as an In-year Asset Consumption and Renewal as shown in Figure 1. The backlog is defined as the gap between the actual Accumulated Asset Consumption and the Accumulated Annual Expenditure.

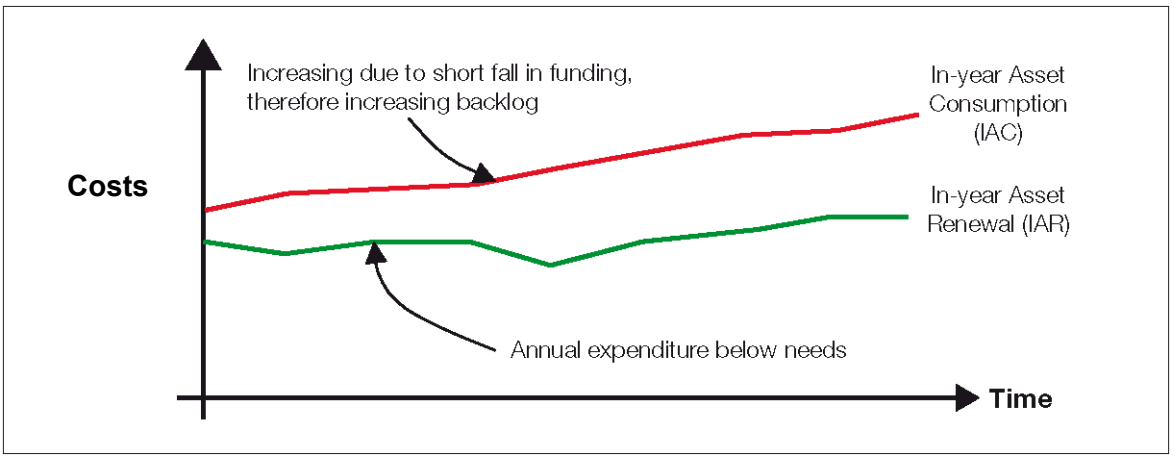


Figure 1 Increase of backlog due to deficient funding for maintenance measures according to [25]

In Switzerland this is standardised for pavements of communal road networks but by using a linear approach for depreciation of pavement in different road categories located in cities and towns [24]. In the United Kingdom a guidance document [25] shows the calculation for roads, segregated footpaths & cycle routes, structures, highway lighting and high mast lighting, land associated with the highway, other highway assets.

Another approach is the Norwegian method which was reviewed amongst others by Mannistö, et al [5]. Backlog for pavements is divided into two components: structural and functional backlog. Backlog is defined as a cost of maintenance and rehabilitation of all road segments exceeding threshold values in the pavement management system and including bridges and gravel roads [5].

In Germany multiple national research projects are dealing with the topic of the determination of future maintenance needs on the actual road system. Basis of the calculation of such a maintenance backlog is a detailed survey of the pavements condition, structures like bridges, tunnels, etc. and the road furniture, e.g. signs, lights or noise barriers. Generally the maintenance backlog is described in two different ways [26]:

- Perpetuation of a certain quality (quality indicator)
- Necessary budget to reach a certain quality (finance indicator)

4.2.4 Summary of Literature Analysis

In summary all the different definitions found in literature can be seen in the following tables 4, 5 and 6. They are divided into definitions with the expression of backlog by a physical (Ph) and monetary value (M) as well as the combination of both expressions.

From the analysis it can be seen that different approaches are in use. This must be taken into account if comparisons between different administrations and/or countries are made. As already mentioned, the analysis of literature could not show to which extent these definitions are used in practice or represent a theoretical approach.

Table 4 Definition for "maintenance backlog" expressed by a physical value available from papers of conferences

Country	Backlog value	Definition available for "maintenance backlog"		
		Pavements	Structures	Furniture
Canada [27]	Ph (M)	Maintenance backlog is referred to assets being in poor and very poor condition.		
Hungary [14]	Ph (M)	-	All bridge elements in the whole network have a present condition distribution. The difference to the higher optimum condition distribution is called maintenance backlog.	-
US Louisiana [12]	Ph (M)	Maintenance backlog is referred to road segments being in poor and very poor condition.	-	-
Wisconsin (WisDOT US) [28], [29]	Ph (M)	Maintenance backlog is defined as a percentage of the network being or with will be in distressed condition (defined rated distresses > 0).	-	-
Alberta, Canada [30]	Ph (M)	Percentage of the network above defined thresholds (ie IRI) by year (measure of backlog).	-	-
City of Portland (BOM) [13]	Ph (M)	Backlog is defined as the streets maintained by the City of Portland that are known to be in fair, poor, or very poor condition.	-	-

Table 5 Definition for “maintenance backlog” expressed by a physical and monetary value available from papers of conferences

Country	Backlog value	Definition available for "maintenance backlog"		
		Pavements	Structures	Furniture
Schweden [2]	Ph/M	The maintenance backlog is defined as the cost of optimal works required due to the maintenance standard. It measures compliance to maintenance standard. It estimates relative road capital value if condition distribution is “reasonable”.		
Finland [5]	Ph/M	Backlog is defined as a cost of maintenance and rehabilitation of all road segments exceeding threshold values in the pavement management system as well as for bridges and gravel roads.		-
London [31]	Ph/M	Maintenance backlog is defined by a threshold of a performance standard and can be expressed as the investment necessary to eliminate it within a certain time period.	-	-
Canton Graubünden Switzerland [32]	Ph/M	Maintenance backlog is referred to road segments and bridges being in poor and very poor condition. The monetary definition of backlog is the funding for the improval of this condition classes.		

Table 6 Definition for "maintenance backlog" expressed by a monetary value available from papers of conferences

Country	Backlog value	Definition available for "maintenance backlog"		
		Pavements	Structures	Furniture
City of Fort Collins, Colorado (CFC) [19]	M (Ph)	Maintenance backlog is defined as a monetary value for needed work on pavements in LOS D (poor) and F (worst).	-	-
World Bank [33], [34]	M	Maintenance backlog is referred to the difference between the present and the agreed higher target LOS under a calculation unconstrained by budget.		-
Colorado, Idaho, Arizona [35]	M	If target LOS is increased above current LOS, inventory data contribute to an estimate of the backlog of deficient items that must be overcome to achieve the higher LOS.		-
US Transit Agencies [36]	M (Ph)	Investment backlog – the total value of all deferred life cycle investments – an amount that reflects the difference between an ideal state of good repair and the current condition of an agency's existing assets (actually no road but public transport network).		
Mississippi (MDOT US) [37]	M	Backlog needs represent improvements to address deficiencies that existed at the start of the analysis period. In opposite to the accruing (or future) needs represent improvements that will be necessary to respond to increasing demand and expected deterioration of infrastructure.		
Nevada (NDOT) [38]	M	Backlog is defined as the necessary pavement work of the measure overlay and reconstruction.	Backlog of bridge is defined as work for corrective maintenance, rehabilitation, replace, seismic retrofit.	
UK Counties [25]	M	The backlog is defined as the gap between the actual Accumulated Asset Consumption and the Accumulated Annual Expenditure.		
Champaign [39]	M	Maintenance backlog considers the work that should be performed today to improve the entire highway network, whether it be through maintenance (e.g., crack sealing and chip seals) or construction (such as HMA overlays and reconstruction) by unlimited budget.	-	-

4.3 Additional Investigation

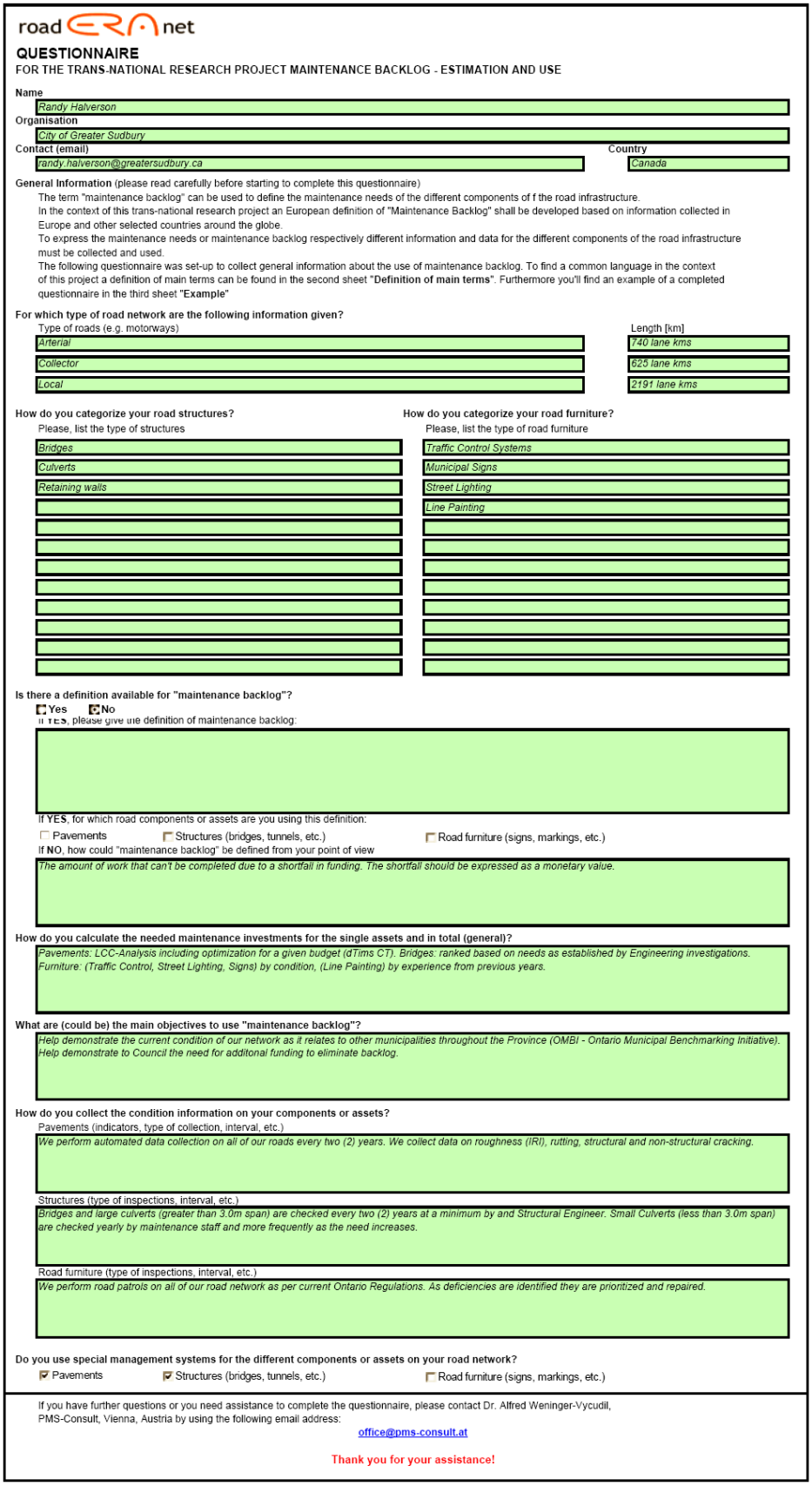
4.3.1 E-mail-questionnaire

Beside the detailed investigation and analysis of the “PEB-Countries” and Germany, Slovenia and 2 concessionaires an additional investigation on this topic was carried out. The main focus of this additional investigation was to find out whether the term “maintenance backlog” is used in other countries as well.

For this reason the “complex” questionnaire for the interviews was reduced and simplified in this manner that only the following questions had to be answered:

- For which type of road network are the following information given?
- How do you categorize your road structures?
- How do you categorize your road furniture?
- Is there a definition available for "maintenance backlog"?
  - If YES, please give the definition of maintenance backlog.
  - If YES, for which road components or assets are you using this definition?
  - If NO, how could "maintenance backlog" be defined from your point of view?
- How do you calculate the needed maintenance investments for the single assets and in total (general)?
- What are (could be) the main objectives to use "maintenance backlog"?
- How do you collect the condition information on your components or assets?
- Do you use special management systems for the different components or assets on your road network?

