AUTOMAIN

Augmented Usage of Track by Optimisation of Maintenance, Allocation and Inspection of Railway Networks

Project Reference: 265722
Research Area: SST.2010.5.2-1

D1.1: Market and Customer Requirements for Planning and Scheduling, Faster Maintenance and Faster Inspection

Deliverable Reference No: D1.1

Due Date of Deliverable: 31/10/2011
Actual Submission Date: dd/mm/yyyy

Dissemination Level		
PU	**Public**	

Document Summary Sheet

This document contains the result of the work in the first phase of WP1 of AUTOMAIN. The main objective of this phase is to define requirements that can be used as an input and reference for the other WP's. The requirements have been founded on a thorough investigation of existing practices in rail (via a questionnaire) and road, a desktop study of existing benchmarks and workshops to define the requirements themselves.

The document is the report covering deliverable D1.1.

Additional information	
Subproject / workpackage:	WP1
Author :	Ted Luiten (PR)
WP1 Participant name:	John Amoore (NR), Gunnar Bauman (DB), Chris Bouch (UoB), Ulla Juntti (LTU) , Christoph Lackhove (DLR), Per-Olof Larsson-Kraik (TV), Anton Lamper (PR), Jon Paragreen (NR), Raja Rebai (Eurodecision), Burchard Ripke (DB), Clive Roberts (UoB), Henk Samson (Strukton), Francis Sourd (SNCF), Lisandro Quiroga (TUB)
Document date:	31 October 2011
Status:	Draft

History			
V1		first draft	Initial document written by Chris Bouch.
V2		updated	
V3		updated	
V4	26 Oct 2011	Updated	Final draft. Structure of chapters adapted to the D1.1 description document. Comparison with road networks added. Requirements chapter reviewed and reorganised. Conclusions added. Several appendices added.
V5	31 Oct 2011	Updated	Text in chapters 2.4 and 6.0 adapted. Disclaimer added to the overview in 3.2. General description and executive summary added. Requirements renumbered. Description of requirement 12 added. Several changes based on review comments.
V6	31 Oct 2011	Final	All changes accepted. Integral text of the questionnaire added in App.A.

Table of contents

Executive Summary:

This document represents deliverable D1.1 of the AUTOMAIN project. AUTOMAIN, being an EU-funded project within the 7th framework, aims at reducing the necessary possession time on railway track in order to create more capacity for freight trains.

The first work package in AUTOMAIN (WP1) has an objective to create a state-of-the-art overview of existing means and methods (by benchmarking) and use that information to define requirements for the following work packages. This objective reflects the system engineering approach that has been used to structure the project.

In order to gain the necessary insight the following work has been done:

- A two-phase questionnaire has been developed and sent out to the participating inframanagers. The questions have been defined in close cooperation with the WP-leaders, in order to cover their need for information as well.
- An investigation has been don e to find out in what way road network maintenance might have interesting good practices that can be transposed to railways.
- A desk research has been done to use the available information form earlier research and publication.

After analysis of the desk research and benchmarking work it became clear that it will not be possible to come to certain overall conclusions. The differences in approach and strategies between the several parties are too big for that. On the other hand some general trends can be mentioned:

- A clear difference can be found between IMs that own the infrastructure themselves and those that don't. This situation affects e.g. de decomposition models and the defined KPI's.
- A same difference can be found between IMs that outsource their work and those that don't. This choice obviously affects the processes of planning of track access etc.
- We notice a huge spread in lead-times to obtain possessions for maintenance related activities (lead-times differ from 12 weeks till 48 months). Although this is also affected by the nature of the work to be done, it seems that some companies have a smoother and more efficient process than others.
- Only some IMs differentiate their KPI's according to the type of infrastructure or line. Existing mechanisms for the measurement of performance vary considerably between IMs. Trafikverket and ProRail are known to have advanced performance indicator systems.
- Not all IMs are able to link track access periods to certain types of work. E.g. because they outsourced the work and are no longer involved in the choice of what to do when.

Based on the research we also conclude that some common fields of interest can be identified that are within the scope of AUTOMAIN. We found that:

- Almost all IMs are searching of better support in the planning of maintenance activities and possession planning. Many already have existing tools, but either they are outdated or they show difficulties in handling the necessary big amount of data.
- The evaluation and assessment of asset condition is a shared field of interest. Also in this subject several IMs indicate a search for supporting tools. The found situation in maintenance of road networks shows that there might be some advance knowledge in this field available there.

Regarding the research in Highway engineering we conclude that the interesting benchmarks are:

- condition based preventive maintenance
- continuous condition monitoring
- prediction of asset condition for decision making
- planning and scheduling with aim to minimize traffic disturbance due to maintenance tasks.

Overall we conclude that, based on the information from the questionnaire and the desk research, we are not able to define a kind of general view of the state-of-the-art. The IMs involved organize their work too differently. Nevertheless they all are looking for ways to reduce track usage for maintenance and gaining efficiency in their planning and maintenance processes.

We consider the information gathered in this work as a “state-of-the-art picture”. The diversity itself is an important result. And the details are important information for the different WPs to start their development (e.g. WP5 uses many of the detailed information found via the questionnaire).

Based on the collected information, a set of requirements has been defined. In order to found these requirements on a common basis, a brief view on future railway developments was written during workshops. Eventually these exercises led to the requirements that are described in this document.

Overall WP1 concludes:

- The overall image of the infrastructure managers’ ways of working related to track access planning and performance measurement is too ambiguous to come to an overall conclusion.
- The information gathered by using the questionnaire and by the desk research gives lots of opportunities to be used as a basis for further research and developments.
- Exploring the results of the benchmark and the work done earlier, it becomes clear that all IMs are searching for improvements in the maintenance and possession planning and in asset condition assessment. These subjects are in line with the proposed work within AUTOMAIN.
- For AUTOMAIN the found results can be considered as a “state-of-the-art picture”, which will serve as an “ AS-IS”-situation for the innovations to be developed.
- The developed characteristics of the future railways are based on several personal opinions and discussions between specialists. This result should not be considered as THE view on future developments. But for AUTOMAIN it can certainly be considered as a future reference.
- The work package succeeded in defining a coherent set of requirements that will form a strong basis for further work in the upcoming WPs.
- The developed requirements will be used as a reference for the work in the several work packages. On one hand they will give focus for the planned developments and on the other hand it will provide a sort of yardstick to evaluate the results in the latter phase of AUTOMAIN.
- There will certainly be a necessity to realign the requirements with the contents of the DoW written earlier. The requirements may be considered as the results of growing insight in what to be achieved. But in some situations this might create the need for a bigger budget that is not available. This means that every WP-leader has to evaluate before they start in what way and to what level they will be able to meet the given requirements. Similarly the need for more specific knowledge about best practices may be pointed out in that stage.

1.0 Introduction:

Freight shippers are finding it increasingly difficult to get the train paths they need on the European railway network. Increased passenger demand has reduced the number of opportunities available to run freight trains during the day. It has also forced infrastructure managers (IM) to concentrate maintenance work in the night-time hours, when passenger traffic is low. The result is a reduction in the overall availability of freight paths.

The AUTOMAIN project aims to reverse this trend, by improving the efficiency of track maintenance to reduce the amount of time the railway is closed to traffic. This will be achieved through the development of innovative technologies and procedures in a number of areas including: analysis and optimisation of maintenance processes; higher speed infrastructure inspection; higher speed track maintenance; modular infrastructure components and sub-systems, and; automatic maintenance scheduling and planning systems.

AUTOMAIN takes a three-stage approach to increasing the availability of freight train-paths. The first stage aims to reduce current night-time maintenance track closures through the application of best-practice maintenance technologies and procedures. The second investigates the development of innovative techniques to facilitate maintenance during the day, in short possessions between trains. Finally, the third explores the development of radically new techniques and procedures to facilitate maintenance at line speed.

Each of the three stages has different requirements in terms of technology and process innovation; each will therefore, deliver its freight train capacity improvement to a different timescale. The first stage is viewed as the least complex; therefore, a target date of 2026, fifteen years from now, has been assumed for delivery on most key routes. For some companies 2026 may not sound very ambitious, as they already have strong efficiency targets in the near future. For a more general view, 2026 seems a reasonable timescale though. The third stage, however, is viewed as the most complex, requiring significant changes to the existing track, to support development of radically new technologies; a target date of 2051, forty years from now, has therefore been assumed. The second stage falls between the other two in terms of complexity and has an assumed target date of 2036, twenty-five years from now.

AUTOMAIN's research is guided by a set of stakeholder functional performance requirements. These describe the functions that stakeholders, such as infrastructure managers, contractors and regulators, want the system to be capable of doing and the level of performance required. AUTOMAIN's work package 1 (WP1) is responsible for developing these requirements. The project's other work packages will use them as a set of guidelines, to develop the new technologies and processes necessary to satisfy the stakeholders' capability needs.

Development of the stakeholder functional performance requirements involved research to: benchmark existing infrastructure maintenance performance in the railway and highways fields, and; generate a set of capability requirements, describing what the maintenance system must be capable of doing to support each stage of the three-stage approach to freight train capacity improvement.

Benchmarking involved a desk-top study of existing benchmarking literature and a questionnaire-based survey of current IM practice. A small, UK-focused IM-workshop was used to gather an initial set of capability requirements, which was reviewed, amended and added to by IM members of WP1.

The benchmarking exercise gathered data on four aspects of infrastructure maintenance:

- asset management strategies,
- policy and performance; maintenance and inspection processes;
- integration of maintenance in the timetable,
- automated maintenance in road networks.

The results were analysed to create a description of the state-of-the-art for infrastructure maintenance, and a summary of the principal criteria used to measure performance.

The results of the benchmarking exercise were combined with those from the capability requirements elicitation process, to create a set of functional performance requirements. This involved IM members of AUTOMAIN WP1 in validating the original capability requirements, and adding additional requirements where omissions were identified. The capability requirements were then converted into functional performance requirements, through the addition of performance criteria, constraints, assumptions and verification criteria.

This document describes the complete functional performance requirements elicitation process. It begins by describing research to establish the state-of-the-art and performance benchmarks, and the workshop process used to develop capability requirements. It then goes on to explain the work done on the capability requirements, to create a set of functional performance requirements together with associated assumptions and constraints.

2.0 Summaries of benchmarking and desk top reviews.

2.1 Benchmarking study using the AUTOMAIN questionnaire

2.1.1 Introduction to the questionnaire.

The AUTOMAIN project has been built up according to the system engineering principles. This includes the definition of overall results and objectives at the start of the project. One of the aspects in the first phase is to search for potential good practices and ideas that can be used later on in the project. We choose to make a questionnaire. The goal of the questionnaire is to provide an overview of good practices and ideas to the members of Automain. It can be used as a start for further investigations. Therefore the questionnaire contains high level questions and no questions for detailed data collection. The target group is the inframanagers of Automain: Network Rail, SNCF, Deutsche Bahn, ProRail and Trafikverket. Finally after consultation with the WP1 leader also Strukton completed the questionnaire.

The questionnaire provides input for all of the deliverables within Task 1.1: Functional requirements:

- T1.1.1: Asset management strategies, policies and performance
- T1.1.2: Maintenance and inspection processes
- T1.1.3: Integration of maintenance in the timetable
- T1.1.4: Comparison with automated maintenance in road networks
- T1.1.5: Definition of market and customer requirements

The process of making the questions is listed below:

- ProRail made a first proposal
- This proposal was reviewed by the members of WP1 and the other WP leaders. Questions were defined by some WP's and incorporated in the questionnaire in order to assure that the information needs form all WP's would be covered.
- The first proposal was updated and send to the Infra Managers
- The first proposal was used by DLR to make a questionnaire for road networks (results are summarized in chapter 2.2, the full can be found in appendix C)
- The answers were gathered by ProRail
- The first plan was to visit all the inframanagers to get more detailed information. Due to costs, planning problems (summer holiday) and efficiency we decided to analyze the results and opt for a second round of (additional) questions by email.
- University of Birmingham and ProRail analyzed the results. It became clear that the initial questions were not specific enough to be the basis for defining the market and customer requirements (T1.1.5 Definition of market and customer requirements).
- WP2 leader formulated specific questions to be able to get started.
- The initial questions, additional questions and answers are in appendix A.
- Results of the additional WP2 questions are not part of this appendix. WP2 will report separately on these issues.

2.1.2 Questionnaire: a summary of the answers.

A summary of the answers from the questionnaire is provided here. The full results of the questionnaire can be found in Appendix A of this report.