The following Figure 2 is a screenshot of the Excel©- questionnaire which was sent out to about 40 addresses in industrialized countries around the globe.



road ERA net

QUESTIONNAIRE

FOR THE TRANS-NATIONAL RESEARCH PROJECT MAINTENANCE BACKLOG - ESTIMATION AND USE

Name
Randy Halverson

Organisation
City of Greater Sudbury

Contact (email) | **Country**
randy.halverson@greatersudbury.ca | Canada

General Information (please read carefully before starting to complete this questionnaire)

The term "maintenance backlog" can be used to define the maintenance needs of the different components of f the road infrastructure.
In the context of this trans-national research project an European definition of "Maintenance Backlog" shall be developed based on information collected in Europe and other selected countries around the globe.
To express the maintenance needs or maintenance backlog respectively different information and data for the different components of the road infrastructure must be collected and used.
The following questionnaire was set-up to collect general information about the use of maintenance backlog. To find a common language in the context of this project a definition of main terms can be found in the second sheet "**Definition of main terms**". Furthermore you'll find an example of a completed questionnaire in the third sheet "**Example**"

For which type of road network are the following information given?

Type of roads (e.g. motorways)	Length [km]
Arterial	740 lane kms
Collector	625 lane kms
Local	2191 lane kms

How do you categorize your road structures?
Please, list the type of structures

- Bridges
- Culverts
- Retaining walls

How do you categorize your road furniture?
Please, list the type of road furniture

- Traffic Control Systems
- Municipal Signs
- Street Lighting
- Line Painting

Is there a definition available for "maintenance backlog"?
☐ Yes ☒ No
If YES, please give the definition of maintenance backlog:

If **YES**, for which road components or assets are you using this definition:
☐ Pavements ☐ Structures (bridges, tunnels, etc.) ☐ Road furniture (signs, markings, etc.)

If **NO**, how could "maintenance backlog" be defined from your point of view
The amount of work that can't be completed due to a shortfall in funding. The shortfall should be expressed as a monetary value.

How do you calculate the needed maintenance investments for the single assets and in total (general)?
Pavements: LCC-Analysis including optimization for a given budget (dTims CT). Bridges: ranked based on needs as established by Engineering investigations. Furniture: (Traffic Control, Street Lighting, Signs) by condition, (Line Painting) by experience from previous years.

What are (could be) the main objectives to use "maintenance backlog"?
Help demonstrate the current condition of our network as it relates to other municipalities throughout the Province (OMBI - Ontario Municipal Benchmarking Initiative). Help demonstrate to Council the need for additonal funding to eliminate backlog.

How do you collect the condition information on your components or assets?
Pavements (indicators, type of collection, interval, etc.)
We perform automated data collection on all of our roads every two (2) years. We collect data on roughness (IRI), rutting, structural and non-structural cracking.
Structures (type of inspections, interval, etc.)
Bridges and large culverts (greater than 3.0m span) are checked every two (2) years at a minimum by and Structural Engineer. Small Culverts (less than 3.0m span) are checked yearly by maintenance staff and more frequently as the need increases.
Road furniture (type of inspections, interval, etc.)
We perform road patrols on all of our road network as per current Ontario Regulations. As deficiencies are identified they are prioritized and repaired.

Do you use special management systems for the different components or assets on your road network?
☑ Pavements ☑ Structures (bridges, tunnels, etc.) ☐ Road furniture (signs, markings, etc.)

If you have further questions or you need assistance to complete the questionnaire, please contact Dr. Alfred Weninger-Vycudil, PMS-Consult, Vienna, Austria by using the following email address:
office@pms-consult.at

Thank you for your assistance!

Figure 2 Simplified questionnaire (example)

4.3.2 General information

As a feedback from this questionnaires 7 answers from the following administrations and institutions were received:

- Australia (ARRB)
- Canada (City of Greater Sudbury)
- Hungary (KTI)
- New Zealand (MWH)
- Portugal (LNEC)
- Serbia (University of Belgrade)
- USA (North Dakota Department of Transportation)

Table 7 gives an overview of the different road types and the lengths of the networks to which the answers are referring. The table shows that different networks or road types are taken into consideration.

Table 7 Road network information (type, length)

Country	Road network information	
	Road network type	**Length** [km]
Australia	State Roads	20'000
Canada (City of Greater Sudbury)	Arterial	740
	Collector	625
	Local	2'191
Hungary	Motorways	950
New Zealand	Various levels	not specified
Portugal	National roads	10'000
Serbia	Motorways	500
	Main roads	4'500
	Regional roads	9'700
USA (ND-DOT)	Interstate / interregional corridor	1'838
	State / District corridor	2'261
	District collector	2'364

Furthermore it was asked to provide a categorization of the different assets and components of the road infrastructure. Concerning the categorisation of road structures and road furniture, the elements that are taken into account are:

- Road structures:
  - Retaining walls (6 countries)
  - Bridges and culverts (5 countries)
  - Tunnels (3 countries)
  - Noise barriers and special structures (2 countries)

- Road furniture:
  - Signs, pavement markings, lighting (6 countries)
  - Guardrails (5 countries)
  - Traffic control systems (3 countries)
  - Traffic islands (1 country)
  - Rock fall protection nets (1 country)
  - Flashing beacons, rumble strips, fences, centreline pipes, other equipment (1 country)

4.3.3 Information about Maintenance Backlog

In the questionnaire, it was also asked to give the definition available for “maintenance backlog” concerning the pavements, the structures and the furniture. Three countries among the seven had this information (Table 8).

Table 8: Definition for “maintenance backlog”

Country	Definition available for "maintenance backlog"		
	Pavements	Structures	Furniture
Australia	-	-	-
Canada (City of Greater Sudbury)	-	-	-
Hungary	The maintenance need as a consequence of the lack of meeting objectively defined performance criteria		-
New Zealand	Backlog is the amount of asset performing outside agreed levels of service. The asset itself can still be in use so therefore has not completely failed but it could be costing too much to hold or maintain at the required level or be beyond minor remediation work. The LoS criteria can be multi-faceted i.e. more than one criteria could define satisfactory condition. There is usually a linkage to the asset valuation approach as well (i.e. an asset in Backlog would have a minimum Remaining Useful Life (RUL)).		
Portugal	-	-	-
Serbia	Funds needed to maintain road network at minimum standard level / Funds needed to bring the network into excellent condition	-	-
USA (ND-DOT)	-	-	-

New Zealand has the same definition for pavements, structures and furniture. It is based on the asset evaluation highlighting that an asset in backlog would have a minimum remaining life. Hungary gives the same definition for pavement and structures only, furniture not included. It is based on the maintenance needs when the defined performance criteria are not met. Serbia has a definition for pavements based on the funds needed to maintain the network at a minimum standard level or to bring it to an excellent condition.

The answers to the question “What are (could be) the main reasons to use maintenance backlog” focused mainly on monetary issues. The main reasons are to determine the maintenance needs, optimise the maintenance activities and evaluate the gap between the investments and the backlog evolution.

4.3.4 Maintenance Needs and Investments

To the question “How do you calculate the needed maintenance investments”, six entities had an information available. Australia, Canada and the USA use life cycle cost analysis. The other countries, except Portugal that has no information available, proceed specifically depending on the network maintenance needs.

4.3.5 Condition assessment and Management Systems

Regarding the collection of the condition information, it is done every 1-5 years depending on the country, the structure (pavements, structures, furniture) and the evaluated parameter.

- Pavements
  - Australia and the USA collect condition data every year
  - Canada collects automatically the data every 2 years
  - Hungary collects data every 3 years, but it happens that bearing capacity is collected between 3 and 5 years
  - Portugal does a visual assessment every 5 years
  - Serbia performs the condition surveys irregularly based on the HDM methodology
- Structures
  - Australia inspects the bridges every 3 years
  - Canada inspects bridges and large culverts (>3m span) every 2 years and small culverts (<3m span) every year
  - Hungary does a visual inspection every year and an detailed one every 3-5 years
  - New Zealand does a visual inspection every 2 years and a detailed one every 6 years
  - Serbia does no systematic inspections as they have specialised equipment for bridge surveys
  - USA (ND-DOT) does bridge inspections every 2 years
- Road furniture
  - Australia and Canada act depending on the local needs
  - New Zealand does a visual assessment depending on the asset type
  - Serbia does not a systematic inspections
  - USA (ND-DOT) does complete annual inspections every year

The answers to the question “Do you use special management systems for the different components or assets on your road network?” can be summarized as follows. New Zealand is the only country to use a special management system for the three elements, i.e. pavements, structures and furniture. Australia, Canada, Hungary, Portugal, USA use a special management system for both pavements and structures and Serbia only for pavements.

5 Analysis of Investigations

5.1 Analysis of Interviews

The following chapters are the results of the analysis of the investigated road administrations and concessionaires. Detailed information about the underlying data can be taken either from chapter 4.1 or from the minutes of the interviews (see Annex A). The following institutions have been considered in this analysis:

- AT: Austrian Motorway Company (ASFINAG) and Federal Ministry of Traffic, Innovation and Technology (BMVIT)
- DK: Danish Road Directorate (DRD)
- FI: Finnish Road Administration (FINNRA)
- NO: Norwegian Public Roads Administration (NPRA/SVV)
- SE: Swedish Road Administration (SRA)
- CH: Swiss Federal Roads Office (ASTRA)
- UK: Highways Agency (HA)
- DE: German Federal Ministry of Transport, Building and Urban Affairs (BMVBS)
- SI: Slovenian Motorway Company (DARS)
- C1: DirectRoute (Fermoy) Ltd. (concessionaire)
- C2: M6-Duna motorway (concessionaire)

The comparison of the different aspects in the context of this project was possible on a general level only as can be seen in the chapters as follows. A detailed comparison of single definitions between the different road administrations is difficult because of different local requirements, input-data, standards, and preconditions. Nevertheless the results of the interviews can be compared individually by the user of this report.

5.1.1 Maintenance and Maintenance Objectives

The following Table 9 gives an overview of the different types of roads, for which the investigation about maintenance backlog was carried out. The table shows that mainly motorways and other primary roads are in the responsibilities of the interviewed road administrations or concessionaires. Gravel roads are in the responsibilities of the investigated institutions in Finland and Sweden only. Beside Finland and Sweden also Norway has a long network of gravel roads, but this is in the responsibility of the counties. Thus this network was not taken into consideration.

Table 9 Responsibilities on different road networks

Road type	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Motorways[1)]	●	●	●	●	●	●	●	●	●	●	●
Other primary roads[2)]		●	●	●	●	●	●	●			
Other roads[3)]			●	●	●	●					
Gravel roads			●		●						

1).....Roads with more than one lane in each direction, separated carriageways (mainly) and level free intersections.
2).....Arterial roads with one lane in each direction (mainly), no separated carriageways (mainly) and level or level free crossings.
3).....All other roads.

The lengths of the concerned road networks can be taken from the respective tables and minutes of the investigated road administrations. The smallest network is the concession of "DirectRoutes" with a length of less than 18 km in comparison to the road network of the Swedish road administration with more than 98'000 km of different road types.

Beside the different road types also the organizational structure of the road administration and concessionaires with respect to maintenance activities was considered during the interviews. The following Table 10 provides an overview..

Table 10 Organization of road administrations

Unit	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Head (central) office	1	1	1	1	1	1	2	1	1	1	1
Regional offices	4	6	9	5	7	5	7	16	8	1	1
Other units	1	-	-	30	8	-	-	-	-	-	-

The strategic decision for maintenance measures and activities (network level decisions) are being made invariably in the head or central offices of the investigated road administrations and concessionaires. The objectives of the regional offices or branches focus mainly on the execution of routine maintenance activities (AT, DE, SI, CH), on the administration of local agendas in the context of contracting and in the planning of major maintenance activities on project level.

Especially for the definition of maintenance programs a combination of bottom up planning by the regional offices or branches with top down requirements from the head or central offices is applied in practice in many administrations.

One of the key tasks in the context of the definition of maintenance backlog is the definition of different maintenance activities and objectives. It could be found out that each investigated organization categorizes the maintenance activities generally in 3 different groups as follows:

- Routine Maintenance
- Planned (major) maintenance
- Upgrade and extension

An exact definition of these different maintenance activities and objectives could be found on

the concessions (stated in the contracts) and in the countries where a high number of activities is outsourced. There are small differences in the definition of the activities under the different titles, however, this can be neglected in this analysis. Detailed definitions and explanations are included in chapter 6.1.

Table 11 gives an overview of the execution of maintenance activities in the different road administrations and the two concessionaires.