Q1.1 What are the strategic company goals of the infrastructure manager? Describe the background of each strategic goal and explain the KPI's that are related to each strategic goal.

In Sweden the Ministry of Enterprise, Energy and Communications uses the European Commission's transport white paper as the basis for producing a 12-year strategic plan for the Swedish transport system as a whole (SFS 2009:236 2009, SFS 2010:160 2010). The plan's principal strategic goal is to, *'Ensure the economically efficient and sustainable provision of transport services for people and businesses throughout the country"* (Näringsdepartementet 2009). In addition there are two sub-goals: **the functional goal**, '*The design, function and use of the transport system will contribute to provide everyone with basic accessibility of good quality and functionality and to development capacity throughout the country. The transport system will be gender equal, meeting the transport needs of both women and men equally"*, and; **the impact goal**, '*The design, function and use of the transport system will be adapted to eliminate fatal and serious accidents. It will also contribute to the achievement of the environmental quality objectives and better health conditions'*. The Ministry of Enterprise breaks down these goals into a series of medium-term goals, which together with funding, are passed annually to Trafikverket (the government agency with responsibility for the strategic planning of roads, railways, shipping and aviation). Trafikverket breaks down the medium-term goals into more a detailed set of delivery tasks, and monitors implementation using performance indicators, including: punctuality; network robustness (down time); traffic information; ride comfort; safety, and; infrastructure availability.

In the Netherlands there are four strategic ambitions. These are: 100% delivery reliability and 0% accidents; 20% reduction of life-cycle cost per train kilometer; 50% more trains on the busiest corridors, and; satisfied customers.

In the UK, Network Rail's high-level goals are set by the Office of Rail Regulation (ORR). A new set of goals is provided for each five-year control period. The current set of goals are to: improve efficiency (reduce costs by 22% over the 4 year period); increase safety (reduce the safety risk factor by 3%); maintain capability (e.g. line speed, gauge etc) at April '09 level; increase capacity (defined by projects such as Thameslink, Reading station re-modelling, Airdrie to Bathgate re-opening, and Felixstowe-Nuneaton line upgrade for increased freight traffic); improve availability by 37%; asset stewardship index (a large range of KPIs to measure the long-term management sustainability of the railway infrastructure ensuring that the assets are not degrading over each control period), and; improve customer satisfaction (based on passenger satisfaction surveys).

In Germany the strategic company goals are: safety (monitored using a range of safety indicators); environmental protection (monitored using measures like carbon emissions, noise levels and amount of weed killer applied); reduction of life-cycle costs, and; increasing quality and capacity (using a range of measures like increase of reliability, number of speed reductions, delay minutes, and train punctuality).

In France the railway has signed a performance contract with the government contract, which defines the infrastructure modernisation objectives and implementation methods, to improve quality, services and safety. The objectives include: the provision of fair access to the network for passengers, shippers and train operators; better project management and delivery; fairer pricing; greater commitment to sustainability, and; higher intensity use of the network. A wide range of measures are used to monitor performance including: volume of freight traffic on the freight-oriented network (in millions of train path/km); RFF response rate to late train path requests within the deadlines promised to the client; number of train path-days affected by unscheduled works possessions, and; punctuality to within 5 minutes.

Q1.2. How strict is the separation between the asset owner, asset manager and service provider (maintenance contractor)? Describe who has the role of asset owner, asset manager and service provider; who are the major stakeholders, and; explain the advantages and disadvantages of this model in relation to the allocation of train-free periods.

In Sweden the government is the asset owner, while Trafikverket is the asset manager. Asset maintenance is carried out by service providers, working under contracts led by Trafikverket. The arrangement is similar in the Netherlands, where ProRail acts as asset manager on behalf of the government, and leads the contracts for maintenance.

In the UK the situation is different in that the asset manager, Network Rail, also owns the assets; however, the UK government still has a role in terms of setting high level requirements for things like network capacity and operating efficiency. Network Rail carries out most maintenance in-house, but it does use contractors for some specialist activities such as track renewal. In Germany and France the arrangements are similar. For Germany, DB Netz owns and manages the assets; some maintenance work is carried out in-house, contractors are also used. In France, RFF acts as asset owner and manager, with maintenance let out to a variety of contractors. SNCF Infra manages the maintenance of the network.

Generally, it is the asset managers who have the responsibility for creating the railway timetable, with built-in allowances for train-free periods; however, train operating companies are major stakeholders in the process and have a major influence. ProRail's experience is that the more parties involved in the timetable planning process, the more difficult it is to reach a solution that satisfies everyone.

Q1.3 How do service providers get the possession time they need, and what effect does flexible working have on this? What does flexible working mean for things like: the amount of out-sourcing; the type of contracts and the size of the asset managers' workforce?

In Sweden long term planning of major infrastructure projects takes place over a rolling 5-year time span. During that time, projects across a range of transport modes are identified and prioritised. Once that has been done, detailed possession planning and timetable development takes approximately 16 months. During the first 4 months Trafikverket selects the major engineering works it wants to carry out. These are sent out for stakeholder comment, prior to being included in the Network Statement, preparation of which takes 2.5 months. The Network Statement, which also includes the principles governing the rights of train operators to run trains, is published in month 7; at the same time, work is going on to identify possessions required to support planned maintenance,

and negotiations are taking place with maintenance contractors and train operators regarding their requirements. These are completed by month 11 and the final draft of the timetable is prepared for circulation to stakeholders at the end of month 13. Stakeholders have the opportunity to comment and suggest minor amendments, before the timetable is issued in month 16. Flexible working is only feasible if there is very good communication between the stakeholders. Sweden has found that outsourcing work does not adversely affect this, but care must be taken to ensure that the interests of the contractor are aligned with those of the asset manager. Outsourcing has lead to specialisation of staff: Trafikverket's staff concentrates on strategic planning, while the contractors concentrate on site work.

In the Netherlands there is a different approach. For normal maintenance work each section of track has 5.5 hour night-time possessions built into the timetable. When contractors bid for maintenance contracts, they confirm their ability to carry out the work in the time available. Possessions for large projects are built into the timetable 1.5 to 2 years in advance. ProRail do not see flexible working as particularly beneficial: there is always the risk that it will lead to an increase in costs.

In the UK, Network Rail carries out most of its maintenance in-house. The availability of possessions is governed by two documents: the Route Utilisation Strategy, which analyses the demand for train paths on each route and tries to make sure best use is being made of available capacity, and the Rules of the Route, which specifies an annual programme of track closures (both at night and for longer periods at weekends) for each line. Possessions are actually built in to the timetable in consultation with the train operating companies. There is some flexibility in terms of agreeing possessions, but only up to 26 weeks before the date of the possession. Beyond that point, flexibility has a cost in terms of compensation to the train operators.

In Germany, major works requiring closure of a line for days or weeks have to be planned up to 4 years in advance. Shorter possessions are organised as part of the timetable planning process, and generally take place at night. Flexible working is assessed in terms of its impact on track availability and cost: flexible working would either have to deliver reduced costs for infrastructure managers, more access for train operators, or a combination of the two.

Arrangements in France are similar to those in Germany. Major possessions are organised 3 years in advance, while smaller ones are planned a year in advance. Flexible working is generally not considered, because it would require a complete re-working of maintenance policy and probably result in an increase of cost and complexity.

Q1.4 What key performance indicators (KPI) do you use related to planned and unplanned availability and possession time?

In Sweden, KPIs relate to governmental performance requirements, and are monitored as part of a balanced scorecard. These top level KPIs (safety, network availability, asset reliability, quality and condition, finance, customer orientation and environment) are applied to the network according to line category. The KPIs are translated by Trafikverket into internal performance indicators, which include: capacity utilisation; capacity restrictions; passenger and freight train delays due to

infrastructure; number of passenger and freight trains delayed due to infrastructure; track standard (Q factor); traffic volume; maintenance cost per track kilometre; number of accidents involving rail vehicles; number of accidents at level crossings; energy consumption; use of environmentally hazardous materials, and; use of non-renewable materials). Within Trafikverket performance quality is also monitored against six headings, each with their own performance indicators, as follows: punctuality (% on-time arrival; train delay); robustness (down-time); traffic information (availability of information; passenger satisfaction; trip planner); ride comfort (% passenger satisfaction; Q factor); safety (injuries/fatalities; vehicle damage); usability (% availability of network).

The arrangements in the Netherlands are similar to those in Sweden, except that KPIs are not applied according to line category. The government sets performance targets for ProRail on the basis of the following KPIs: capacity; delivered train paths; partially delivered train paths; train path quality; punctuality; major disruptions; major disruptions on main routes; average of five worst performing KPIs; passenger modal transfer quality; passenger security; travel information quality during disruptions; accessibility; availability; maintenance time, and; downtime. The KPIs are translated into internal performance indicators, which are used as part of a balanced scorecard to manage overall performance. ProRail also uses a set of safety performance indicators, which monitor: train/train collisions; derailments; accidents while on duty; electrocution; transfer incident; collisions on level crossings, and; suicides.

The UK is also similar to Sweden in that KPIs are provided by the government, via the Office of Rail Regulation; however, performance is not monitored on the basis of line category. A range of performance indicators are used to monitor the impact that maintenance has on the train service; however, more important in terms of deciding what sort of maintenance to carry out are the asset condition performance indicators. These indicators are listed in detail in the questionnaire in Appendix A

In Germany the KPIs are: the number of speed restrictions; the number of delay minutes, and; the number of delayed trains. Money also plays an important part, because maintenance contractors have to pay DB Netz a penalty if they disrupt train services, and DB Netz has to pay compensation to operators whose trains are delayed due to infrastructure problems. Quality indicators are related to funding from the federal government. The indicators include: theoretical loss of travel time; number of infrastructure defects; platform functionality; asset quality; power supply security; mean time to repair faults; age of infrastructure, and condition of bridges and tunnels. Additional assessment indicators are: delay minutes; total train kilometres; number of train stops at each platform, and; energy consumption.

In France, performance indicators are derived from the performance contract between RFF and SNCF. However, there are four KPIs in the infrastructure management agreement, which are: quality of track geometry; number of train delays; number of train delay minutes, and; the mean time to repair faults.

Q1.5 What trends, developments and opportunities do you see in the length or the effectiveness of the train free periods

In Sweden the current, dynamic possession planning arrangements are regarded as too complicated. A move must be made towards a system where enough pre-planned train free periods are available for the amount of maintenance necessary. A trade-off needs to be made between enough time for maintenance, and the desire to run more trains.

In the Netherlands the target is 'more-for-less': that is, running more trains with less infrastructure. Like in Sweden, ProRail is concerned about the trade-off between efficient maintenance and the train free periods required, and the need to find more capacity. It has developed its own tools to help maintainers make these decisions. However, the situation is even more complicated, because ProRail wants to reduce the safety risk to its staff by reducing the number of people working on the track while trains are running. ProRail is developing a new maintenance planning system (Maintenance Planning 2020) to help with this. The Netherlands share Sweden's concerns, that flexible maintenance working adds to costs. This trade-off needs to be better understood.

Network Rail has a number of projects underway, designed to help improve maintenance efficiency in the future. These are: greater use of in-service rail vehicles to monitor asset condition; greater use of lineside equipment to monitor asset condition; modular S+C designed to speed up maintenance and renewal; high output track renewal trains, and; new road/rail vegetation clearance equipment. Network Rail predicts a trend towards shorter possessions, and that payments for night working will push up costs; however, increasing automation of maintenance work will help mitigate this. Network Rail sees a trend towards doing more work in shorter possessions, helped by more efficient taking and handing back of possessions. Research suggests that flexible maintenance to support a 'seven day' railway would cost an extra 100 million Euros, but could facilitate the addition of an extra €120 million in freight train revenue.

DB Netz sees a trend towards preventive maintenance, based on mid to long-term planning. This will reduce the amount of maintenance carried out at short notice and result in better management of track capacity. Increases in maintenance tend to be as a result of increased traffic. DB's strategy for addressing this is to move in the long-term towards higher track quality, better able to carry high levels of traffic. Track access charges, which are related to maintenance costs, are used to help balance demand for train paths, but more paths will only be provided if more trains mean more revenue to the maintainer.

In France innovation is seen as one way of increasing the safety of track maintenance staff, while trains are running. The trend is towards more efficient packaging of maintenance work, using longer possessions.

Q1.6 What good practices/benchmarks do you know that European infrastructure managers use to link company goals with asset management strategies.

There has been a number of European benchmarking studies, which are described in more detail in section 2.3 of this report. With regard to individual infrastructure managers, Network Rail's policy of decomposing high level KPIs into a range of detailed performance indicators, linked to maintenance

tasks, is interesting. Performance data is stored on computer and can be accessed by engineers through a user interface called 'the dashboard': this is a reference to the dashboard of a car, which provides the driver with information about the status of the vehicle. In France, SNCF have developed advanced infrastructure degradation models, and improved maintenance efficiency greatly using SAP for asset management. Trafikverket and ProRail are known to have advanced performance indicator systems. Good practices on track include: four-sleeper tamping machines; high speed grinding; preventive maintenance; optimised track construction, and; specialised teams for S+C maintenance.

Q1.7 Available data on performance killers and possession over-runs

In Sweden this information is currently being gathered. In the Netherlands data is available on possession over-runs for planned maintenance work, but it is not possible to identify which maintenance activities are the causes. In the UK information is available on those planned activities that have most impact on track availability. The 'gut' feeling is that the activities with most effect are: wet bed removal; tamping and; overhead line electrification maintenance. In Germany the 'gut' feeling is slightly different; there worst performance killers are: tamping; grinding, and; renewal of track components.

Q2.1 Process to plan a possession

The strategy in Sweden is a mix of CBM and predetermined maintenance (PdM) i.e. time based or tonnage based. There are internal regulations for PdM for some of the S&C maintenance, for insulted joints etc. In Sweden the process for CBM starts with track inspection. Based on the results, the maintenance contractor decides what maintenance is required; the decision is based on Trafikverket regulations, which differ depending on line category. This is the case for condition based maintenance (CBM).

The inspection data is recorded on a computer system (BESSY) and analysed on another (OPTRAM). Work is carried out in possession if the track inspection data indicates track condition is outside acceptable standards.

In the Netherlands and UK possession planning is carried out to a detailed timetable, which is described in the questionnaire in Appendix A. France has similar arrangements, though the answers to the questionnaire do not provide quite so much detail. In Germany, the need for a possession is determined by track quality, the tonnage that the line has carried, and the availability of plant.

Q2.2 What are the relevant timescales for booking a possession?

In Sweden this depends on how quickly the contractor moves his application through the planning process, which is described in the questionnaire. In the Netherlands long possessions have to be booked 21 weeks in advance, while shorter ones need 11 weeks. Possessions can also be arranged at very short notice for emergency works. Network Rail's process has already been described in 2.1 above. In Germany the timescale is between 14 weeks and 2 years, depending on the size of the job. The arrangement in France is described in the questionnaire.

Q2.3 Incentives, bonuses or penalties for possession time

There is no bonus system in Sweden at the moment, but there are plans to introduce one in the future. In the maintenance contracts – there is a clause for exceeding the possession time. An incentive contract has been tested in a traffic-contract between Banverket and SJ AB. In France there is also no bonus system, though there is a high-level arrangement between SNCF and RFF, which takes account of track availability. In the Netherlands there is a bonus/penalty system for possessions, but this does not apply to all types of work: for example, tamping is not covered by the system. There is a well established system in the UK, where Network Rail has to pay compensation to train operators if trains are delayed due to the infrastructure. Sometimes large sums of money are involved: in 2009/10 Network Rail paid 170 million Euros in compensation. In Germany there are penalties if a possession is not handed back in time, but the sums of money involved are commercially confidential. The French use a global bonus/penalty arrangement between RFF and SNCF covering track availability and train delay.

Q2.4 Does the maintenance equipment involved affect decisions on possessions?

The method of working, and in particular arrangements for protection of maintenance staff, play a big part. More detail is available in the questionnaire.

Q2.5 Involvement of the infrastructure manager in the efficient use of possession time

All of the infrastructure managers play some role in helping to ensure the efficient planning of possessions. The involvement tends to be more direct in UK, Germany and France, where much of the maintenance is carried out in house.

Q2.6 To what extent do safety rules affect the organisation of possessions?

Safety demands/regulations can be both performance killers and cost drivers! In all cases, safety plays an important part. However, there are national variations in what is considered safe.

Q3.1 Do you use planning/scheduling software for maintenance activities?

Most of the infrastructure managers use planning tools, but experience a variety of problems: in the Netherlands it is the inability to gain an overview of the relationship between all maintenance activities, and; in the UK and France it is incompatibility between databases. More detail about individual planning tools is provided in the questionnaire.

Q3.2 Would an automated planning tool be useful?

All infrastructure managers agreed such a tool would be useful

Q3.3 Estimation of percentage of possessions for each work type

See the questionnaire in Appendix A

Q3.4 Are tasks combined to reduce possession time?

All infrastructure managers combine tasks.

Q3.5 Are task combined successfully in most cases?

Generally, combining tasks is successful; however, there can be problems, which are described in more detail in the questionnaire.

Q3.6, Q3.7 and Q3.8 See questionnaire

2.2 Highway Engineering

This chapter contains the two main paragraphs of the comparison report. The full report can be found in Appendix C, the questionnaire itself and the received answers are available in appendix D.

2.2.1 Introduction

Benchmarking is a process to measure products, services and practices of a company against those of the industry leader. It is the search for best practices in order to reach excellence. In this particular case, practices in maintenance for rail and road are being compared. Although both fields are of the transportation sector, processes and practices cannot be compared in detail. Therefore, the benchmarking is carried out on a functional level. The main topics to be focussed on are asset management strategies, policies and performance; maintenance and inspection processes; and planning and scheduling of the maintenance.

To gather the relevant information, three separate ways have been taken. First, the authority for road construction and traffic in Lower Saxony, Germany, was visited. The interview has then been used to design a questionnaire also based on the one sent out to the railway infrastructure managers. There have been replies by the road authorities of the Netherlands (Rijkswaterstaat) and of Sweden (Transverket). Finally, existing studies on road maintenance have been taken into account, especially the EU project ISTIMES (Integrated System for Transport Infrastructure surveillance and Monitoring by Electromagnetic Sensing).

2.2.2 Conclusion

Concluding the asset management strategies, policies and performance, different business models in the rail and the road domain lead to specific company goals. The business relation between railway infrastructure and transportation companies affect stricter constraints considering planning and scheduling. Lines are sold to transportation companies which gives them the right to use it. Thus traffic disturbances directly influence the infrastructures income, considering lines which could not be sold or compensation which had to be paid. Railway infrastructure companies have more emphasis on revenue compared to road domain. The goals of railway infrastructure companies are therefore similar to road-PPP[1] consortiums.

Due to significantly larger road network, road infrastructure managers rely very much on PMS[2]. The measurement of the road condition takes place in larger time scales, i.e. at least each year for rail and every 1-4 years for roads. To predict the road quality is therefore inevitable for decision making between measurements. Nevertheless, full automation of decision making is not suitable for the

[1] PPP: Public Private Partnership.
[2] PMS: Pavement Management System, which is a highway asset management system.

road domain. Software solutions deliver suggestions for upcoming maintenance tasks and the spending of limited resources. The final decision is based on expertise and engineering knowledge. Diagnosis and prognosis in the road domain can be seen as the benchmark for condition based maintenance.

Maintenance and inspection processes are pushed towards condition-based, preventive maintenance in both domains. In-service inspection without traffic disturbance is state of the art for highway engineering and benchmark for the railway domain. On the other hand, continuous monitoring of road assets takes place only for some tunnels or bridges. The project goal of AUTOMAIN to continuously monitor the condition of the whole rail network therefore can be seen as the benchmark.

For the planning and scheduling of the maintenance, the reduction of traffic disturbances is a main goal for railway infrastructure managers. For road maintenance, this optimisation criterion is less important. The scheduling of maintenance is far more complex for rail due to timetables and reduced opportunities for detours. The coordination between administrations on different levels and in different areas is a huge challenge for highway engineering due to a larger network. Combining maintenance tasks takes place in both domains for efficiency reasons. There are hints that a very strong compression of tasks seems to bear safety issues for road.

Summing up, the benchmarks are condition based preventive maintenance; continuous condition monitoring; prediction of asset condition for decision making; planning and scheduling with aim to minimize traffic disturbance due to maintenance tasks.

2.3 Desk-top Study

The European Commission-funded BEST Programme (Railway Working Group, 2002) defined benchmarking as, 'A practical tool for improving performance by learning from best practices and understanding the processes by which they are achieved'. In their paper on the use of maintenance performance indicators (MPI) for benchmarking the railway infrastructure, Åhrén and Parida (2009) stressed the difference between MPIs and benchmarks: MPIs are used by companies internally to understand the present maintenance status and the opportunities for improvement; benchmarks on the other hand, are measures of performance recognised by industry as being suitable for measuring performance between companies. To ensure therefore, that benchmarking is effective, variations in the way each infrastructure manager compiles its own MPIs must be accounted for: not an easy task.

2.3.1 European Commission-sponsored Research

<u>IMPROVERAIL</u>

IMPROVERAIL, a major European Union research project to improve track maintenance and develop planning tools to increase capacity, concluded in 2003 (IMPROVERAIL, 2003). The focus was on business process re-engineering, with benchmarking techniques being used to identify best practice.

The project review states that long-term decisions by infrastructure managers (IMs) should be aimed at satisfying the demand for train paths; short-to-medium term decisions should be aimed at

resource optimisation, while delivering contracted track access. It also identifies life-cycle costing and efficient infrastructure charging systems as having an important part to play in improving the efficiency of track maintenance.

The aim of the benchmarking part of IMPROVERAIL was to help with the creation of methodologies for comparative analysis within railway infrastructure firms. The approach adopted covered development of definitions and harmonization of concepts for benchmarking methodologies, to final assessment of the operational, commercial and managerial performance of the railway infrastructure managers, using an integrated approach. This process included the definition of proper and specific indicators for the industry.

The benchmarking exercise showed that railway infrastructure companies are large, complex, and their scopes of operation differ between European countries. Existing mechanisms for the measurement of performance (such as the measurement and definition of train delay) vary considerably between IMs. The influence of geography, infrastructure and operational characteristics, and local economics can mask the effects of efficient maintenance procedures. Comparability of performance measures between European IMs is therefore, a major barrier to benchmarking.

The Business Process Remodelling (BPR) Approach to track maintenance procedure improvements used the following steps: Step1 - Understand the environment; Step 2 - Set the Objectives; Step 3 - Use tools to accomplish them; Step 4 - Produce outputs; Step 5 - Recommend activities / implementation. Benchmarking was carried out in Step 2. The key characteristics of the benchmarking methodology developed and proposed in IMPROVERAIL was that it should cover all the dimensions of the IM, and not only the traditional dimensions related to costs or reliability.

The IMPROVERAIL benchmarking approach suggested that Key Performance Indicators (KPIs) should be divided into four hierarchical groups: Core; Second order; Contributory, and; Pre-cursor. ImproveRail used: train-km per track km, train-km per route km and tonne-km per main track km as the core KPIs. Second order KPIs were broken down on the basis of passenger and freight traffic and covered percentage utilisation of track capacity and the percentage of available time given over to track maintenance. The project did not benchmark individual maintenance activities, but was interested in establishing the impact of different maintenance processes on KPIs, including cost measured using LCC techniques, together with how train services should be planned to make the most of any additional capacity created.

<u>INNOTRACK</u>

Innotrack (INNOTRACK, 2010) is the European railway industry's response to the need to develop a cost effective, high performance track infrastructure. The project involved the development of innovative solutions aimed at the reduction of investment and maintenance-related infrastructure costs. As such, it was not in the first instance a benchmarking project; however, one of the early tasks in the project involved identification of the priorities for innovation, which could be of use to AUTOMAIN in the development of the functional performance requirements. The innovation priorities are shown in Table 1 in Appendix B.

2.3.2 Published Research

The literature suggests that the European Commission and Europe's national railways started to address the issue of performance benchmarking in the mid-1990s, initially with some work by UIC on its **Lasting Infrastructure Cost Benchmarking (LICB)** programme, which is still on-going. LICB is focused on maintenance and renewal expenditures and investment costs (UIC 2004): maintenance and renewal are analysed using an integrated life-cycle cost approach for entire railway networks; investment costs are compared for track renewal projects. Key performance indicators used by LICB include: asset utilisation (annual train frequency on main tracks for both passenger and freight); annual expenditure per track km, and; average maintenance and renewal expenditures. Activity-specific information is also generated: for example, unit costs for sleeper and ballast renewal. However, publically available information from LICB is limited, because of its commercial sensitivity. It is not known therefore, whether tamping and grinding activities have been benchmarked.