Table 11 Outsourcing of activities

Category	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Routine maintenance		●	●	●	●	●	●			○	○
Planned (major) maintenance	●	●	●	●	●	●	●	●	●	●	●
Improvement and extension	●	●	●	●	●	●	●	●	●		

●.....completely outsourced
○.....outsourced to a separate operation company (part of concessionaire)

The use of computer-assisted systems in the context of managing the road infrastructure is an integral part in the road organizations in the meantime.

Of course, there are differences in the methods and models which are implemented into the applied systems. It could be found out that a high number of administrations is using LCC-analysis to select the optimum measures and strategies under given preconditions. LCC-analysis replaces increasingly simple ranking methods, mainly on the pavement management sector but also in the context of managing structures.

Otherwise the investigation shows that individual solutions are being preferred by the organizations in comparison to complex, overall solutions. The following Table 12 gives an overview of the practical application or ongoing development of management systems and data bases in the investigated institutions.

Table 12 Management systems and data bases in use

System	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Pavement Management System	●	●	●	●	●	●	●	●	●	●	●
Structure Management Systems	●	●	●	●	●	●	●	●	○	●	●
Management System for Road furniture		●		○							
Asset Management System										●	

○.....only database

5.1.2 Data Collection and Assessment of Condition

5.1.2.1 General

Given the definition and the availability of adequate standards maintenance backlog can be calculated only by the use of underlying data and information about the condition of the different assets. Thus the collection of condition information was investigated during the interviews as well. The results of these investigations are performance indicators which describe the different characteristics and their condition or degree of distress.

The collection of condition data varies for the different components or assets. In the following chapters the method of investigation, the performance indicators in use, and the procedures for the assessment are summarized. The analysis was carried out in a similar manner to get a comparable overview of this information. More detailed information can be taken from the tables in chapter 4.1 or from the minutes of the interviews in Annex A.

5.1.2.2 Pavements

Table 13 shows the different condition surveys which are carried out on the networks of the investigated road administrations or concessionaires.

Table 13 Interval of condition surveys on pavements in years

Category	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Visual inspection[1)]	5	1	3			4	1	4	2	4	
Measurement	5	1 – 2	1 – 3	1	1 - 5	4	1	4	2	1 – 4	1 – 5
Others											

1).....includes inspection methods by using video/picture systems, with or without automated distress detection

The intervals of condition surveys are between 1 and 5 years and are usually carried out as measurements in combination with visual inspections. The outcomes of condition surveys are technical parameters which can be grouped into different characteristics which describe the condition of the road pavements. A list of performance indicators (groups) related to the investigated road administrations and concessionaires can be taken from Table 14.

Table 14 Performance indicators for road pavements

Indicator (group)	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Transverse evenness	●	●	●	●	●	●	●	●	●	●	●
Longitudinal evenness	●	●	●	●	●	●	●	●	●	●	●
Skid resistance	●	●		o	●	●	●	●	●	●	●
Surface defects[1)]	●	●			●	●	●	●	●	●	
Cracking	●	●	●			●	●	●	●	●	
Bearing capacity		o	o	o	●	o				●	●
Road geometry			●	●	●					●	●

●.....collected periodically
o.....collected not periodically or on project level only
1).....e.g. ravelling, bleeding

The technical parameters are the basis for the assessment of the road condition. At least thresholds of single indicators must be available to enable an assessment. In many countries the technical parameters are transformed to dimensionless indices and finally to combined indices which describe the overall condition of different aspects of the road pavements (safety, comfort, structural status, etc.) [1]. Besides indices, classification scales are used in practice to categorize the pavement condition in different condition classes (e.g.: 1 - very good to 5 - very poor) in many countries. The allocation to a certain condition class can be related to a Technical Parameter or to an index.

Table 15 gives an overview of the different assessment procedures and methods which are used on the respective networks.

Table 15 Assessment of performance indicators for road pavements

Assessments	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Technical parameters	●	●	●	●	●	●	●	●	●	●	●
Single indices	●		●			●		●	●		
Combined indices	●		●			●		●	●		
Classification scale	●		●	●		●		●	●		

5.1.2.3 Structures

The overall term “structures” covers different components or assets of the road infrastructure. Thus it was necessary to categorize the structure into 4 main groups (bridges, tunnels, walls and others) and to find out which sub-assets are taken into consideration in the context of managing structures. The following Table 17 (see next page) shows the list of sub-assets for the different categories for all investigated institutions.

Table 16 shows the different condition surveys which are carried out on the networks of the investigated road administrations or concessionaires.

Table 16 Interval of inspections on structures in years

Inspection type	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Main inspection	6	1 – 6	5	5	6	5	6	6	6	6	1
Interim inspection	2		1	1	1	2	2	2	3	1/52	
Other inspection	R	R	R	R	1/4	R	R	R	R	R	R

R .....as required

As shown in Table 16 the intervals of main inspections on structures in the majority of the investigated road networks are between 5 and 6 years. Exceptions could be found on one concession, in Finland and in Denmark, where the inspection interval is related to the condition of the bridge so that a bridge in poor condition will be inspected every year. Beside main and interim inspections different “other inspections” were mentioned during the interviews. Most of them are defined as special inspections which were carried out either in the context of defining exact maintenance measures or because of already detected problems of the condition.

Table 17 Categorization of structures

Category	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Bridges	Bridges	Major bridges	Bridges	Bridges	Bridges	Bridges	Bridges	Bridges	Bridges	Bridges	Bridges
	Troughs	Minor bridges	Culverts	Culverts		Culverts	Large culverts			Viaducts	Culverts
			Road on piles				Small culverts			Culverts	
Tunnels	Galleries	Tunnels	Constructed tunnels	Concrete tunnels and entrance sections	Tunnels	Constructed tunnels and galleries	Tunnels	Tunnels	Tunnels		
	Constructed tunnels		Mined tunnels	Mined tunnels		Mined tunnels		Trough structures	Galleries		
	Mined tunnels										
Walls	Retaining walls	Retaining walls	Retaining walls	Walls	Retaining walls	Retaining walls	Retaining walls	Retaining structures	Retaining walls	Protection fences	
	Noise barriers	Noise barriers			Noise barriers	Noise barriers		Noise barriers			
Others	Gantries		Piers and quays				High masts	Gantries			Drainage systems
	Protection structures						Others				Operation base

Table 18 shows the indicators used in the context of the assessment of structures. The background for the definition of the structure condition is an assessment of single components or elements. With exception of Sweden the components are also described by dimensionless indicators in different forms (combination of number and letter, number, value, etc.) which refer in many cases directly to possible maintenance measures. Beside the use of single indicators also combined indicators and indices are used in practice in the majority of the investigated institutions. Special indicators (e.g. lack of capital value) are used in Sweden and Finland to get a more comprehensive conclusion about the condition of structures for strategic decisions.

Table 18 Type of performance indicators for structures

Indicators	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Single indicators/indices	●	●	●	●	●	●	●	●	●	●	●
Combined indicators/indices	●	●	●	●		●	●	●	●		
Other indicators/indices			●		●						
Classification scale	●	●	●		●	●	●	●		●	

5.1.2.4 Road furniture

Road furniture is the last group of road components or sub-assets which were evaluated in the context of this project. The general definition of road furniture which is everything of the road infrastructure except pavements and structures brought a high number of different components which is difficult to describe in detail. To get an overview of the different road furniture a categorization into 3 main groups has been applied in this analysis. The groups could be defined as follows:

- Protections systems
  - Guard rails
  - Concrete barriers
  - Rope barriers
  - Buffers
  - etc.
- Equipment
  - Traffic signs and signals
  - Markings
  - Lightning
  - Guide posts
  - etc.
- Others
  - Noise barriers (if not defined as structures)
  - IT-equipment and monitoring systems
  - Animal fences
  - Drainage (if not defined as part of the pavement)
  - Earth works and geotechniques (if not defined as part of the pavement)
  - Side and rest areas (if not defined as part of the pavement)
  - Sidewalks (if not defined as part of the pavement)
  - etc.

These groups could be used for a more detailed investigation in the future. At the moment there were not enough data and information, therefore only a general overview is given. A detailed list of road furniture in the respective group can be taken from the country specific tables in chapter 4.1 or from the minutes of the interviews in Annex 1.

With exception of safety controls and some pilot projects no periodical inspections of road furniture are carried out on the investigated road networks. Thus the number of available condition information is very poor and the assessment of road furniture is mainly based on the experiences of the operational staff. No road administration or concessionaire carries out a detailed planning of maintenance measures. Recognised backlogs must be eliminated as soon as possible. Only an upgrading to a higher standard (e.g. because of new or additional EU-regulations) causes special efforts in some countries.

Nevertheless the collection of information of road furniture is a task oriented to the future. Some road administrations already started with pilot projects in this field. The following Table 19 gives an overview of the available performance indicators and of the use of indices.

Table 19 Type of performance indicators for furniture

Indicators	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Single indicators/indices		o	o	o	o		o			o	o
Combined indicators/indices											
Other indicators/indices											
Classification scale			o								

o.....for some components only

The analysis shows that in the countries and at the concessionaire where the operational work is outsourced a certain number of technical parameters is defined in the contracts and controlled by the clients. Only Finland has defined in theory the use of single indices and a classification scale for road furniture which is equal to the scale for pavements and structures.

5.1.3 Maintenance Standards

The assessment of the collected information and data is done through the use of performance indicators and related predefined maintenance standards. At all investigated road administrations these standards are available in form of national guidelines for pavements and structures (mainly bridges) at least. Some institutions started to define standards for road furniture as well, especially for the activities which are outsourced to private or semi-private road operators.

Related information about the threshold values and the respective national guidelines can be found in the minutes of the interviews in Annex A. It was not the objective of this project to compare and analyse these various standards.

5.1.4 Maintenance Strategy

The definition of maintenance backlog must be seen in close connection with the definition of the “optimum” maintenance strategy for a sub-asset or component. To get an optimum solution different approaches are applied in practice in the different road administrations.

Most of them focus either on minimize cost or on maximize benefit solutions. Based on the results of the investigations “Life-Cycle-Cost-Analysis” (LCC-analysis) is the state of the art method. Detailed definitions and explanations are included in chapter 6.5.

5.1.5 Maintenance Backlog

5.1.5.1 General

One main objective of this project is to give a state of the art report about the use of maintenance backlog in the investigated institutions. Thus one major task focuses on the availability of maintenance backlog definitions and their practical application. Based on the results of the investigations the given answers could be categorized into 3 different groups:

A) Maintenance backlog is defined and applied in practice

B) Maintenance backlog is not directly defined but there is a comparable approach available (theoretically, but not used in practice)

C) Neither maintenance backlog is defined nor is any kind of approach available

As it can be seen from Table 20 only the Scandinavian countries (DK, FI, NO, SE) and Germany are using a definition of maintenance backlog which is also applied in practice. In Austria, Switzerland, United Kingdom (England), Slovenia and at one of the concessions a comparable (theoretical) approach is available but not officially used in practice. A lack of maintenance backlog definition and approaches can be seen in the category road furniture.