In 2000, the EU established **"BEST" ("Benchmarking European Sustainable Transport")** as part of the 5th Research Framework, working on airports, road transport and rail. In June 2001 BEST decided to establish two railway working groups: one would examine the contractual relationships between railway operators and their respective governments, the other would examine issues of railway performance. The railway performance working group consisted of eight countries: Austria; Denmark; Finland; Japan; Hungary; Netherlands; Norway and UK. Its work concentrated on punctuality; the closest the working group got to benchmarking infrastructure was to identify the percentage of delays that resulted from infrastructure problems.

In 2003 the LEK consultancy in conjunction with TTCI of the United States and the Halcrow Group, carried out a study into **international benchmarking of track maintenance practices** (LEK et al, 2003); this was on behalf of the United Kingdom's Office of Rail Regulation, the Strategic Rail Authority, and Network Rail. The study was carried out in three phases. Phase 1 involved the identification of, and contact with a group of comparator railways comprising 7 from Europe (including the UK), 2 from Australia and 3 from North America. Of the 12 railways identified in Phase 1, 8 agreed to participate in Phase 2, which consisted primarily of the first round of face-to-face meetings. The meetings investigated the policies, processes and working practices of the comparator railways in managing their track assets. The aim was to identify best practice in each of the comparators across a range of practices. After the meetings, the data collected was analysed and 8 practices were selected for further, more detailed work in Phase 3, with the ultimate aim of providing quantified benchmarking data.

The 8 areas covered the following practices:

- slab track / asphalt track / formation wide sleepers – experience in Germany suggested that providing a more stable track form lowered maintenance costs, though initial implementation cost was higher than ballasted track;
- Asset intervention – experience in Spain suggested that the use of differentiated track standards was one way to reduce maintenance costs on lightly used lines;
- Trend analysis – experience in North America suggested that monitoring trends in track condition was an effective way of helping to plan maintenance interventions;

- Life-cycle modelling – experience in France suggested that life-cycle models could predict the optimum time for component renewal, though this may be before the component is completely worn out (the leaders in life-cycle modelling, OeBB and ProRail, were unfortunately unable to take part in the study)
- Possession planning – experience in North America suggested that the efficiency of track maintenance work could be increased by carrying out as much work as possible in a few, unusually long possessions. This was similar to the findings of the LEK report on Radical Possessions Strategies, which was also carried out in 2003, under the guidance of Network Rail, The Office of Rail Regulation and The Strategic Rail Authority;
- Procurement – experience in Spain suggested that there were efficiency benefits in making use of out-sourced plant and labour;
- Maintenance technologies (Ballast distribution) and (ballast tamping and regulation) – experience in North America suggested that there were efficiency benefits in using new, high output plant.

Predicted potential cost savings for Network Rail on these activities were a maximum of 7%; however, the publically available report did not provide data benchmarking the maintenance activities themselves.

LEK completed another study in 2003, this time **benchmarking variations in unit costs** within Network Rail across the regional business units (LEK 2003). The aim was to provide an estimate of how much Network Rail could reduce cost by achieving internal Best Demonstrated Practice (BDP) consistently across the company. BDP was defined as the lowest normalised unit cost in a given cost category across all regions and areas. One of the key challenges of the project was obtaining sufficient robust data. At the time information systems in a number of areas such as asset condition, detailed job costings and operational metrics, were not as developed as they now are. The emerging results were discussed with managers throughout the project. This was particularly helpful in normalising unit costs to take account of a variety of structural factors allowing fair comparison between regions and areas. Care was taken not to confuse structural factors requiring cost normalisation, and efficiency factors, where normalisation was not required. The project found that there were potential cost savings of 11 to 24% on maintenance activities if BDP were achieved nationally. This was across a total of 21 maintenance activities covered by the study; however, the list of activities covered was removed from publically-available copies of the report.

ProRail continued with research into benchmarking and in 2004 an article appeared in Railway Gazette International, describing work carried out to expose **'real railway cost drivers'** (Swier, 2004). This compared drivers of cost on three different types of railway (heavy-haul in North America, high efficiency metros in south-east Asia and mixed traffic lines in Europe). The work showed that the drivers of maintenance cost were strongly related to the type of railway being considered. These findings confirmed those of the IMPROVERAIL project: that geography, infrastructure and operational characteristics must be taken into account when trying to compare the performance of different railways

In 2008 BSL consultancy carried out a study **to benchmark the efficiency of Network Rail with other European infrastructure managers** (BSL, 2008). The study covered maintenance and renewal costs

of track and was based on data from the UIC Lasting Infrastructure Cost Benchmarking study. The study points out that to get a realistic picture of any efficiency gap, comparisons need to be based on steady-state activity levels; it is important to know whether there is a maintenance backlog that may be affecting the efficiency figures

The report notes that the most efficient IMs approach maintenance on the basis of a consistent output-focused planning and work programme, with freezing of deadlines and strict compliance; the report calls this the 'clockwork' mentality. However, it suggests that an industrial, engineering-driven, track possession and utilisation approach should be adopted, because there appears to be a strong correlation between work site length and unit costs, with unit cost falling as worksite length increases. Asset configurations should be standardised to capture economies of scale and facilitate use of leaner processes, and a genuine 'quality' approach to maintaining asset condition and using skilled labour and high-output plant.

2.3.3 Other Research

The work of the **Asset Management Club Project (AMCP)**, between 2007 and 2011 ((Lloyds Register/BSL, 2009) and (Civity 2011)), provided some useful insights into the different approaches being tried by IMs on a range of maintenance activities. It was not intended to be a benchmarking exercise in the strict sense of the term; instead, it compared what AMCP partners were doing at the time in a number of key areas. As such, it provides context to the requirements work of AUTOMAIN, gives an indication of which areas Infrastructure Managers (IMs) regard as being the most important, and provides some insight into development trends.

AMCP grew out of an asset management study commissioned by Banedanmark in 2007. It focused on topics from the original study, identified as being of importance to the participating railways. Initially, AMCP partners were: Banedanmark (BD); Banverket (BV); Deutsche Bahn (DB); Jernbaneverket (JB); Network Rail (NR); Oesterreichische Bundesbahn (OeBB); ProRail (PR), and Schweizerische Bundesbahn (SBB). DB and OeBB withdrew before the final stage and were replaced by Infrabel (IB). AUTOMAIN is grateful to all AMCP partners for their permission to publish some of the project findings.

AMCP's first stage ran between August 2008 and January 2009. Three workshops were held, the results from these analysed, and a final report produced. This stage concentrated on three work packages: KPIs and condition assessment; Activity planning, and; Life-cycle costing (LCC). The final report presents the findings in four chapters: KPIs; Condition assessment; Activity planning, and; LCC. In 2010 stage 2 of the project took place, studying asset registers and RAMS/LCC.

In **Stage 1**, the study began by investigating **Key Performance Indicators (KPIs)**. It found that line categories play a big part in KPI selection and maintenance prioritisation. All AMCP partners segmented their networks into line categories, generally according to traffic types and utilisation. Half of the partners were found to have a broadly similar, three-strand approach: namely, primary, secondary and rural/freight lines. The remaining partners differed from this only in that their categorisations had more strands. Most of the partners used similar criteria for line categorisation:

typically traffic density; traffic type, and; importance to society. However, one partner based its categories on axle load and vehicle weight, while two more used a combination of both approaches.

Most AMCP partners were found to have concluded agreements with government, based on KPI-based targets, but less than 50% of these resulted in the partner having a financial penalty if they failed to meet the target. The focus for the targets was chiefly safety and infrastructure availability, with all of the partners being set targets for these. Asset reliability, quality and condition, together with finance and customer satisfaction seemed to be regarded as less important, with only approximately 50% of partners being set targets. Environment came last, with just over 30% of partners being set targets

It was recognised by partners that an interface between external and internal KPIs is required to facilitate the translation of government targets into internal company targets, which can be applied to daily business processes. However, the findings suggested that perhaps only 25% of the partners had such a structure in place. With regard to internal KPIs, it was noted that railway infrastructure performance is affected by a wide variety of factors; therefore, KPIs have to be chosen carefully, so that together they create a balanced scorecard. The study found that at least 30% of the partners had a balanced scorecard structure for KPIs, including things like: customer satisfaction; safety; availability; finance; asset reliability; environment, and; efficiency. Track KPIs were regarded as being of particular importance; examples include: compound quality figure; mean time to repair; track geometry target values, and; weekly delay minutes and related causes.

All AMCP partners agreed that **Condition Assessments** were crucial to an optimised track maintenance planning system. As if to confirm this, all partners had detailed regulations for condition assessments, predominantly differentiated according to line categories. The study findings suggest that the railways are currently making a transition from a situation where knowledge about assets and asset condition is held in the heads of railway staff, to one where asset condition data is held electronically, and analysed to generate the necessary asset knowledge. In support of this change, automated inspection of track is becoming more common; however, expensive and potentially dangerous manual inspection methods are still used, and there is a question mark over whether the human operator can ever be entirely replaced. A wide range of patrolling frequencies was found among AMCP partners: 25% patrolled between once a week and once a month; 37% patrolled between once and twice a year, and; the rest adopted a frequency somewhere in between. There was also a wide range of frequencies for inspection by ultrasonic measurement train: one of the partners inspected high speed lines every two months, while three partners carried out inspections every three to four months, and the remainder between once and twice a year. In most cases the actual frequency of inspection was dependent on line speed, with higher speed lines receiving more regular inspections.

Technology plays an important part in condition assessment. One partner had adopted a diversified procurement strategy to try to enhance competition: this involved using a mixture of single-function trains designed to carry out specific tasks and multi-functional trains that can carry out a range of tasks. The single-function trains are cheaper to lease and easier to use, which produces cost savings, while the multi-functional trains can collect a wide range of data on things like: overhead line

condition; rail surface; track geometry; rail cross-section, and; geographical position. Some of the multi-functional trains can operate at high speed (125 mph or 200 KPH). At least one partner was found to have outsourced all their track and infrastructure condition monitoring work; however, others have kept theirs in-house

Some partners used fixed installations on the track side to monitor the condition of particular assets: for example, one partner had fixed equipment monitoring the condition of switches, giving early warning of failure. It also had equipment in place to record the tonnages that particular track segments are carrying. Some partners have fixed equipment mounted on trains, to monitor things like the pantograph forces. Partners have introduced grading systems to help them assess infrastructure condition across a number of parameters, and at least two partners have grading systems to help them manage their bridges.

Evaluation of condition data is a complex business. Only two of the partners were found to be running integrated systems for maintenance management, incorporating failure management, design, maintenance activity planning and long term planning. Two more were in the process of developing such tools, while the rest had integrated systems with limited functionality, or a range of standalone applications. All of the partners were working to develop and improve their systems, though the emphasis varied from IM to IM: one was focusing on the introduction of an off-the-shelf, integrated maintenance package; one was looking at degradation rates of track and overhead line; one was trying to move towards maintenance-free infrastructure, and finally; one was concentrating on better management and analysis of the data collected.

For **Activity Planning**, AMCP found that generally, maintenance and renewal activities were identified at the local level, and then bundled at the regional level, with modelling and strategic planning being carried out at the national level. In some cases, bottom-up and top-down approaches were carried out together, to check how well strategy matched what was happening out on the track. In some cases top-down involved setting targets for the regions and local work units, and the KPIs against which performance would be monitored. With regard to strategy, one of the partners wanted to move to a maintenance 'steady state' situation within thirty years. Maintenance and renewal activities were found to have different planning cycles and budgets. Renewal planning horizons were between two to ten years, while the vast majority of partners had maintenance planning horizons of twelve months. 50% of the partners held only annual planning meetings, while the remainder had monthly meetings.

There was found to be a variety of ways of bundling maintenance and renewal activities: within a track section; across two or more track sections, and/or; across track sections and time. All railways considered bundling in the planning process but only a few demonstrated a systematic and comprehensive approach. Bundling/possession management was done at both the regional and head office level, but the key to success appeared to be coordination of local asset knowledge and central system know-how. About half of the partners looked ahead two to three years when trying to bundle activities. The remainder were split equally between those who looked a year ahead, and those who looked ahead more than three years. Only one of the partners restricted itself to bundling only track activities; the others bundled track with other maintenance work. Optimised bundling/possession management appeared to have major benefits in terms of reducing costs and

train delays. One partner analysed a number of scenarios to identify the best, another set up a special department to work on minimising cost and possession time.

Among the partners there appeared to be two approaches to activity prioritisation: the scoring approach, and; the clustering approach. Just over half of the partners used the scoring approach, 25% used the clustering approach and one partner used a combination of the two. The scoring approach involves the selection of criteria (for example, economics, safety, quality and performance), and weighting factors such as geography, importance of line and the potential impact of the work. The number of scoring criteria used was found to vary considerably among the partners using this system; the same was the case for weighting factors, but line importance featured in most cases. Activities removing safety-critical conditions on primary lines were generally found to attract the highest priorities

Almost all AMCP partners have developed tools to support their activity planning. Bundling and optimisation were not generally included in the planning tools; however, some partners used stand-alone tools to facilitate such calculations. One drawback to this approach was that the output from bundling or scenario calculations had to be manually transferred to the planning tools. In many cases planning tools were available to be used by both local and central staff. Some tools were found to be reaching their limits of their ability to handle the large amounts of data involved; therefore, some partners were looking for new, off-the-shelf solutions.

The study found limited information on cost modelling tools used by the partners. One of the models was based on unit costs and output measurements, with three basic levels of unit rate: composite (total spend divided by total volume of materials); category (total spend on renewals divided by volume of renewals), and; job (spend for S+C renewals on that job divided by number of S+C units on that job). This model had detailed rules as to what should and should not be included in the cost calculations, to ensure the resulting unit costs were comparable from job to job. Another model took more of an 'expert' approach, with multi-disciplinary teams working in workshops modelling quantitative and qualitative data under the guidance of a trained moderator and using IT tools to assist the process. The third method involved the creation of a business model aimed at forecasting the effects of changes to the total network, lines or single projects, resulting from the planned work.

Application of **Life-Cycle Costing (LCC)** was found to be widespread among partners, but differed greatly in terms of the areas in which it was used. Half of the partners used it for long-term planning, 75% used it to help them make product/system decisions, and just over half of them used it to make decisions about maintenance strategies; however, only about 30% of them used it to help with decisions on project scenarios. None of the partners used LCC in all of these areas, half of them used it in three of the areas, and 25% of them used it in only one of the areas. Approximately 30% of the partners used one LCC tool across all asset classes, the others used a range of asset specific tools. Partners approached LCC from a range of different perspectives, seeing it as: a tool to help them with product decisions; a tool to facilitate a wider, project and business view, and; a tool to help them drive long-term improvement across all asset classes.

At least two of the partners were found to use LCC to help them assess and prioritise maintenance and renewal projects. Generally a four-stage approach was used involving: scoping the project; identifying potential project scenarios; assessing the scenarios, and; reporting.

Stage 2 of AMCP investigated asset registers and LCC coupled with Reliability, Availability, Maintainability and Safety (RAMS). The **Asset Register** work found a variety of approaches to asset inventories, ranging from centralised applications to a number of stand-alone applications linked together. Inventories structured by asset category (track, signalling etc.) were found to be very similar; however, the hierarchies below that level, and the number of data items showed a large spread. Good asset data was acknowledged as being vital to strategic planning; however, only a small number of examples could be identified, where the link between basic asset data, cost and performance data was clear, and where this data could be retrieved through one application.

Asset register(s) were found to be widely accessible to staff within each partner IM. Direct access for external parties was much more limited; however, a few infrastructure managers had transferred the responsibility to provide complete asset data during a construction phase to the contractor and provided structures, guidelines and tools to support them in this.

A comprehensive set of measures for better data management were identified including: detailed process descriptions; regular audits; data collection campaigns; frequent best practice meetings; training of users, and; change management support. Monitoring use of the asset register and the information stored there was seen as one important aspect of good practice.

Almost all partners were found to have implemented Geographical Information Systems (GIS) to some degree; however, few partners had developed fully integrated systems, with GIS being seen as a useful add-on to the asset register and related applications. One of the reasons for this was thought to be that implementation requires substantial investment and a convincing business case.

With regard to **RAMS/LCC**, partners appeared to approach implementation from a number of different perspectives: namely, improving technology of single assets such as switches; supporting renewal or investment decisions; creating scenarios for network development; defining specifications for procurement, and; modelling railway system performance with different base values of reliability. The factors used to inform decision-making, or used in simulations varied among the partners. Partners also tended to concentrate on single asset categories/objects, such as track and signalling, rather than taking a system view. This was thought to be because in general, these factors account for most of the failures with a direct impact on network availability. The extent to which RAMS/LCC techniques were applied varied between partners, as indicated by the differing levels of resource allocated.

2.4 Analysis of Benchmarking Results

The findings of the benchmarking exercise were analysed to identify the performance criteria to be included in the functional performance requirements.

While reading the previous work it becomes clear that it will not be possible to come to certain overall conclusions. The differences in approach and strategies between the several parties are too big for that. On the other hand some general trends can be mentioned:

- A clear difference can be found between IMs that own the infrastructure themselves and those that don't. This situation affects e.g. de decomposition models and the defined KPI's.
  - A same difference can be found between IMs that outsource their work and those that don't. This choice obviously affects the processes of planning of track access etc.
  - We notice a huge spread in lead-times to obtain possessions for maintenance related activities (leadtimes differ from 12 weeks till 48 months). Although this is also affected by the nature of the work to be done, it seems that some companies have a smoother and more efficient process than others.
  - Only some IMs differentiate their KPI's according to the type of infrastructure or line. Existing mechanisms for the measurement of performance vay considerably between IMs. Trafikverket and ProRail are known to have advanced performance indicator systems.
  - Not all IMs are able to link track access periods to certain types of work. E.g. because they outsourced the work and are no longer involved in the choice of what to do when.

Based on the research we also conclude that some common fields of interest can be identified that are within the scope of AUTOMAIN. We found that:

- Almost all IMs are searching of better support in the planning of maintenance activities and possession planning. Many already have existing tools, but either they are outdated or they show difficulties in handling the necessary big amount of data.
- The evaluation and assessment of asset condition is a shared field of interest. Also in this subject several IMs indicate a search for supporting tools. The found situation in maintenance of road networks shows that there might be some advance knowledge in this field available there.

Regarding the research in Highway angineering we conclude that the interesting benchmarks are:

- condition based preventive maintenance
- continuous condition monitoring
- prediction of asset condition for decision making
- planning and scheduling with aim to minimize traffic disturbance due to maintenance tasks.

Overall we conclude that, based on the information from the questionnaire and the desk research, we are not able to define a kind of general view of the state-of-the-art. The IMs involved organize their work too differently. Nevertheless they all are looking for ways to reduce track usage for maintenance and gaining efficiency in their planning and maintenance processes.

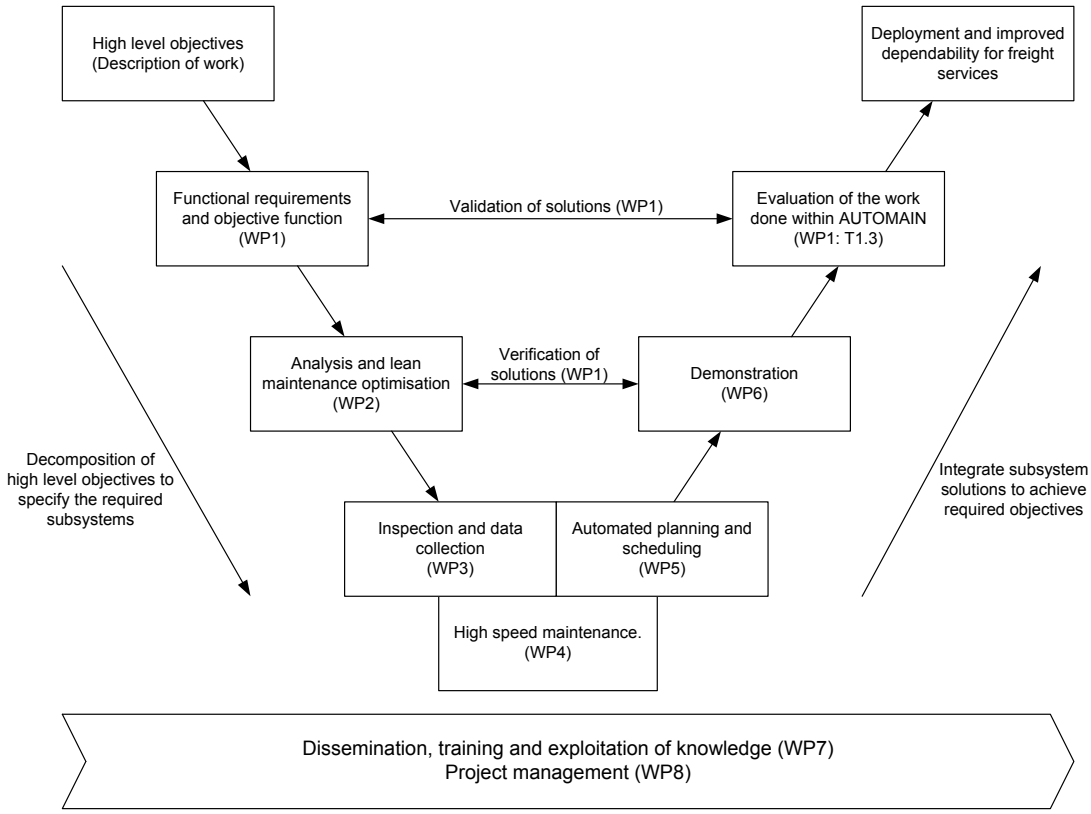
We consider the information gathered in the previous chapters as a "state-of-the-art picture". The diversity itself is an important result. And the details are important information for the different WPs to start their development (e.g. WP5 uses many of the detailed information found via the questionnaire).

For AUTOMAIN this is the startingpoint. The final view has been defined and described in chapter 3.0.

3.0 A description of future stages of railway infra business.

3.1 Introduction

AUTOMAIN has used systems engineering (SE) techniques to help to develop functional performance requirements (see figure). SE normally operates as a top-down process, starting with a basic statement of need: in AUTOMAIN's case, this is the need to reduce the amount of time the network is closed for maintenance, by developing innovative maintenance techniques and processes. Stakeholders, such as IMs, maintenance contractors and regulators, then develop a set of capability requirements, which describe what they would like the system to be able to do to meet the need.



Capability requirements are normally elicited with the help of operational concepts or 'use cases': models of how the system might operate, which help to raise questions about the capabilities required (Hull, 2005). Capability requirements are converted into functional performance requirements by adding performance criteria and stating how delivery of a requirement will be verified.

AUTOMAIN's capability requirements were developed using three operational concepts. The first focused on the reduction of night-time possessions, with an assumed target date for implementation of the new technologies and processes of 2026: fifteen years from now. The second concerned reducing day-time, between-train possessions, with an assumed implementation target date of 2036: twenty-five years from now. Finally, the third concentrated on maintenance at line-speed, with an assumed implementation target date of 2051: forty years from now.

Operational concepts and capability requirements were initially developed from a U.K. perspective in a small workshop held at the University of Birmingham. As a result of this workshop a raw description of the three phases was given and developed in a set of functional requirements. ProRail used this result in a second internal workshop joined by several specialists who were not part of AUTOMAIN. Their background knowledge of other developments (such as the EU white paper) has been used in that session. That workshop resulted in a more condensed overview (see paragraph 3.2) identifying the development drivers, the railway characteristics and the maintenance operational concepts for 2026, 2036 and 2051.

As a final check, this approach and the defined stages have been checked against the *EU White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* and the ERRAC vision *Rail route 2050: the sustainable backbone of the Single European Transport Area.* They appeared to be fully aligned.

The capability requirements were converted to functional performance requirements in a process involving all infrastructure manager members of WP1. The capability requirements were circulated to the IMs with a request for comments on: requirement validity; performance criteria; verification criteria, and; operational concept assumptions and constraints. Based on this, the capability requirements were amended where necessary, to ensure they covered the needs of Europe's railways as a whole. Performance criteria, such as production or data transfer rates, were added, and assumptions and constraints emerging from the workshop were identified, clarified and listed.