Table 20 Availability of maintenance backlog definitions

Category	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
General	B	A	A	A	A	B	B	A	B	C	B
Pavements	B	A	A	A	A	B	C	A	B	C	C
Structures	B	A	B	A	A	B	C	A	C	C	C
Road Furniture	C	A	B	A	B	C	C	C	C	C	C

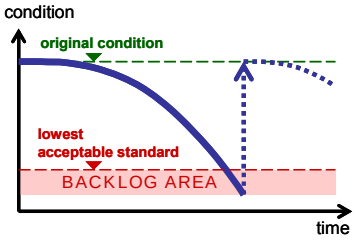
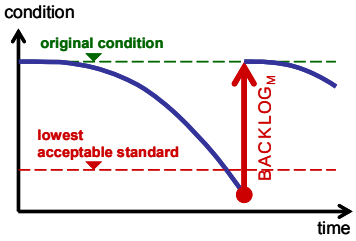
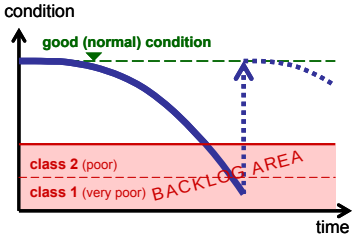
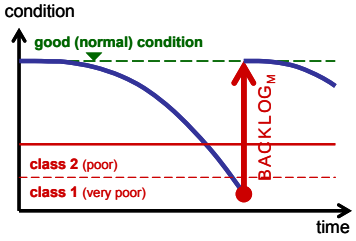
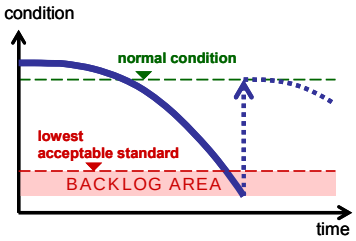
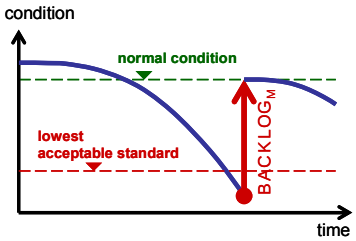
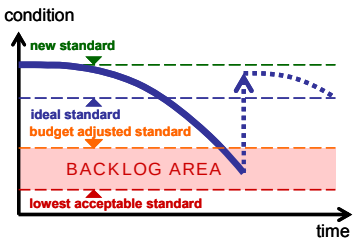
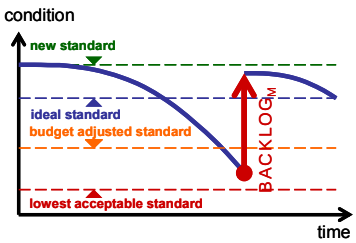
A .....Maintenance backlog is defined and applied in practice
B .....Maintenance backlog is not directly defined but there is a comparable approach available
C .....Neither maintenance backlog is defined nor is any kind of approach available

5.1.5.2 Maintenance Backlog Definitions

The investigations showed that with small exceptions the general definition of maintenance backlog is used for the different sub-assets as well. Thus, the analysis focuses on the general definitions of maintenance backlog which should be the basis for the recommendations in the following chapters. Of course, for the recommended mathematical definition of the maintenance backlog a detailed observation of the asset-specific definitions is necessary.

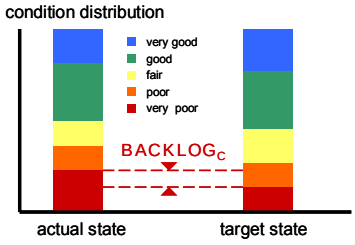
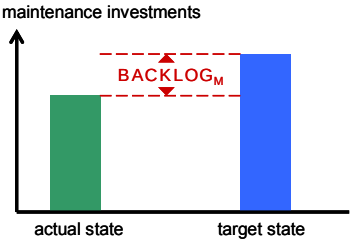
With regard to the 3 different groups described above (A, B, C) a comparison of definitions was carried out. The main target of this analysis is a first categorization of the different available approaches and the provision of background information for the planned recommendations. The following Table 21 shows the general definition of maintenance backlog in those countries, where it is applied in practice (group A). Table 22 shows a list of comparable approaches of maintenance backlog definitions from other countries (group B). In both tables a distinction between condition based backlog and backlog expressed in monetary terms is included.

Table 21 Maintenance backlog definitions used in practice

Country	Definition		Term
	Condition based backlog	Backlog in monetary terms	
DK	Maintenance backlog expresses the need in form of a monetary value to bring the assets from a condition below or at the lowest acceptable up to an agreed, better level (normally equal to the original condition)  		P+M
FI	Maintenance backlog is referred to components which are in bad condition = class 1 or 2 (scale from 5 = very good to 1= very bad). In monetary terms maintenance backlog is expressed by the costs of maintenance measures to bring up the components to a “good” (normal) level including not fulfilled needs from years before. In non-monetary terms maintenance backlog is expressed by the length or number of assets in class 1 and 2.  		P+M
NO	Maintenance backlog for a road infrastructure component is the cost of bringing the condition of the component from its current condition to a defined condition level in such a way that it will fulfil its intended purpose for a normal life cycle period  		M
SE	If a threshold value of the standard is passed but no works are performed a backlog occurs. The value of the backlog is the cost of the optimal maintenance measure at the moment. The optimal maintenance measure is the first measure of the optimal maintenance strategy respecting the maintenance standard during the analyzed time period and giving the lowest cost during the period. Maintenance Backlog for a road network can be expressed as cost for all delayed maintenance at the moment or as volume (%) of the net below the threshold values (length, area).  		P+M

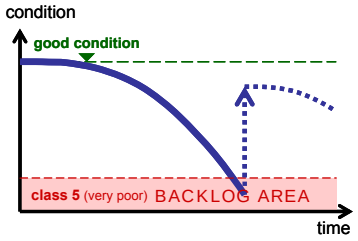
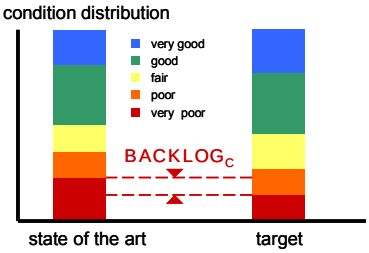
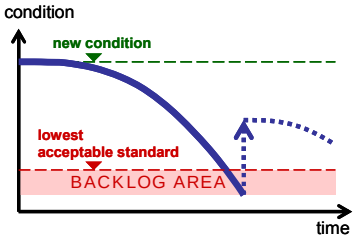
P .....non-monetary, physical value (e.g. length, percentage)
M.....monetary value

Table 21 Maintenance backlog definitions used in practice – cont.

Country	Definition		Term
	Condition based backlog	Backlog in monetary terms	
DE	Maintenance backlog is the money to be invested over a longer time period to reach the maintenance objectives. A comparison of target and actual results is the basis for the calculation of the maintenance backlog. To reach the objectives an increase of investments is necessary → amount to be increased = maintenance budget backlog.  		M

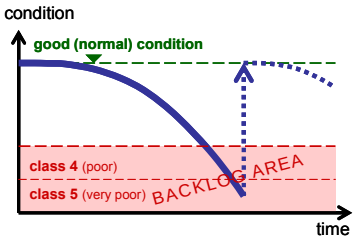
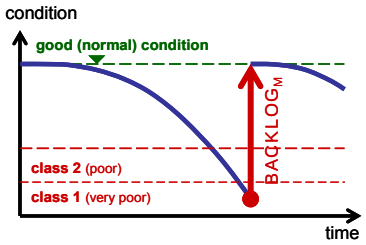
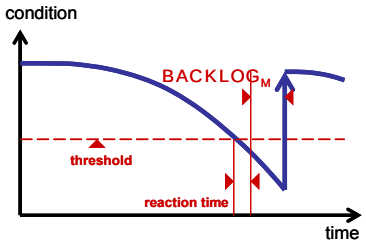
P .....non-monetary, physical value (e.g. length, percentage)
M.....monetary value

Table 22 Maintenance backlog definitions as comparable approach

Country	Definition		Term
	Condition based backlog	Backlog in monetary terms	
AT	Percentage of network-length or number of units in condition class 5 (very poor). 		P
CH	Difference between targeted condition distribution (main objectives) and actual condition distribution. This is calculated for each condition class but especially for class “very poor” 		P
UK	Condition below “lowest acceptable standard” is theoretical maintenance backlog 		P

P .....non-monetary, physical value (e.g. length, percentage)
M.....monetary value

Table 22 Maintenance backlog definitions as comparable approach – cont.

Country	Definition		Term
	Condition based backlog	Backlog in monetary terms	
SI	Amount of money which would be needed (in a certain time period) to ensure that the condition of network is out of poor and very poor condition. 		P+M
C2	Concessionaire does not react to condition below threshold within given reaction time → consequences are penalty points which cause a reduction of payment = monetary maintenance backlog.		M

P .....non-monetary, physical value (e.g. length, percentage)
M.....monetary value

The terms “good”, “normal”, “certain time”, etc. in the tables above are related to the definitions given by each single administration and cannot be taken as general ones. From both tables (Table 21 and Table 22) the following conclusions can be drawn:

- In the Scandinavian countries (DK, FI, NO and SE) almost the same definition of maintenance backlog is used, for condition based backlog as well as for monetary expressed backlog
- The approach in Germany is similar, but more related to the condition distribution and focusing on budgetary backlog
- Similar approaches for the condition based maintenance backlog could be found in AT, SI and theoretically in UK, while in CH the backlog is based on the condition distribution like in Germany
- At the concession C2 the backlog in monetary terms is time and traffic related and based on the time-delay of the repair activity

Based on this comparison it is possible to categorize the existing definitions of maintenance backlog of the road infrastructure into two main groups representing non-monetary, condition related (functional) backlog and backlog in monetary terms (see Table 23).

Table 23 Categorization of maintenance backlog definitions

Category	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
Condition based backlog	o	●	●	●	●	o	o	●	●		
Backlog in monetary terms								●			o

●.....approach applied in practice
o.....comparable approach (theoretically, but not used in practice)

Table 23 shows that most of the existing definitions express the maintenance backlog in form of length, area or numbers of assets which are below a given, predefined standard of the condition, followed by costs which must be invested into the network to bring up the condition from a "backlog status" to a defined normal or ideal one.

As already mentioned, the general definitions of maintenance backlog are used in a similar form for the calculation of maintenance backlog for the different single assets or components of the road infrastructure. Only some smaller exceptions show differences between the general definition and the practical application on the single component. The reason for these differences are on the one hand already existing pragmatic solutions which have been used for many years and are preferred against a complex calculation process and on the other hand the limited underlying information that does not allow the calculation of maintenance backlog in the desired method. Especially the lack of information about the condition of road furniture and missing thresholds (standards) causes this problem. Thus the estimation of maintenance backlog for road furniture is mainly based on experiences and not on an exact calculation, if a calculation could be executed in practice at all.

Interesting applications were reported from the UK and from Denmark with specific relation to the pavement part. In the UK there is the general regulation that – at least for safety related pavement condition indicators – no status below the minimum requirement (standard) is allowed at all and therefore expressis verbis a backlog cannot exist in these cases per definition. In Denmark the definition of the backlog is similar to the one in the other countries but the calculation/estimation of the backlog is performed by the comparison of the need for replacement of the surface layers based on average lifetime assumptions and the replacement executed in reality. The difference between these two figures is taken as the maintenance backlog.

5.1.6 Use of Maintenance Backlog

One of the key questions about maintenance backlog is the use of the results in the different fields of application. The following Table 24 shows the use of maintenance backlog subdivided into 3 different fields of application subject to the different road administration or concessionaires.

Table 24 Use of maintenance backlog

Category	AT	DK	FI	NO	SE	CH	UK	DE	SI	C1	C2
General use	o	●	●	●	●		o				
Internal use	o	●	●	●	●	o		●	o		o
External use	o	●	●	●	●	o		●	o		

●.....approach applied in practice
o.....comparable approach

There was a rather big consensus from the interviews in the different countries and stakeholders concerning the possibilities of the practical use of the estimation of the maintenance backlog of a road network. In all cases a distinction was made between internal and external use of the results. Detailed recommendations can be seen from chapter 6.8.

5.1.7 Total Maintenance Budget and Budget Allocation

The total maintenance budget for the whole road infrastructure and finally the total backlog of all components is expressed on all investigated road networks and concessions as sum of the costs for maintenance measures and treatments on the single components or assets.

An additional major question during the interviews was the allocation of the available maintenance budget on the one hand to the different components or sub-assets and on the other hand to different regions or states.

In most of the investigated countries the allocation of budget to the different components is carried out through the use of a “distribution key” which is based on long to medium term experiences and on the results of the management systems (e.g. PMS).

In two countries (Switzerland and Austria) and on the concessions a distribution to different components will not be carried out because of the definition of maintenance projects which include the necessary maintenance measures on all sub-assets or components. The main objective of this approach is to minimize user disturbance by uncoordinated measures. The coordination can be in conflict with the budget allocation so that no fixed distribution key is applied on these road networks.

In many cases the allocation of budget to different regions or states (Germany) is based on the length of the regional networks, the traffic load and strongly influenced by the organizational structure of the road administration (central – regional).

5.2 Output of Literature, Projects and additional Investigation

5.2.1 Literature and Projects

During the search for potential references in literature or projects dealing with the background of Maintenance Backlog it could be realized, that this term is used, but in quite some different ways. In managing infrastructures there always could be found a kind of backlog calculation even if the word is not known. But in real every day management it is still used too little. There is a big potential in using Maintenance Backlog for the asset management. The most experiences in using this figure could be found in the US and the UK (others than HA network). There it is already used periodically for detecting realistic deficits of funding the maintenance and as well for comparing different regions in their maintenance quality.