3.2 An overview of the main aspects.

	2026	*2036*	*2051*
Main characteristic	**Optimisation of existing technology and working methods.**	**Upcoming new technologies and new working methods.**	**Major technology shift.**
Development drivers	1. Cost reduction 2. Improving sustainability 3. Improved reliability. 4. Important effects to be expected from the relative position of railway against cars and lorries as accepted means of transportation.	5. Further cost reduction. Improvement of cost/performance ratios. 6. Further improved sustainability, 7. Integration of different means of transport (smooth transition between bus, tram, train, car). 8. Main shift in supporting technology in ICT[3] (rather than in conventional systems). 9.	10. Important shift in technical systems is necessary to keep railway in business.
Railway characteristics	11. Differentiation between lines based on different users and user patterns. 12. Standardisation of applied technical systems. 13. Definition of “infraconcepts”, meaning several types of infrastructure meeting several types of usage. 14. Strong reduction of the complexity of the railway system. 15. Interoperability will be of growing importance. 16. Maximum speed will not increase, but differences in speed will be reduced.	17. Differentiation in technical systems based on chosen infraconcepts. 18. New technical concepts will become visible. 19. ICT-systems will enable the optimisation of the transport system, 20. ERTMS available on the main corridors. 21. Interoperability is an integral demand; the infrastructure has to support that completely. 22. Maximum speed will probably be much higher than current maximums, an estimate in not available.. 23. Enhance acceleration of local trains	24. Electrical trains will use other sytems than catenary for energy transport. 25. No more outside signalling. All controls will be train borne. 26. Unmanned trains and cars (no active drivers required). 27. New systems????

[3] ICT: information and communication technology

	2026	*2036*	*2051*
		in order to reduce the differences in speed between local and long distance trains.	
Maintenance operational concepts.	28. Maintenance will be differentiated according to chosen infraconcepts (such as freight lines, main commuter lines, secondary lines etc). 29. Operational cost reduction. 30. Condition measurements automated. 31. Design for maintenance enforced on object level e.g. by introducing “pull and plug” solutions. 32. Less disturbances, more preventative activities. 33. Visualisation of maintenance and maintenance necessities is based on geographical oriented man-machine interfaces.	34. ICT supported track access for maintenance, reducing preparation times. 35. Advanced condition monitoring feeding real-time decision support systems in which advanced knowledge about behaviour is embedded. 36. Design for maintenance commonly used in object and in lay-out design.	37. Extremely advanced knowledge about system behaviour and how to influence that by maintenance is available in the sector. 38. Condition monitoring and decision support embedded in system design.

Disclaimer:

This overview has been developed by a limited set of specialists in order to be used as a basis for the development of the functional and capability requirements within AUTOMAIN. It reflects the knowledge and ideas of the people involved. It certainly does not reflect a thorough and well researched future vision of the railway infrastructure. It is not a separate result or deliverable from AUTOMAIN. It just serves as a steppingstone to come to the requirements in the next paragraphs.

4.0 Requirements

4.1 Introduction.

Based on the characteristics mentioned above, a number of requirements can be found. Due to the scope of AUTOMAIN and the defined work in the work packages only relevant high-level requirements are mentioned. Other may be relevant as well, but are out of scope of Automain or the WP's 2,3,4 and 5 or will be part of the detailed requirements to be defined within the WP's.

4.2 Capability requirements.

4.2.1 For 2026

The following capability requirements were identified as being important to railway maintenance in 2026:

Capability Requirement I.D.	Capability Requirements (what stakeholders want)
CR01	To be able to collect data using automated methods.
CR02	To be able to transmit data rapidly.
CR03	To be able to process and disclose data within 24 hours.
CR04	To be able to collect and measure data at linespeed (140 kph).
CR05	To be able to reduce the necessary time for activities (TTR/TTM). To be able to renew track components easily.
CR06	To be able to predict trends in track degradation.
CR07	To be able to package work.
CR08	To be able to record loads applied to the track.
CR09	To be able to reference all track condition data/faults against a network map.
CR10	To be able to access work sites rapidly (planning)
CR11	To be able to egress work sites and handover to operations rapidly (planning)
CR12	To be able to carry out reactive maintenance rapidly
CR13	To be able to plan on the basis of very low levels of reactive maintenance.
CR14	To be able to achieve very low frequencies for planned maintenance.
CR15	To be able to have very low track renewal frequency.

4.2.2 For 2036

In addition to the requirements for 2026 years, the following capability requirements were identified as being important to railway maintenance in 2036:

Capability Requirement I.D.	Capability Requirement
CR20	ICT-supported access regimes and safety measurements.
CR21	To be able to have real-time data processing.
CR22	To be able to have instant access to processed data results.
CR23	To be able to have new switch and crossing designs with far fewer discontinuities (more like plain line).

4.2.3 For 2051

In addition to the requirements for 2026 and 2036, the following capability requirements were identified as being important to railway maintenance in 2050:

Capability Requirement I.D.	Capability Requirement
CR30	To be able to embed knowledge and decision rules in the design of objects and their control systems.
CR31	To be able to optimise scheduled activities automatically on multiple aspects based on measurements, known behaviour and trend analysis.

4.3 Functional Performance Requirements Development

Capability requirements were originally developed with a U.K. perspective. These were subsequently reviewed, and where necessary amended, by the members of WP1, to ensure they gave a more European view. The full set of capability requirements was then elaborated, so that each requirement was qualified by the addition of: its source; the steps taken to validate it; required performance levels; constraints applying; verification criteria, and; and relevant comments. The results of this exercise are shown in sections 3.6.1, 3.6.2 and 3.6.3 of this report.

It should be noticed that in some situations and countries the mentions requirements are already valid. There is certainly a different pace in development within the different systems and networks. Nevertheless for the purpose of AUTOMAIN the requirements are grouped against the three mentioned stages.

4.3.1 Functional Performance Requirements for 2026

Functional requirement ID	FR01
Capability Requirement ID	CR01
Functional requirement	To be able to collect performance and condition data using automated methods.
Source	WP3, WP4
Validation	The WP's have to show that their data collection process is fully automated.
Performance	No human interaction is needed in collecting data and disclosure of data to the user.
Constraints	Not relevant for manual measuring methods.
Verification	In WP6
Comments	By avoiding human interaction in the datacollection process, the chance of introducing mistakes is diminished, the continuous availability of data is improved and the costs of datacollection can be reduced.

Functional requirement ID	FR02
Capability Requirement ID	CR02
Functional requirement	To be able to transmit data rapidly.
Source	WP3
Validation	WP's have to organise the whole chain from measurement till datastorage and disclosure.
Performance	Data has to be accessible in a "back-office" database within 1 hour after collection.
Constraints	
Verification	
Comments	This requirement serves as a condition to be able to install a back-office, a workforce and procedures to anticipate on the data.

Functional requirement ID	FR03
Capability Requirement ID	CR03
Functional requirement	To be able to process and disclose data within 24 hours.
Source	WP3
Validation	WP's have to show the ability to enrich data for end-users within the mentioned period.
Performance	End-users can access enriched data within 24 hours after measurement.
Constraints	
Verification	
Comments	Where CR02 mainly covers the availability of raw data, this CR deals with enriched data. E.g. the comparison with information about the installed base, known trends and conducted maintenance etc.

Functional requirement ID	FR04
Capability Requirement ID	CR04
Functional requirement	To be able to collect and measure data at linespeed (140 kph).
Source	WP3
Validation	WP has to show that measurements at line speed deliver an accurateness that meets the end-user requirement for making maintenance prognosis.
Performance	The required precision of measurements has to be set by the end-users and system specialist as an input for the WP.

Constraints	
Verification	WP6
Comments	The accuracy to be achieved will be at least as good as the state of the art in 2011.

Functional requirement ID	FR05
Capability Requirement ID	CR05
Functional requirement	To be able to reduce the necessary time for activities (TTR/TTM). To be able to renew track components easily.
Source	WP2, WP4
Validation	WP will show the result by measurements.
Performance	The MTTM for grinding, tamping and replacement of parts in S&C will be reduced by 50%.
Constraints	An overall reduction of MTTM can also be achieved by reducing the necessary frequency of activities, as long as the overall time is reduces by 50%.
Verification	
Comments	This CR is based on: The benchmark possession time for installation, maintenance and inspection during the life of the asset will be reduced by at least 50%. (Objective 4, Automain description of work, part B.) As this verification is not included in the DoW of WP6, other means of verification have to be found.

Functional requirement ID	FR06
Capability Requirement ID	CR06
Functional requirement	To be able to predict trends in track degradation.
Source	WP3
Validation	WP shall show that earlier information is used to calculate trends and potential failures.
Performance	
Constraints	The nature of the degradation process has to make this kind of prognosis possible.
Verification	WP6
Comments	

Functional requirement ID	FR07
Capability Requirement ID	CR07
Functional requirement	To be able to package work.
Source	WP5
Validation	WP has to choose scenarios and a demonstration line of which the activities will be processed showing the overall results.
Performance	After clustering a given set of proposed activities an overall reduction of the necessary trackaccess time has to be realised of at least 40%.
Constraints	What kind of activities will be taken into account? WP5 can only show the effects of packaging work during track possession. A model that represents how work can be organized is required in order to demonstrate further packaging possibilities. It may be useful to identify different kind of activities such as inspection and maintenance work.
Verification	WP5 has to demonstrate this.
Comments	Based on objective 5: To develop a new maintenance planning and scheduling tool that is able to optimise the programme of required maintenance activities, taking account of the benefits brought about by other improvements in the AUTOMAIN project. The tool, together with the other individual subsystem level improvements will reduce the overall benchmark possession time by 40%.

Functional requirement ID	FR08
Capability Requirement ID	CR08
Functional requirement	To be able to use recorded loads applied to the track.
Source	WP3 (T3.2)
Validation	WP shall show the results of the measurements.
Performance	Accuracy of the measurement has to be defined in the WP.
Constraints	Track only.
Verification	WP6
Comments	Cumulative load is expected to be a main indicator for preventative maintenance and quality assessment. Several systems such as Gotcha, DafuR and others are already in use. Same load but different settlement in the track of the switch results in different lifetime and “health”.

Functional requirement ID	FR09
Capability Requirement ID	CR09
Functional requirement	To be able to reference all track condition data/faults against a network map.
Source	WP3 (T3.2), WP5
Validation	WP’s shall present their result in a man-machine interface with a geographical set-up.
Performance	Some potential users (not involved in AUTOMIAN) will assess the shown MMI.
Constraints	
Verification	
Comments	As stated in the description of work: After analysis, it has to show on a common map the problems along the track and provide the maintenance requirements for the network, together with planned maintenance activities (WP5). The Man Machine Interface will be simple and easy to use, related to the maintenance needs (given by experience, and developed in WP2). Existing standards will be used for data transfer and presentation (e.g. web interface, XML format), as well as outputs of the InteGRail project. This will reduce the development time. For demonstration purposes WP5 will represent scheduling in a Gant chart and a time distance graph (ref. DoW, WP5, T5.3.4).

Functional requirement ID	FR10
Capability Requirement ID	CR10
Functional requirement	To be able to access work sites rapidly (planning)
Source	WP2, WP4, WP5
Validation	WP2 shall deliver best practices showing the potential gain in MTTM by organising a rapid track access. WP5 shall show that a clear separation and clustering of different kind of activities accelerates track access.
Performance	50% reduction of preparation time.
Constraints	Focus on grinding, tamping and modular exchange of parts of S&C.
Verification	
Comments	Different kind of activities (preparation, core activities, post activities) will probably need different planning and optimisation rules in order to optimise track access. WP5 can build a tool to optimize the insertion of logistic train to access work sites in between commercial trains. Such a tool will consider that the commercial train paths are given as an input and the optimization will minimize the number of canceled or delayed trains due to logistic trains. Conversely, WP5 can build a tool that builds the schedule of commercial trains so that the insertion of commercial trains (when necessary) is easier.

	The relevancy of both options has to be discussed in preparing the WP5-work.

Functional requirement ID	FR11
Capability Requirement ID	CR11
Functional requirement	To be able to egress work sites and handover to operations rapidly (planning)
Source	WP2, WP5
Validation	WP2 shall deliver best practices showing the potential gain in MTTM by organising a rapid track egress and worksite handover. WP5 shall show that a clear separation and clustering of different kind of activities accelerates track egress.
Performance	50% reduction of egress and handover time.
Constraints	Focus on grinding, tamping and modular exchange of parts of S&C.
Verification	
Comments	Different kind of activities (preparation, core activities, post activities) will probably need different planning and optimisation rules in order to optimise track access. The finalising activities concerning a safe handover of the track to operations need special attention. WP5 can build a tool to optimize the insertion of logistic train to access work sites in between commercial trains. Such a tool will consider that the commercial train paths are given as an input and the optimization will minimize the number of canceled or delayed trains due to logistic trains. Conversely, we can build a tool that builds the schedule of commercial trains so that the insertion of commercial trains (when necessary) is easier. The relevancy of both options has to be discussed in preparing the WP5-work.

Functional requirement ID	FR12
Capability Requirement ID	CR12
Functional requirement	To be able to carry out reactive maintenance rapidly.
Source	WP5 (T5.3)
Validation	WP5 shall take into account the possibility to arrange necessary possessions for reactive maintenance on very short term.
Performance	A possession of 2 hours has to be integrated in the planning within 24 hours.
Constraints	
Verification	
Comments	Real high priority activities will be executed immediately and will not be part of a planning process.

Functional requirement ID	FR13
Capability Requirement ID	CR13
Functional requirement	To be able to plan on the basis of very low levels of reactive maintenance.
Source	WP3, WP4
Validation	WP3 and WP4 shall show a combined business case in which the relation between (costs of) preventative maintenance and the remaining risks.
Performance	The number of disturbances due to technical failures will be reduced by 50%.
Constraints	Does not include random failures due to wrong usage of the infrastructure.
Verification	
Comments	The choice for preventative maintenance should always be based on a thorough analysis to balance costs and performance improvements. The societal costs of non-availability due to preventative and/or reactive maintenance have to be taken into account. The risks to be taken into account have to be identified by the WP's.

	The desired level of reactive maintenance may depend of the type of infrastructure. Strategic choices may result in different ratios reactive/preventative for different line types.

Functional requirement ID	FR14
Capability Requirement ID	CR14
Functional requirement	To be able to achieve very low frequencies for planned maintenance.
Source	WP3, WP5
Validation	WPs shall demonstrate that their developments (better inspection regime, improved planning) lead to a serious reduction of the necessary maintenance frequencies and thus to a better, higher availability of the track.
Performance	The reduction of maintenance frequencies shall be at least 25% in the chosen demonstration line (ref. CR09)
Constraints	
Verification	
Comments	The choice for preventative maintenance should always be based on a thorough analysis to balance costs and performance improvements. The societal costs of non-availability due to preventative and/or reactive maintenance have to be taken into account. The ideal frequency cannot generally be achieved due to several constraints (including track possession periods). The planning tool (WP5) will create a schedule where real frequencies are as close as possible as the ideal frequencies. Maintenance frequencies may be a mid-tem effect and may therefore be difficult to verify within the time horizon of the project.

Functional requirement ID	FR15
Capability Requirement ID	CR15
Functional requirement	To be able to have very low track renewal frequency.
Source	WP3, WP4
Validation	WP shall demonstrate that the development of modular S&C's combined with improved grinding and tamping strategies leads to a serious reduction of the necessary renewal frequencies.
Performance	The reduction of renewal frequencies shall be at least 50% (life time will be double).
Constraints	
Verification	
Comments	One output from "Modular S&C" (WP3) might be increased renewal of modular parts.

4.3.2 Functional Performance Requirements for 2036

Functional requirement ID	FR20
Capability Requirement ID	CR20
Functional requirement	ICT-supported access regimes and safety measurements.
Source	WP2
Validation	WP shall mention best practices concerning ICT-supported track access methods end technology.
Performance	
Constraints	
Verification	
Comments	The availability of ERTMS will rise opportunities to automate the formal handover of track to maintenance teams v.v.

Functional requirement ID	FR21
Capability Requirement ID	CR21
Functional requirement	To be able to have real-time data processing.
Source	WP3
Validation	WP's have to show that measured data is processed without further delays after measurements and what advantages can be reached by that.
Performance	Applications that enrich the raw data have real-time access to data.
Constraints	
Verification	
Comments	Comment from WP3: Real-time access to data is not planned in WP6. May be we can think about automatic data transfer using WiFi at special stations.

Functional requirement ID	FR22
Capability Requirement ID	CR22
Functional requirement	To be able to have instant access to processed data results.
Source	WP3, WP4
Validation	WP's have to show the ability to enrich data for end-users and on-the-fly decision making to take action based on the measurement.
Performance	End-users and next-in-line applications can access enriched data real-time.
Constraints	Historic data and knowledge rules have to be available.
Verification	
Comments	As an example: in one train measuring and grinding and/or tamping without reducing speed. Train speed and distance between measurement tool and actuator define the necessary processing speed.

Functional requirement ID	FR23
Capability Requirement ID	CR23
Functional requirement	To be able to have new switch and crossing designs with far fewer discontinuities (more like plain line).
Source	WP4
Validation	Design review of the results of WP4 T4.4. In case of actual installation of a new design a measuring train will be used to show the effects.
Performance	The number of discontinuities has to be at least 10% less than in the state-of-the-art designs. The WP has to define the relevant parameter.
Constraints	Implementation of the new design in an actual track is still to be discussed.
Verification	
Comments	Low impact S&C's (swing-nose crossing and stub points). This requirement in its full size is out of scope of AUTOMAIN. Nevertheless it will be relevant for the developments in WP4.

4.3.3 Functional Performance Requirements for 2051

Functional requirement ID	FR30
Capability Requirement ID	CR30
Functional requirement	To be able to embed knowledge and decision rules in the design of objects and their control systems.
Source	WP3, WP4
Validation	WPs have to show in a design review that the embedding of knowledge and decision rules is a realistic future option.
Performance	
Constraints	
Verification	Shall be part of the deliverable report.
Comments	Example: a future switch point will not only signal a degraded situation but will also have the knowledge to propose the necessary activity, urgency and reactiontime.

Functional requirement ID	FR31
Capability Requirement ID	CR31
Functional requirement	To be able to optimise scheduled activities automatically on multiple aspects based on measurements, known behaviour of infrastructure and objects and trend analyses of quality and behaviour.
Source	WP5
Validation	WP shall show in its design review that optimisation on multiple aspects is a realistic future option.
Performance	
Constraints	
Verification	Shall be part of the deliverable report.
Comments	Example: future optimisation will take many more aspects into account such as proposed activities and their urgency as given by objects (ref. CR41) or environmental aspects, life cycle costs etc.

5.0 A brief review of the relevant WP-leaders regarding the applicability of the developed requirements.

The requirements have been reviewed by the different WP-leaders during the process of writing this document. Their comments have been incorporated in the defined requirements.

In general it turns out that some requirements may not be consistent with the content of the DoW[4] of a certain WP, or with the available budget. This should be a point of consideration at the start of each WP. Taking the DoW and the requirements as a starting point, the team has to consider if all desired requirements can be met and what will be the consequence of any choice.

[4] DoW: description of work, a document last changed at 8 November 2011 and sent in during the application phase as Annex I to the consortium's proposal.

6.0 Overall conclusions

As demonstrated in this document a lot of work on benchmarking has been done earlier and within AUTOMAIN. Using all this information we come to the following conclusions:

- The overall image of the infrastructure managers' ways of working related to track access planning and performance measurement is too ambiguous to come to an overall conclusion.
- The information gathered by using the questionnaire and by the desk research gives lots of opportunities to be used as a basis for further research and developments.
- Exploring the results of the benchmark and the work done earlier, it becomes clear that all IMs are searching for improvements in the maintenance and possession planning and in asset condition assessment. These subjects are in line with the proposed work within AUTOMAIN.
- For AUTOMAIN the found results can be considered as a "state-of-the-art picture", which will serve as an " AS-IS"-situation for the innovations to be developed.
- The developed characteristics of the future railways are based on several personal opinions and discussions between specialists. This result should not be considered as THE view on future developments. But for AUTOMAIN it can certainly be considered as a future reference.
- The work package succeeded in defining a coherent set of requirements that will form a strong basis for further work in the upcoming WPs.
- The developed requirements will be used as a reference for the work in the several work packages. On one hand they will give focus for the planned developments and on the other hand it will provide a sort of yardstick to evaluate the results in the latter phase of AUTOMAIN.
- There will certainly be a necessity to realign the requirements with the contents of the DoW written earlier. The requirements may be considered as the results of growing insight in what to be achieved. But in some situations this might create the need for a bigger budget that is not available. This means that every WP-leader has to evaluate before they start in what way and to what level they will be able to meet the given requirements. Similarly the need for more specific knowledge about best practices may be pointed out in that stage.

7.0 Bibliography

1. Åhrén T., and Parida A., 'Maintenance Performance Indicators (MPI) for Benchmarking the Railway Infrastructure – A Case Study', Benchmarking: An International Journal, 16:2 247-258.

2. BSL, 2008, 'Rail Infrastructure Cost Benchmarking: Brief LICB-gap Analysis and Cost-driver Assessment', BSL, Hamburg, Germany

3. BSL, 2009, 'Asset Management Club: Final Report', BSL, Hamburg, Germany

4. Civity Management Consultants, 2011, 'The Asset Management Club Project: Phase 3 – Asset Registers and RAMS/LCC', Civity Management Consultants, Hamburg, Germany

5. EU, 2003, 'IMPROVERAIL: Deliverable 10 – Project Handbook', EU, Brussels

6. Gibson J. E., Scherer W. T., Gibson W. F., (2007), 'How to do Systems Analysis', John Wiley and Sons Inc., New Jersey

7. Hull, E., Jackson, K., Dick, J., 2005 'Requirements Engineering', Springer, USA

8. INNOTRACK, 2010, 'INNOTRACK: Innovative Track Systems – Concluding Technical Report', Edited by Eckberg A., and Paulsson B., UIC, Paris

9. Kelly M., (1950), 'The Bell Telephone Laboratories – An Example of an Institute of Creative Technology', Proceedings of the Royal Society, 23rd May 1950, London

10. LEK, 2003, 'Regional Benchmarking: A Report to ORR, Network Rail and SRA', LEK, London, Great Britain

11. LEK Consulting LLP, TTCI, Halcrow Group Ltd, 2003, 'International Benchmarking: A Report to ORR, Network Rail and SRA', LEK, London, Great Britain

12. Network Rail, 2009, 'Control Period 4 Delivery Plan 2009: More Trains, More Seats, Better Journeys', CDS009/March 2009, Network Rail, London, Great Britain

13. Railway Working Group, 2002, 'International Railway Benchmarking: Report of the Railway Working Group', second draft June 2002

14. Swier J, 2004, 'Exposing the Real Infrastructure Cost Drivers', Railway Gazette International

15. UIC, 2004, 'Lasting Infrastructure Cost Benchmarking', December 2004, UIC, Paris, France

Appendix A: results of the state-of-the-art questionnaire.

AUTOMAIN

Questionnaire

The AUTOMAIN project has been built up according to the system engineering principles. This includes the definition of overall results and objectives at the start of the project. One of the aspects in the first phase is to search for potential good practices and ideas that can be used later on in the project. We choose to make a questionnaire. The goal of the questionnaire is to provide an overview of good practices and ideas to the members of Automain. It can be used as a start for further investigations. Therefore the questionnaire contains high level questions and no questions for detailed data collection. The target group is the inframanagers of Automain: Network Rail, SNCF, Deutsche Bahn, ProRail and Trafikverket. Finally after consultation with the WP1 leader also Strukton completed the questionnaire.

The questionnaire provides input for all of the deliverables within Task 1.1: Functional requirements:

- T1.1.1: Asset management strategies, policies and performance
- T1.1.2: Maintenance and inspection processes
- T1.1.3: Integration of maintenance in the timetable
- T1.1.4: Comparison with automated maintenance in road networks
- T1.1.5: Definition of market and customer requirements

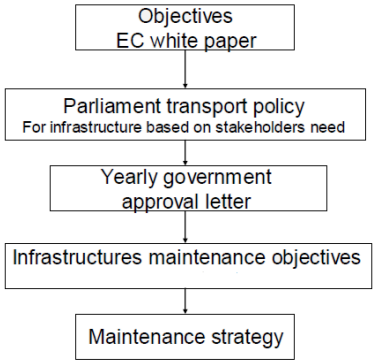
The process of making the questions is listed below:

- ProRail made a first proposal
- This proposal was reviewed by the members of WP1 and the other WP leaders
- The first proposal was updated and send to the Infra Managers
- The first proposal was used by DLR to make a questionnaire for road networks (results are reported separately)
- The answers were gathered by ProRail
- The first plan was to visit all the inframanagers to get more detailed information. Due to costs, planning problems (summer holiday) and efficiency we decided to analyze the results and opt for a second round of (additional) questions by email.
- University of Birmingham and ProRail analyzed the results. It was clear that the initial questions were not specific enough to be the basis for defining the market and customer requirements (T1.1.5 Definition of market and customer requirements).
- WP2 leader formulated specific questions to be able to get started.
- The initial questions, additional questions and answers are in the appendix.
- Results of the additional WP2 questions are not part of this appendix. WP2 will report separately on these issues.

We decided not to present a short overview with highlights and best practices on each subject. This means we decided only to show the raw answers of the IM's. Each IM and work package member can look through the questionnaire and find what is relevant for him / her. When needed each work package can define additional questions to the different IM's.