From the literature point of view there are some important facts to point out:

- Maintenance Backlog is the definition of a deficit in maintenance management of the road network with a predefined standard in a time period.
- There are a lot of different definitions in use of backlog and no definition is internationally widely accepted.
- There should be a common accepted methodology for calculating maintenance backlog which gives the possibility to benchmark with other road networks.
- It gives the possibility to include almost all sub-assets of the road network.
- Using a physical value just makes sense for one sub-asset or component, therefore a monetary value should be preferred.
- For the calculation of maintenance backlog there have to be certain standards like a level of service with different defined thresholds (performance based indicators).
- Maintenance backlog should be measured or calculated and used in the management on a frequent basis.
- Maintenance backlog has a great potential for the use in asset management, because it gives the possibility for comparing and judging for priority the different assets. This can then be used to support the asset management decision making process.

5.2.2 Additional investigation

The information collected in the context of an additional investigation (questionnaire) is a further basis for the definition of maintenance backlog. The output of this investigation refers to a limited number of answers coming from countries around the globe. Thus these results are with limited significance but should be taken into consideration anyway.

The term maintenance backlog is used similarly to the definitions given by the interviewed road administrations and concessionaires. It is expressed by the needed funds to bring up an asset or a part of an asset from the backlog condition to an improved condition. It is expressed on the one hand by monetary values (maintenance needs) and on the other hand also by physical or functional values expressing the amount of asset performing outside

agreed levels of service.

Differences could be seen in the targets to be achieved. Some administrations focus on an approach to improve the condition to an excellent level in comparison to other administrations which aim to bring up the condition to the minimum requirements.

The main reasons for the use of maintenance backlogs are to determine the maintenance needs, optimise the maintenance activities and evaluate the gap between the investments and the backlog evolution. The basis for the calculation of maintenance backlog and the maintenance needs is mostly life cycle cost analysis (Australia, Canada and USA).

The collection of condition data on pavements and structures is more or less state of the art in the industrialized countries around the globe. There are differences in the intensity of investigations and in the methods (visual inspections, measurements). It could also be found out that the collection of the condition of road furniture is at the beginning only or not applied at all, which is similar to the results coming from the interviews.

Also the use of management systems is widespread and could be defined therefore as state of the art.

6 Conclusion and Recommendation

The following chapter is the result of the analysis and the discussion of the collected information and data from investigated road administrations, concessionaires and from the additional investigation of the current literature and questionnaire. The intention is to cover all the existing definitions and procedures as far as possible and to bring them together to general recommendations.

6.1 Maintenance and maintenance objectives

In the course of this project the term Maintenance covers all types of activities on the road infrastructure aiming at conservation or restoration of the condition of road components (sub-assets). The main objective of road maintenance is to provide a suitable and safe road condition to the present and future road users and in the same time secure the long term conservation of the value of the property.

It could be found that each investigated organization categorizes the maintenance activities generally in 3 different groups as follows, even if they have different names in some countries:

- **Routine Maintenance** (also called road operations): small measures to repair local deterioration (cracks, potholes, repair of damaged guardrails etc.) and operational activities (e.g. winter maintenance / winter operation). The objective of these measures is to keep the road (pavement and the other sub-assets) in a defined (minimum) condition level and to avoid progressive deterioration. They have a limited lifetime and are normally performed on demand based on routinely periodic observations. They are not really planned and therefore they are not taken into account for the evaluation of the maintenance backlog. These works are either conducted by the road administrations themselves or are contracted out.
- **Planned (major) maintenance**: maintenance measures with a long lasting improving effect to the condition of the sub-asset or component (rehabilitation). The objective is to provide a better condition to the present and future road users. These measures are conducted at components or sections close to or below an unacceptable condition level. They are planned as soon as the condition of the component falls below a given warning level and they have to be conducted according to a priority rating (e.g. LCC-analysis)using the relevant management system taking into account the given budget availability. These measures normally are combined to bigger construction sites and are contracted out following a tendering process. The requirement for such maintenance measures forms the basis for the calculation of a maintenance backlog.
- **Upgrade and extension**: measures which upgrade the existing sub-asset or component or extend the infrastructure to a higher level than the original new condition (e.g. additional lane, strengthening, higher requirements for retention systems etc.). These measures are also planned depending on the condition of the existing road but taking into account the need and the timeframe for the additional upgrading combining both objectives to one construction measure. Normally only the part of the works which is attributed to the basic improvement

(rehabilitation) of the existing part of the road is paid from the maintenance budget and thus contributes to the calculation of the backlog. The extra costs of the upgrade and/or extension are covered by the budget for investments.

An exact definition of these different maintenance activities could be found at the concessions and in the countries where a high number of activities is outsourced and therefore has to be defined clearly in the respective contracts. There are small differences in the definition of the activities under the different terms. However, this can be neglected in this analysis.

6.2 Condition and Performance Indicators

Information about the condition of the sub-assets or components expressed by performance indicators form the basis for the definition and finally the calculation of maintenance backlog. Beside inventory data (extent, location, construction type, etc.) and the necessary parameters for LCC-analysis condition data should be available in a certain density and quality according to the different assets and local requirements.

For the characterization of the condition or functionality of a sub-asset or component performance indicators (PI) should be used and should describe the different characteristics in a balanced way. The selection of adequate performance indicators is strongly dependent on the type of asset.

The following list is a general recommendation of indicators which should be taken into consideration for the assessment of road infrastructure and thus for the calculation of maintenance backlog:

- Performance indicators for pavements according to COST354 [1]
  - User related single performance indicators to describe the safety and the comfort of the pavement
    - Skid resistance / texture
    - Rutting
    - Longitudinal evenness
  - Structure related single performance indicators to describe the structural (technical) status of the pavements
    - Cracking
    - Other structural defects (ravelling, bleeding, etc.)
    - Bearing capacity
  - Environment related indicators to describe at least the noise emission
  - Combined performance indicators for:
    - Safety
    - Comfort
    - Structure
    - Environment
  - General performance indicator to describe the overall condition of the pavement
- Performance indicators for structures
  - Component specific single performance indicators to describe the distresses as follows:

        - Type
        - Extent
        - Severity
    - Combined performance indicators to describe the following characteristics of the structures
        - Stability
        - Safety
        - Durability
    - General performance indicator to describe the overall condition of the structure

- Road Furniture
  The functionality is the key performance indicator of the assessment of road furniture condition, so that either a “yes” or “no” describes the condition of most road furniture.

The performance indicators can be expressed by technical parameters and/or by dimensionless indices, but they must be in coincidence with given limits or thresholds of the predefined standards.

From this list the user related performance indicators describing the safety issues should be available at least. It is recommended to start with this minimum requirements and to extend the data basis by a stepwise approach, if not all the mentioned information are available from the beginning.

6.3 Data Acquisition

The performance indicators for road pavements, structures and road furniture describe the condition of the assets which is the basis for the calculation of maintenance needs and finally of maintenance backlog. This data is based on condition surveys in form of measurements or visual inspections. The respective information should be available for the whole road infrastructure so that measurements and visual inspection on network level are the best basis to get the needed input parameters. If periodic net-wide condition surveys are not possible or available, measurements and inspections on selected sample sections, representative for defined parts of the network, can be conducted and by extrapolation be used to describe the condition of the whole network. This (stepwise) approach can help to start with the procedure of backlog assessment, even if only limited money for condition surveys is available.

Subject to the different types of sub-assets the following investigations are being recommended:

- Pavements
    - Measurements for user specific performance indicators (skid resistance / texture, rutting, longitudinal evenness), bearing capacity and environmental indicators (noise emission)
    - Visual inspections in combination with video-systems or images for structural performance indicators (cracking and other surface defects)

- Structures
  Visual inspection of sub-components with video- or image documentation
- Road furniture
  Visual inspection and functional testing

As already mentioned the condition information for the whole road infrastructure must be available to calculate the maintenance backlog. Thus the interval of the measurements and visual inspections are a decisive factor for the quality of the results. Furthermore the intervals must be in coincidence with the local requirements and the given national and/or European standards (especially for bridges and tunnels). The following values are a recommendation for the **maximum intervals** of measurement and visual inspections on network level.

- Pavements: max. 5 years
- Structures: max. 6 years
- Road furniture: max. 1 year for functional testing

If safety problems are being detected the maximum intervals should be reduced accordingly to ensure the minimum requirements of the respective asset. The recommended maximum intervals should not be exceeded in normal situations.

Beside the condition of the different sub-assets or components of the road infrastructure additional data must be available to calculate the maintenance backlog. This information is needed to find the optimum maintenance strategy of a certain sub-asset or component and must be collected, updated in a certain interval, and checked for plausibility as well. It concerns the following information:

- Inventory data (extent of assets, location and reference, construction types, maintenance history, etc.)
- Input parameter for the definition of the maintenance objectives which are in coincidence with the performance indicators in use (threshold values, percentages of condition classes, etc.)
- Input parameter for finding the optimum maintenance strategy based on LCC-analysis (cost, triggers, performance prediction models, economic parameters, etc.)

For an easy handling of all the necessary data it is recommended to store data in electronic databases which are already standardized in most of the investigated countries or organizations.

6.4 Maintenance Standard / Maintenance Goals

The main objectives of maintenance activities to be achieved must be expressed by parameters which are in coincidence with the performance indicators in use. To evaluate the need for maintenance and to calculate a maintenance backlog the following standards should be available for the sub-assets and components to be assessed:

- Threshold values which define the border line between fulfilled and unfulfilled demands [backlog threshold value] (e.g. in form a condition related value or a

maximum deterioration rate)

- Thresholds values which define the lowest acceptable condition (can be equal to the backlog threshold value) (e.g. in form a condition related value or a maximum deterioration rate)
- Target values which define the optimum condition to be achieved after maintenance measures (e.g. in form a condition related value)
- Percentage of condition classes or ranges to be achieved (in case of given condition distribution standards)

These values are related to functional and structural requirements and are laid down in the respective national guidelines or manuals. Ideally they are derived from an analytical relationship between the indicator and the consequences to the road user, but in most cases they are adapted in some way to the given or accepted condition distribution at the network and the related risk assessment (e.g. traffic accidents).

Especially for pavements and structures these input parameters are widely available. To assess road furniture the functionality is the key parameter. For safety specific road furniture (e.g. protection systems) the functionality must be guaranteed so that the transition from “yes” to “no” can be defined as backlog threshold value. For other road furniture it is possible to allow that a certain number of components do not work (e.g. 3% of lights). Thus the thresholds can be expressed by a percentage of working furniture to be achieved. Generally a lack of condition indicators for road furniture and equipment could be found and it is recommended to improve this situation.

In the course of this study it was not intended to analyse the condition indicators and the related threshold values used in the various countries in detail and to give recommendations. They are expressing the existing maintenance standards and form the basis for the evaluation and the calculation of the maintenance backlog (see chapter 6.6).They can be used for the calculation of the minimum annual maintenance cost to keep an agreed constant condition (deterioration costs) and for the demonstration of the consequence of a limited maintenance budget to the development of the condition of the road network.

6.5 Maintenance Strategy

One of the main issues in the context of maintenance backlog calculation is finding the optimum maintenance strategy. The term maintenance strategy comprises the accumulation of single maintenance measures or treatments on elements (or sections) of an asset during a given analysis period summarized for the whole road network.

It must be stated, that the optimization process for the maintenance strategies takes place on network level based on general information, even if it is related to single elements or components of the asset. However, for the final decision on project level sometimes different technical solutions can be necessary based on detailed investigations.

To get an optimum solution either the strategy costs must be minimized or the benefits must be maximized under given constraints. The decision about the types of treatments or measures, which should be taken into consideration for this major maintenance procedure, is in the responsibility of the road administration.

The costs (present value) for a strategy on a section or element are the sum of the costs of each single measure on this section or element. Benefits are normally defined as positive effects (after subtraction of all disadvantages) of a measure which is gained by the users but

also by the responsible road administration. The benefit can be expressed either by a monetary or by a non-monetary value. Monetary benefits are equal to monetary savings caused by single treatments and finally summarized over the whole analysis period. The non-monetary benefit is expressed by a surrogate in place of the monetary benefit describing the effect of the treatment or the whole strategy on the condition of the asset and weighted by the number of affected users. Independently from the unit of the benefit it is a comparable value which must be referred to a base value. This base value can be the “do-nothing-strategy” or the “routine-maintenance-only-strategy”.

Based on the results of the investigations and the experiences from the authors “Life-Cycle-Cost-Analysis” (LCC-analysis) is the recommended method for finding the optimum maintenance strategies for the sub-assets to be assessed. The decisive factor for the practical application of LCC-analysis is the availability of adequate performance prediction models (deterministic or probabilistic) which describe on the one hand the deterioration of the different characteristic of a sub-asset or component and on the other hand the impact of maintenance measures according to the condition.

LCC-analysis should be used on those assets where an economic assessment of maintenance measures is reasonable and efficient. Especially on road furniture LCC-analysis would cause some problems, on the one hand because of a lack of needed information and on the other hand as maintenance measures on road furniture are usually carried out on demand or as required and not as a result of a planning process. Thus a constant interval of maintenance measures (based on experiences) or replacements can be used as first estimation.

To find the optimum solution, which is equal to the optimum strategy two possible approaches subject to the given preconditions or requirements can be used in general as follows:

- Minimize the costs of the treatment strategies for keeping the predefined standards without budgetary limits
- Maximize the benefits of the treatment strategies under given monetary constraints (budgetary limits)

In comparison to “minimize cost optimization”, the restrictions for the “maximize benefit optimization” are defined by the available budget in each single year of the analysis period. For the time being the available budget for a single year is based on an estimation which can be different from the actual budget given by the money provider. So the output of the analysis must be compared anyway with the actual investments which enables to define the maintenance backlog.

As already mentioned, many administrations define the main objectives of maintenance activities by an aspired condition distribution. This means that beside budgetary constraints also condition related constraints must be taken into consideration which causes a mathematical conflict. However the maximize benefit analysis has the advantage that the yearly budget can be iterated, so that the given condition distribution can be stepwise approached by changing the budgetary constraints.

For the practical application of LCC-analysis special commercial software products (Viapms™, HDM 4™, etc.) or tailor made solutions are available today and used from the road administrations or concessionaires. According to [10] there are a number of optimization techniques available and implemented in different systems (linear programming, non-linear programming, etc.). To reduce the calculation time many systems are using heuristic

approaches to solve the optimization problem.

A decisive factor for the performance of LCC-analysis is the number of sections or elements and the different types of treatments to be taken into consideration. The number of sections or elements to be assessed is strongly dependent on the quantity and density of the underlying data. Especially for pavements it is recommended to use “longer” sections, which are homogeneous from the construction type and the deterioration or loading point of view. For structures the number of sub-assets should be reduced to a minimum as well. The advantage of a low number of sections or elements in the context of LCC-analysis is beside the calculation time also the needed time for the engineering assessment of the results and the following up work to generate a construction program and to calculate the maintenance backlog.

A detailed description of the process for finding the optimum solution including mathematical specifications can be taken from Annex B.

6.6 Maintenance Backlog

6.6.1 Recommended Definition of Maintenance Backlog

The analysis of the collected information from road administrations and concessionaires provides different definitions and approaches of maintenance backlog for road infrastructure assets. Some of them have been applied in practice for many years and are an inherent part in underlining the maintenance needs on the respective road networks.

Based on the collected and analyzed information the following general definition of maintenance backlog is recommended, which covers most of the existing approaches of maintenance backlog in use in the investigated countries.

> ***Maintenance backlog of the road infrastructure is the amount of unfulfilled demands at a given point of time in explicit reference to the predefined standards to be achieved. Maintenance backlog can be expressed in functional (non-monetary) or monetary terms and it refers to single components, sub-assets or to the whole road infrastructure asset of a given road network.***

An essential output of the analysis was the categorization of the different maintenance backlog definitions into the following groups:

- Maintenance backlog expressed in volume (non-monetary) terms (condition based):
  - Length, area or numbers of components which are below a predefined/lowest acceptable standard of the condition
  - Difference between the actual condition distribution (with main focus on the lowest class) and the predefined/accepted condition distribution (%)
- Maintenance backlog expressed in monetary terms (based on the previous one, condition based):
  - Total costs which must be invested to bring up the assets in “backlog” condition to predefined standard (total monetary backlog), absolute value irrespective of the available budget

- Additional costs (additional to available budget) which must be invested to bring up the assets to the predefined condition within a given time period taking into account the available budget (budgetary backlog)

In reality all four definitions mentioned above are closely connected and are forming several steps in a consecutive procedure as shown in Figure 3.

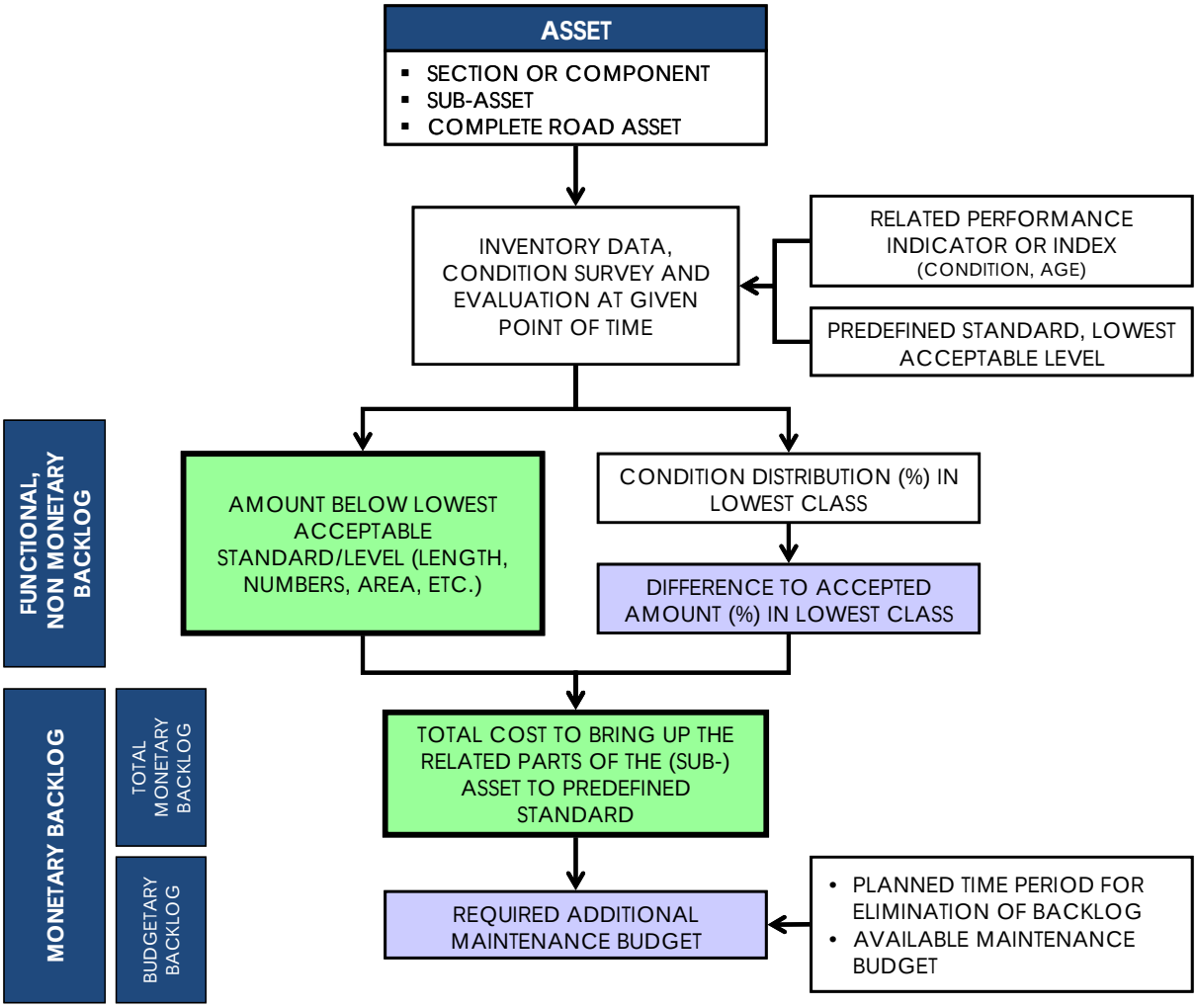


Figure 3 Steps for definition and evaluation of maintenance backlog

In most cases the input parameters are the result of condition surveys or inspections and the evaluation against defined threshold values. In some cases, however, based on engineering life-cycle experiences age can be used as a substitute for the condition assessment (e.g. defined age limits for bridge-elements, pavement layers, etc.).

The extent of application of this procedure depends from the situation and from the background. The highlighted green boxes in Figure 3 are related to the terms used in most of the investigated countries and thus recommended as minimum requirements for the use of maintenance backlog. The highlighted blue boxes are additional possibilities also used in some of the countries.

As mentioned, the total monetary backlog expresses the total necessary amount of money at

the given point of time to bring the respective asset to the predefined standard, without taking into account the available budget. The main input factor is the predefined standard.

The related budgetary backlog is very much influenced by the maintenance strategies, development of effectiveness, condition distribution and the planned time period for the elimination of the backlog, as the deterioration of the component or the asset increases by time, and some other issues.

A special approach for expressing the monetary maintenance backlog adds each year the difference between the estimated fund needs, which are based on estimated deterioration rate and projected to the actual year, and the actual maintenance budget. It can be used for a short time period only due to its increasing divergence from the actual condition.

From the analysis point of view it is difficult to decide which of the different approaches is the best one and should be stated as the recommended solution. All described definitions and theoretical approaches refer to an existing background and have their qualification subject to their field of application. Thus the recommended definition provides a general solution which can be adapted or transferred to the local requirements of the road administrations and concessionaires without any fundamental inconsistence. Nevertheless for reasons of internal and external argumentation and for the competition with other public budget sectors it is recommended to use the monetary expression of maintenance backlog whenever it is possible.

It has to be stated that the assessment of the maintenance backlog can be done for one component, one sub-asset, or for the complete road infrastructure asset depending on available data and the objectives for the further use.

Beyond this procedure described above a wider approach could be applied in the future. From literature (e.g. Swedish benchmarking study 2008 [40, 41], Snaith et al., 2008 [42]) it can be seen, that there is a trend to go further than to assess the maintenance backlog alone, which takes into account the situation of the components below a given acceptable condition only. This extension is taking into account also the condition of the other components being in a better condition and thus leading to the calculation of a condition-related road capital. This would also give a better picture of the asset value based on the real condition of all the components than the procedures using depreciation calculations based on general aging functions. Within this study no detailed investigation was made on this topic, but there seem to be several models under development. An extensive further research into this approach is recommended.

6.6.2 Calculation of Maintenance Backlog

The mathematical model for the definition of maintenance backlog must have an explicit reference to the predefined standards. For the mathematical definition of maintenance backlog these standards must be defined and available, otherwise it is not possible to make this calculation. To calculate the maintenance backlog an algorithm must be applied which consists of the following steps:

- Finding optimum maintenance strategy
- Calculation of representative values for the optimum strategy (e.g. distribution of condition, total treatment costs)

- Calculation of the respective maintenance backlog

The described calculation of maintenance backlog indicators is based on the categorization which can be seen in Figure 3. Independently from this categorization the calculated value can be expressed for one component or single sub-asset or the complete road infrastructure asset. Thus the maintenance backlog indicators can be subdivided into:

- Single maintenance backlog indicators (e.g. length of sections in poor condition of a certain condition attribute in year t, costs of measures for replacement of the extension joints in backlog condition on bridges in year t)
- Combined or cumulated maintenance backlog indicators (e.g. length of all sections where at least one condition attribute is in poor condition in year t, costs of measures for replacement of the extension joints in backlog condition on bridges)

The combination of single maintenance backlog indicators to more general values must be carried out carefully to avoid misunderstanding in the interpretation of the value and in combining things with different units.

A detailed description of the management process for finding the optimum solution including mathematical specifications can be taken from Annex B.

6.6.2.1 Functional, non-monetary Maintenance Backlog Indicators

Functional, non-monetary maintenance backlog indicators refer to performance indicators which describe the condition of a sub-asset or component of the road infrastructure (condition related maintenance backlog). Contrary to the monetary definition (see chapter 6.6.2.2) it is difficult to combine different assets with different units so that the following indicators are referring to single components or sub-assets.

According to Figure 3 condition related maintenance backlog indicators can be expressed in form of “absolute” values or as “difference” between an aspired condition distribution (defined as objective) and the actual condition distribution of a single or combined indicator. Based on the results of the investigations both solutions are used in practice. The amount below the lowest acceptable standard/level (length, numbers, area) is the basis for all condition related maintenance backlog indicators and can be mathematically defined as follows (see Figure 4):

$$MB_{cond,i,t,A} = \sum_{j} \left(X_{i,j,t} \cdot E_{j,A} \right) \tag{1}$$

subject to

$$X_{i,j,t} = 1 \text{ for } \left[PI^{opt}_{i,j,t,A} \leq z^{*} \right] \text{ otherwise } X_{i,j,t} = 0 \tag{2}$$

where

$MB_{cond,i,t,A}$ ..... maintenance backlog of condition attribute i of sub-asset A in year t

$E_{j,A}$ ..... extent of element j of sub-asset A

$X_{i,j,t}$ ..... decision variable of condition attribute i on element j in year t

$PI_{i,j,t}^{opt}$ ..... condition on element j of sub-asset A of condition attribute i in year t

z^{*} ..... backlog threshold value of attribute i

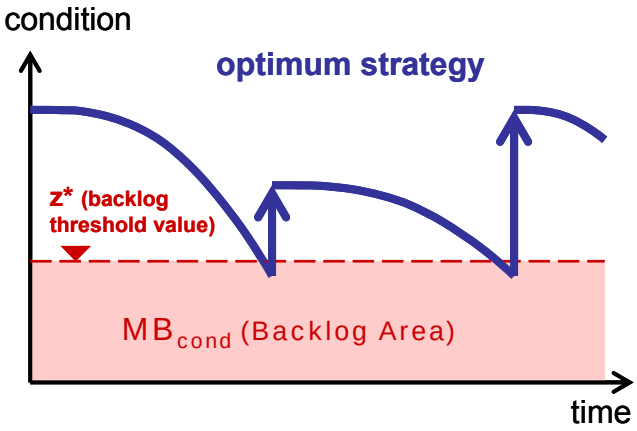


Figure 4 Condition related maintenance backlog MB_{cond}

This value refers to one single indicator (condition attribute) of a respective sub-asset or component. Based on it the following additional values can be calculated easily:

- Difference of the sum of elements (length, area, numbers, %, etc.) in maintenance backlog of the whole network for this single indicator and a given condition distribution expressed by an accepted amount of maintenance backlog (% in lowest class, see Figure 5)
- Sum of elements (length, area, numbers, %, etc.) of the whole network where at least one single indicator is in backlog situation in form of an
  - o absolute value or as
  - o difference to an given condition distribution expressed by an accepted amount of maintenance backlog (% in lowest class see Figure 5)

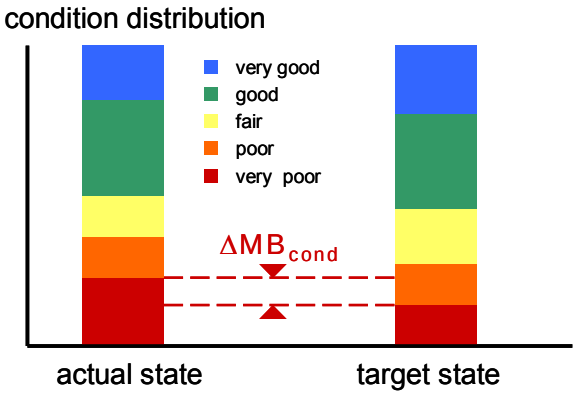


Figure 5 Differential condition related maintenance backlog ΔMB_{cond}

6.6.2.2 Monetary Maintenance Backlog

The monetary backlog refers to the maintenance needs, expressed in monetary terms (costs) to bring up the related parts of the (sub)-assets to a predefined standard. As seen in Figure 3 it can be expressed as “Total Maintenance Backlog” or as “Budgetary Maintenance backlog”.

Total Maintenance Backlog

The total maintenance backlog is the sum of costs to bring up the related parts to a predefined standard or at least to a defined better condition above the backlog threshold value. This is equal to the budget or fund needs.

$$MB_{monetary,A,t} = TTrtCst_t \quad (3)$$

where

$MB_{monetary,A,t}$ ..... total monetary maintenance backlog of sub-asset A in year t
$TTrtCst_t$ ..... present value of total treatment costs in year t

This value refers to one single sub-asset A. Based on it the following additional values can be calculated easily:

- Sum of costs of all sub-assets in one single year to answer the question how much money must be invested into maintenance activities
- Sum of costs of one single asset during a given time period to answer the question how much money must be spent into an asset in this time period (especially for concessions)
- Sum of costs of all sub-assets during a given time period to answer the question how much money must be spent into the whole road infrastructure in this time period

Budgetary Maintenance Backlog

According to the general maintenance backlog definition the budgetary maintenance backlog is the difference between budget or fund needs and the currently available budget.

$$MB_{budget,A} = TTrtCst_A - B_A^{act} \quad (4)$$

where

$MB_{budget,A}$ ..... budgetary maintenance backlog of sub-asset A related to a given time period
$TTrtCst_E$ ..... present value of total treatment costs for sub-asset A to a given time period
B_A^{act} ..... present value of current (available) budget for sub-asset A related to a given time period

This value refers to one single sub-asset A. Based on it the following additional values can be calculated easily:

- Sum of differences of all sub-assets to answer the question how much money must be additionally invested to achieve the objectives or goals
- Sum of differences of all sub-assets during a given time period to answer the question how the budgetary maintenance backlog is growing on the whole road infrastructure by time

6.6.3 Practical Application of Algorithm

The mathematical algorithm can be applied in practice on all types of assets and components of the road infrastructure, provided the needed input parameters are available. The algorithm is defined in a way that it can be adapted easily to the local framework conditions of the road administration or the concessionaire as well as to the different types of road. The algorithm can also be applied on gravel roads if the necessary standards and condition data are available.

In the context of the practical application of the defined maintenance backlog indicators not only a single value should be presented. From the authors' point of view a monetary value should always be displayed in combination with a corresponding non-monetary indicator or the effects of the maintenance measures (e.g. comparison of total benefits), however the effects are defined (safety effects, economic effects, environmental effects, etc.). Thus it is recommended again to use at least the following maintenance backlog indicators:

- Functional, non-monetary backlog: amount below lowest acceptable standard/level (length, numbers, %, etc.)
- Total maintenance backlog: costs to bring up the related parts of the (sub)-assets to predefined standard

Nevertheless it should be aimed to present the backlog with all possible indicators subject to the available input data and predefined standards.

The practical application of the maintenance backlog procedure focuses more on information concerning the network level (see use of maintenance backlog, chapter 6.8) but can be used on project level as well. The extent of use of maintenance backlog indicators on project-level and network level is strongly dependent on the accuracy and the density of the underlying information. If the information for maintenance backlog calculation is based on network level data the results will represent the network level. But in spite of that the process is independent from the field of application.

6.7 Consequences of Maintenance Backlog

For the stakeholders of the road network management, the information about the volume of the maintenance backlog is usually not sufficient enough today. Thus a more detailed description of short and long term consequences is needed with special focus on positive and negative effects in the following fields:

- Effects to the road users (accidents, loss of time, disturbance, etc.)
- Effects to the road operators / administrations (monetary/budgetary effects, effects on responsibility, etc.)
- Economic and socio-economic effects (strengthening of construction industry, preservation of jobs, etc.)
- Environmental effects (increase and reduction of emissions and pollution)

To which extent the different effects can be assessed by using maintenance backlog indicators is strongly dependent on the underlying performance indicators of the different sub-assets or components.

Maintenance backlog indicators which are based on user-specific (functional) performance indicators have consequences mainly for the road users. Then the consequences are usually described in terms of so-called traffic effects (vehicle operating costs, travel time, traffic safety, comfort, environmental impact etc.). Usually the consequences are described by comparing the traffic effects with the maintenance backlog to the traffic effects without the maintenance backlog. Nevertheless these consequences are interesting for both the road users and the road owner.

The consequences of maintenance backlog which take primarily structural performance indicators into consideration can be different. It has therefore a main impact for the road owner and future road users. The consequences are normally calculated using either simple regression or deterioration models.

6.8 Use of maintenance backlog

As there is a certain difference in the detailed definition of maintenance backlog between the investigated countries and projects and between the various sub-assets as well also the way of use can be different. Though in some countries there exists already a clear definition of maintenance backlog expressed in monetary terms together with a procedure for the calculation, in other countries the term is known and even used but only used in a more general way. This of course is also the reason for very different applications of estimated or calculated values for maintenance backlog throughout Europe and the way this backlog is presented and used for argumentation.

6.8.1 Use of Maintenance Backlog for different Sub-assets

One of the main outcomes of the investigation performed within this project was that there is a general difference in the use of maintenance backlog with respect to the different sub assets.

In almost all countries which were contacted and interviewed within the project for the pavements and the structures – and here especially for the bridges to a higher extent than for other engineering structures – a clear procedure exists how to express and/or calculate the maintenance backlog. In all the countries there exist related guidelines and manuals for the conditions survey, the survey and inspection intervals and for the evaluation of the lack in the condition of the respective asset related to a given minimum condition or standard. It is recommended to keep this approach and eventually improve the procedures for setting the threshold values and for the calculation of the budget-related optimum maintenance strategy.

For the part of the road furniture the situation is quite different. Besides some differences from country to country to what is included in this sub asset (e.g. earthworks, drainage) in almost all cases there exists neither a standardised inspection procedure nor a strict standard for the required condition as a basis for the assessment of a backlog. In almost all the cases the maintenance measures comprise a replacement of the object (traffic signs, guard rails, fences etc.). The maintenance backlog is calculated in these cases from the necessary expenses during the last years and from engineering judgement.

Generally it is recommended to improve this situation by developing related deterioration functions for the most important components to allow at least the calculation of a condition based backlog for these parts. Within a first approach a simple relationship between age and expected life-time of the component could be used. However, in a first step an inventory of the complete sub-asset has to be established, as it is underway or planned in many of the investigated countries.

6.8.2 Possibilities for the practical Use of Maintenance Backlog

Generally maintenance backlog can be used to assess the degree of target achievement based on actual value, estimation of annual cost of keeping status-quo and available budget. Then the result is compared to the goal and analysis is performed to explain the difference. This analysis is used for internal and external presentation and argumentation.

These different aspects are listed below.

6.8.2.1 Internal Use

This means the use of maintenance backlog within the given road administration. In many countries the internal use is rather limited for several reasons and reservations (see chapter 6.8.3). Possible applications are

- the backlog can (ideally) form the basis for allocating of grants for maintenance of sub assets
- to get reliable data for internal quality assessment
- use for internal management and for assessment of development trend for internal effectiveness
- benchmarking of condition and internal effectiveness between regions, sub-networks, etc.
- link to regional network level management, also based on benchmarking
- benchmarking between different road administrations: level of backlog for financing discussions
- network level management in the relation between the Director General and regional units
- indirect use for change of distribution of money between investment and maintenance because of increasing maintenance needs (shown by the trend)

One of the goals mentioned above is the use of maintenance backlog for assessing the internal effectiveness of the road administration. Internal effectiveness is expressed by the ratio between the road deterioration cost including the maintenance backlog and the maintenance costs spent per year. The internal effectiveness can be used in a similar way as the results of the backlog calculation for

- reporting to stakeholders (see also external use)
- budget allocation
- assessment of goals in and benchmarking between the regions
- analysis of results of re-organisations

This approach is applied in Sweden [41] and could be recommended for use or adaptation in other countries as well.

6.8.2.2 External Use

This means the use of maintenance backlog as basis for argumentation within negotiation with the related money providing ministry or government, the politicians and the public as well. This is also the basis for the acceptance of the need for money for the road sector in competition with many other sectors asking for public budgets, like e.g. social institutions. These arguments are of very high importance to clearly explain the need of additional funds which are required/expected because of the maintenance backlog.

Possible applications are

- to explain the procedure for assessing the maintenance backlog
- to better describe the consequences of increased backlog to road users and politicians
- to show the consequences of reduced budget (problem of understanding by public as long as condition is obviously good) related to
  - road user effects: higher transport costs, economic consequences, environmental consequences (noise, fuel consumption, air pollution, etc.); [heavy tool: speed reduction]
  - economic effects: increased depreciation if shorter life-cycle → financial consequence on budget; real estate definition (depending on the willingness of users to pay) versus technical definition (relation investment – maintenance) → more connections to users
- to compare theoretical (objective, measured) condition with subjective impressions of road users, evaluate road user's satisfaction
- to explain the importance of the standards used and the consequence, if standards are changed (lowered or increased)
- reporting and communication to policy level
  - department of transportation / ministry of transport: comparison of backlog from year to year (increase, same price level), periodic backlog reports
  - annual report, detailed to different assets
- information to parliament, long term planning
- communication to interested public and press (media strategy)
- budget negotiation
  - discussion with politicians
  - discussion with ministry
  - easier comparison of arguments with other competing public areas (health care, etc.)
- to show that maintenance creates local jobs
- better marketing to compete with other sectors (assets), big backlog in the whole public sector (improve the marketing)
- benchmarking between other countries (external); but sometimes problems with the comparability (different basis)

6.8.3 General Benefits and Reservations

The objective of the management of road maintenance is clearly to implement well known basics and procedures of operational management into the field of road administrations. This management has to provide the preconditions for reaching the defined targets and requirements of the enterprise. Brought to the level of road administrations this means that these in a first step have to define the targets which shall be reached. Based on these targets it is possible to assess in advance, whether on the one hand the required or available budget is in accordance with the fulfilment of these targets and if on the other hand it is possible to assess afterwards whether the available budget has been used adequately and with a maximum efficiency.

The definition of the target can - independently from the chosen indicator (single or combined performance indicators or a somehow defined user's benefit) - follow two different approaches which should be combined:

- Definition of a minimum service level, which has to be reached and kept and
- definition of a maximum accepted backlog (expressed either in percentage of the network, length or monetary terms)

The minimum service level must secure the user safety in any case and this parameter can also be combined with an average service level of the respective network also to express the users' benefit. The definition of a maximum acceptable backlog on the other hand has to ensure a sustainable planning for the necessary budget. Therefore for the definition of the backlog in the latter case especially structural aspects like bearing capacity of the pavement or age of the different components of the sub-asset must be taken into account.

With this approach of a twofold definition of the targets it can be avoided that maintenance measures are conducted only from a "cosmetic" viewpoint satisfying the service requirements while necessary structural measures are postponed leading to a peak of measures which are becoming urgent at a later stage.

From all the discussions and the interviews within this project it became evident that the calculation and use of maintenance backlog provides valuable benefit for the administrations. As described above it is possible to express the consequences of maintenance backlog for the present road users on the one hand and to the road administration and thus indirectly to the future road users on the other hand. Periodical reporting of the maintenance backlog and related time series can be used as a measure for evaluating the rate of preservation of the condition based road capital.

Independently from the way and the procedure the maintenance backlog is assessed or calculated the key factor always is the standard or the threshold value which is taken as a basis. The higher the standard the higher also the amount of backlog will be. Therefore the definition of the threshold values to be applied is of maximal influence. In this context it has to be distinguished between safety related indicators, which in all cases are related to the users' requirements, and other indicators.

For the first group almost no default can be accepted. But even for the safety related performance indicators often there is no clear functional relationship available. In most cases

threshold values are set depending on statistical approaches looking for the relationship between e.g. skid resistance or rutting and road accidents. The investigations during the COST action 354 (Performance indicators for road pavements [1]) also clearly showed the wide variety of the threshold values in use for the related indicators. Additional research in this matter is recommended looking for better functional approaches and wider harmonisation.

For the second group of indicators, like structural inadequacy or not user safety related deficiencies, a more flexible definition can be used. Therefore in many countries the standards or threshold values for these indicators are somehow related to the possibility of fulfilment, this means to the existing budget and the given acceptance by the public and consequently by the politicians. For the road administration this is not really satisfying as the users and also the public are not aware of these deficiencies in a short and medium term and therefore will not understand repairs based on these needs and thus not be willing to provide the related budget or to expand the existing maintenance budgets for these works. But as expressed earlier such postponement of maintenance measures to a later stage in many cases will lead to a rapidly deteriorating asset, which then will be evident for the users because driving comfort and/or safety are already influenced negatively. But at this stage the necessary improvement can be much more expensive than preventive maintenance at the appropriate time. Therefore also for these indicators a realistic objective definition of threshold values is necessary. On the other hand the assessment of the maintenance backlog using the limits given by the available budget can be a very valuable tool to express and to display the related further degradation of the road assets.

Some reservations against the use of maintenance backlog have been recorded and should be taken into account when setting up this procedure. The calculation procedure should not be too complicated in order to be practicable and transparent for the related users and addressees. As the quality of the results is directly linked to the quality of the input data the accuracy and the availability of these data is of highest importance. Therefore the degree of detailing must be well adapted to the existing data without too much estimation. Sometimes the lack of data can cause problems for the assessment of a realistic maintenance backlog.

Furthermore the use of maintenance backlog calculation for the internal benchmarking can lead to rejections within the administration itself. Therefore it is important to implement this procedure within a process which includes the regional administrations and the responsible personal in an open and transparent way from the very beginning, convincing them of the benefits of the use of the maintenance backlog assessment also for their duties and tasks. This is especially important also because of the fact that these regional administrations are to a big extent also the providers of the necessary input data.

With respect to possible reservations from the external partners like ministries and politicians it is important that the basis for the backlog calculation is realistic. There is often the accusation of overestimation of needs and wishes which in turn leads to rejection of the results. Permanent argumentation and transparency is needed to avoid this negative effect. The presentation of results of periodic calculations of internal effectiveness can support this effort.

Two other aspects for the successful presentation of maintenance backlog have been addressed already. One is the clear distinction between the needs for raising the existing

condition to the “normal” condition level and to the needs for upgrading the overall condition to a higher level than earlier required (higher actual standards due to new regulations etc.). In the latter case the necessary additional costs normally have to be covered by the budget for investments. This distinction between maintenance and investments for new roads must also be made consequently to receive a clear and representative picture of the real maintenance backlog. The second aspect is the necessity to take into account changes of the underlying unit prices to avoid that the condition change (calculated monetary backlog) is masked by increased prices.

The special situation for concessionary roads (PPP-projects) was mentioned sometimes during the interviews. In this case there are clear requirements laid down in the maintenance contract and in principle no backlog is allowed at all. Therefore a comparison with the situation at the road network under public administration is not relevant.

The implementation of maintenance backlog calculation can be a complex procedure that needs a lot of work to be done in advance (data base, condition survey, etc.). This can in some cases lead to reservations and objections to start with the whole process at all. Therefore it is recommended to start from a minimum level of requirements (primarily safety related indicators) and to extend the data basis and the whole procedure by a stepwise approach, if not all the mentioned information are available from the beginning.

7 Dissemination

7.1 Database

In general, a database is simply a storage and indexing system for information. When a set of data consisting of many parameters is being considered, or when multiple data sets are to be considered, it becomes advantageous to develop a storage and indexing scheme for these results. The storage and indexing system will ensure that information, details of where, when or by whom the data were recorded, etc. is not lost or misinterpreted over time.

To compile the database for the ERANET ROAD project “Maintenance Backlog – Estimation and Use” Microsoft ACCESS 2003™ has been used. Microsoft ACCESS 2003™ was chosen for several reasons, including the ubiquity of the software (bundled with MS Office), the compatibility with other Office applications, and the capability to use a separate programming language for accessing/interfacing the database.

The current database includes the results of the accomplished interviews within this project. Thus data of altogether 11 interview partners are stored in a fixed data structure. This database structure is strongly connected to the developed questionnaire. The following data is stored in different tables of the database:

- Interview Partners
- Description of the Network
- Description of the Organisation
- Definition of Road Maintenance Activities
- Management Systems
- Definition of Maintenance Backlog in General
- Use of Maintenance Backlog
- Condition of surveys of Pavements
- Performance Indicators for Road Pavements
- Assessment of Pavements
- Definition of Maintenance Backlog for Pavements
- Categorisation of Structures
- Condition Inspection of Structures
- Performance Indicators for Structures
- Assessment of Structures
- Definition of Maintenance Backlog for Structures
- Categorisation of Road Furniture
- Condition Inspection of Road Furniture
- Performance Indicators for Road Furniture
- Assessment of Road Furniture

- Definition of Maintenance Backlog for Road Furniture
- Cross Asset Management and Management Systems

A more detailed description of the structure, the content and the use of the database can be taken from Annex C. The main menu of the database program is shown in Figure 6.

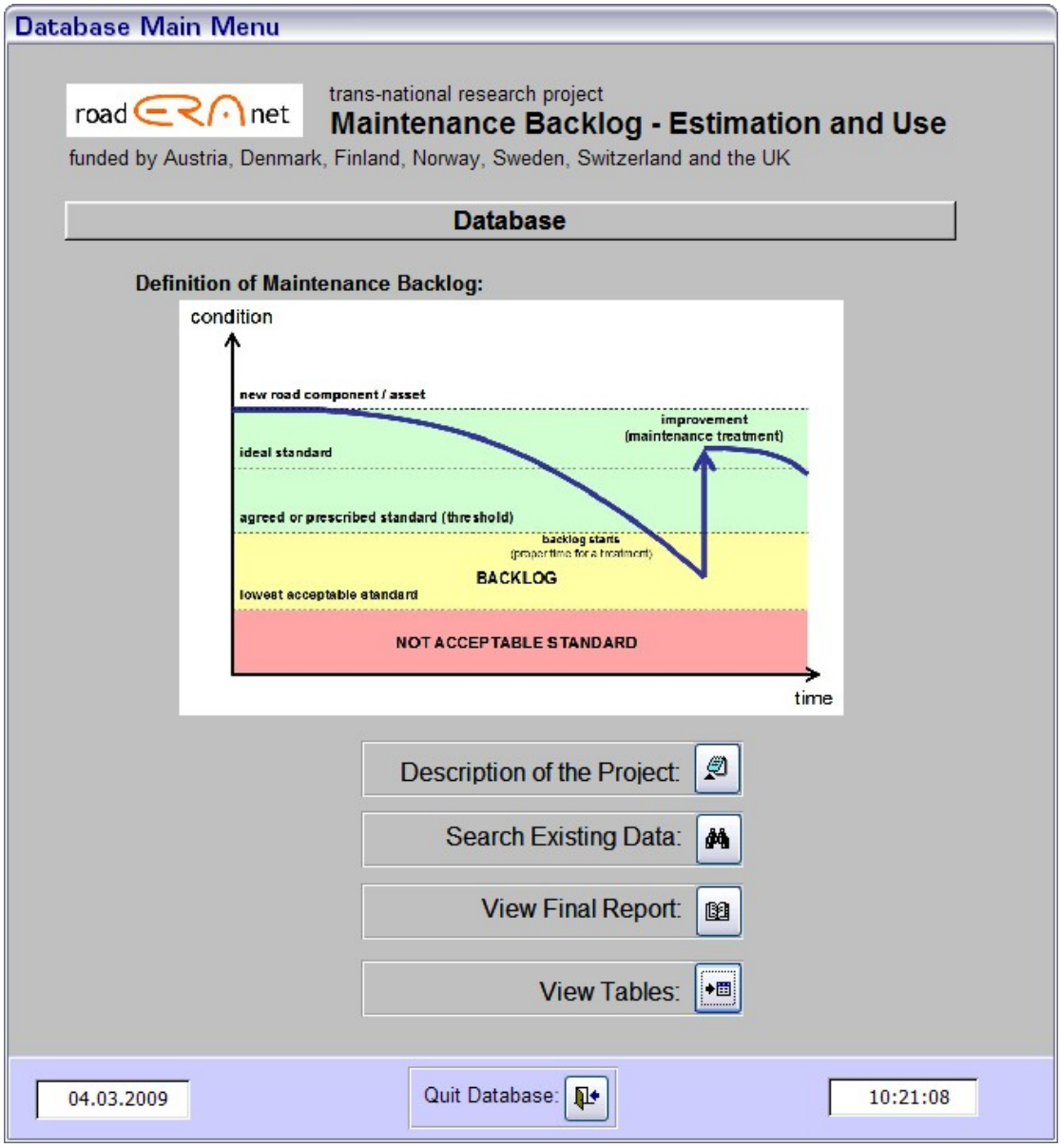


Figure 6 User interface of the database program

7.2 Website

During the project phase it was necessary to exchange data and information with the PEB but also within the Consortium. Therefore a special web-site was provided by the Consortium with the functionality as follows:

- General information about the project
- Download / upload area for the exchange of information

The download and upload area is protected with restricted access authorization (private area). The access to the private area is available for the PEB and all partners of the Consortium.

PMS-Consult hosted this web-site during the whole project and an additional six months afterwards at least.

The URL of the web-site is as follows:

http://www.pms-consult.at/enr

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