Asset management strategies, policies and performance

- **What are the strategic company goals of the Infra Manager (IM)?**
  - Describe the background of each strategic goal
  - Mention and explain the KPI's that are related to each strategic goal

IM	***Answer***
TV	Trafikverket (TV) is a governmental agency in Sweden whose responsibility is the strategic planning of roads, railways, ship transports and aviations. TV started its work 2010-04-01, at the same time as Banverket (The Swedish Rail Administration) and Vägverket (The Swedish Road Administration) were terminated. The railway network is divided into different line classes, based on the type of trafficoperating. The different classes are; City, Major Lines, Other Important Lines, Minor Lines and No or Little Traffic (Banverket 2010). Näringsdepartementet, The Swedish Ministry of Enterprise, Energy and Communications (The Ministry of Enterprise) is principal for TV. The Ministry of Enterprise controls TV by an annual appropriation letter, with mid-term goals and funds for reaching them. The mid-term goals are based on the overall goals and the objectives in the strategic plan for the transport system, which is settled by the government for ten year periods, with funding, as a governmental bill. The overall goals and objectives are broken down in a top-down manner through the organisation. Sub-goals and sub-objectives are formulated, facilitating the operational planning. Internal PIs and KPIs are used throughout the hierarchical levels to monitor the performance development according to the set plan. Since half the budget is spent on maintenance and renewals of the railway infrastructure assets, PIs for monitoring the condition of the track are of highest importance. TV is also using a scorecard model in their management, which is based on the balanced scorecard by Kaplan and Norton, but with five perspectives instead of four. The governmental goals are set on 10 years log term goals and those goals are then broken down into yearly governmental approval letters by the Ministry of Transport. In these letters, Trafikverket's tasks for the fiscal year are given. The letter starts with the overall goals, which provides a system of transport for the citizens and the business sector all over the country that is economically effective and sustainable in the long term. See figure 1 (ref. Ulla Juntti (Espling), "Maintenance Strategy for a Railway Infrastructure in a Regulated Environment", Doctorial Thesis, ISSN: 1402-1544, ISRN: LTU-DT—07/54 – SE, 2007:54 Luleå University of Technology, (2007)).  *Figure 1. Railway infrastructure management* The objectives are then translated into the infrastructure management task. The maintenance strategy is formulated by considering the following

- Yearly funding according to governmental approval letter.
- A client/contractor organization with outsourced external contractors.
- Maintenance contract duration time which is longer than one year. Usually 3-4 years with options for continuation 1-2 years
- Different kinds of contracts with different duration time, scope, payment forms. Functional (performance) contracts are used today as a general strategy.
- Traffic operation agreements with the traffic companies, putting the focus on effectiveness and efficiency.
- Internal and external regulations.
- Safety demands.
- Demands in increased punctuality and train traffic availability in combination with competition of time on track between traffic operation and maintenance activities (daily work and re-investments)
- Asset with different complexity, age and standard
- Limited access to the track for maintenance work due to high utilization from train traffic needs
- Train planning scheduling process, not always synchronies, with budget process and maintenance and re-investment planning processes
- Life Cycle Cost (LCC), total asset cost management and train traffic planning routines with priority guidelines based on society economical principal judgments
- Public Procurement Act
- The maintenance strategy has five strategic challenges:
  - Energy efficient transport system
  - Good working transports (goods and passenger) in urban areas
  - Efficient industry transports
  - Robust and available infrastructure
  - High valuable utilization level per invested dollar

Goals

The main strategic goal and two subgoals have been settled for the transport system by the Ministry of Transport, whereas the main strategic goal is to:
"Ensure the economically efficient and sustainable provision of transport services for people and businesses throughout the country" – (Näringsdepartementet 2009)

And the two strategic sub-goals are the following:
"The Functional Goal – The design, function and use of the transport system will contribute to provide everyone with basic accessibility of good quality and functionality and to development capacity throughout the country. The transport system will be gender equal, meeting the transport needs of both women and men equally." – (Näringsdepartementet 2009)

"The Impact Goal – The design, function and use of the transport system will be adapted to eliminate fatal and serious accidents. It will also contribute to the achievement of the environmental quality objectives and better health conditions." – (Näringsdepartementet 2009)

Background of the Strategic Goals

The Strategic goals of the Swedish transport system have been set in collaboration with industry and the IMs of roads, railways, aviation and maritime. This was before TV was launched, whose responsibility is the strategic planning of roads, railways, ship transports and aviations. Also investigations were carried out by SIKA (The Swedish Institute for Transport and Communications Analysis), now replaced by Trafikanalys (the Swedish Transport Analysis). See Figure 2 below for an overview of how the strategic goals and the strategic plan were developed. Also KPIs with annual quantitative objectives until 2021 are

found for the operation and maintenance in the strategic plan.

Figure 2: Sketch of the development of the latest strategic plan.

KPIs Related to the Strategic Goals

TV's operation and maintenance objectives can be found in the strategic plan of the transport system for 2010-2021, which are objectives to the political main goal and its two sub-goals. The objectives are the following six, called Delivery Qualities, or Operational Qualities; Punctuality, Robustness, Traffic Information, Comfortability, Safety and Usability (Banverket, Vägverket et al. 2009). The Delivery Qualities have three levels of accomplishment, "Base", "+" and "++". Each delivery quality has KPIs connected, where most of them have a quantitative value established, i.e. quantitative objectives. For example, the values for Punctuality are 88 %, 90 % and 96 %. A punctual train is defined to be no later than five minutes. Another example is Comfortability, which is measured by the track geometry Q-number. The three subgoal levels for the Q-number are 65, 88 and 94. In addition to the Delivery Qualities, environmental consideration has to be taken into account in the operation and maintenance planning. See Figure 3 for the break down structure of strategic goals to operation and maintenance objectives

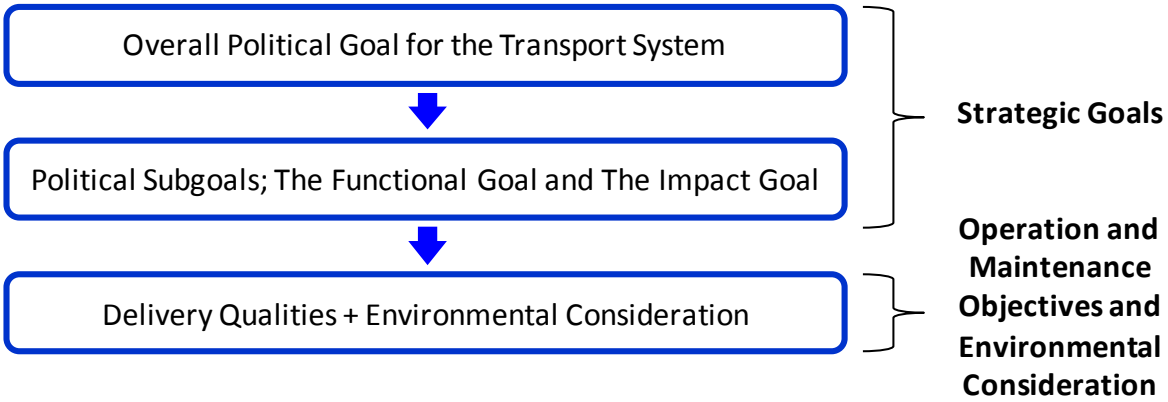


Figure 3: Top-down break down structure of strategic goals to operation and maintenance objectives.

The delivery qualities with KPIs are found in the following table, Table 1:

Table 1: Delivery qualities, or operational qualities and their underlying indicators used by Trafikverket.

Delivery Quality	Performance Indicator (KPI)	Unit
Punctuality	- Arrival Punctuality - Train Delay	% h/Million-train-km
Robustness	- Downtime, or Restoration Time	h/days
Traffic Information	- Availability of the traffic information system - Passenger Satisfaction (NKI) - Trip-planner	% % Quantity
Riding Comfort	- Q-value - Passenger Satisfaction (NKI)	- %
Safety	- Kills and Injuries - Vehicle damages	Quantity Quantity
Usability	- Availability of Infrastructure	%

The environmental consideration does not have any overall quantitative values or objective established, instead there are several subgoals and objectives that are going to be meet during 2010-2021 (Banverket, Vägverket et al. 2009). There is also a three step priority principle when planning for investments. It is as follows; first step is to prioritise measures that benefits in both environmental and economical aspects. Second step is to choose the most environmentally friendly action if the cost is the same for other similar actions. The third step is if there is an environmentally friendly choice but the cost is high, then one looks into the socioeconomic benefit and regulations.
The delivery quality Safety together with environmental consideration facilitates for overall monitoring of the HSE (health, safety and environmental) aspects.
The main environmental goals found in the long term plan are to reduce energy usage, clean polluted ballast, reduce noise from roads and railways and clear land near railways and roads (Banverket, Vägverket et al. 2009). The energy cost associated to lights, ventilation and heating of switches in the railway infrastructure is about 150 million SEK. This cost is estimated to be reduced with 44 million SEK when the planned actions are carried out. Some of the activities are changeover of light-bulbs to LED, rail grinding, improved heating system of switches and improve usage of light systems. The use of materials to roads that reduces the noise from vehicles is estimated to increase the maintenance cost up to six times. This makes it contradictive to other environmental goals, and raises the question that this subgoal of reducing noise maybe should be a goal within the comfortability goal of the Delivery Qualities. If it comes up a need to prioritise between the Delivery Qualities, punctuality and safety comes in first hand (Trafikverket 2010a).

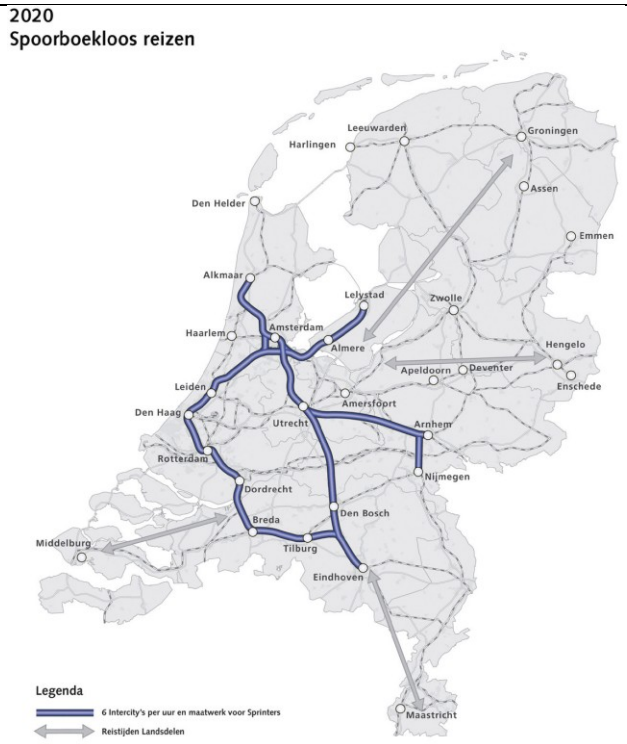
PR

ProRail has 4 major strategic ambitions as descried in our contract with the government ("Beheerplan 2011"):

1. 100 % delivery reliability and 0 % accidents
The track is an open system that is directly exposed to weather and other external factors such as collisions, fallen trees, roadside fires, and even sabotage. Under these conditions, achieving the highest possible reliability and to minimize the likelihood and impact of disruptions is an everyday challenge. Making the track season proof has a high priority. We may not be surpised by hot summers (buckling of rail), autumn storms (leaves on the track), cold winters (frozen switches) or lightning.

Besides a highly available and reliable railway, ProRail wants - despite intensification of track use -

	together with train operators work on the improvement of the punctuality. ProRail shall 2011 start with a differentiated approach per line by simplifying the infrastructure and optimize the control of the system. Smart logistics solutions are the basis of functionality change projects and 1:1 renewal projects. Too tight uniform company rules will in 2011 be gradually revised to make room for smarter solutions. Corporate social responsibility includes a strategy aimed at travel safe, work save and live save on and along the rail and covering its share in the total safety of the railway, as stipulated in the Third Rail security framework document of the national government. Travel safe means that train operators and passengers are safe on the track, meaning e.g. that signals are clearly visible, switches are working properly and a safely designed trainschedule. Live safe means that nobody is at risk around the track. Railroad crossings are well organized and work well, the track is not free accessible and suicide on the track is actively reduced. Work safe means ProRail and contractors together ensure that anyone who works on the track is safe. Track workers can safely stand in the track that is out of service and the risks of their activities are controlled. ProRail has the ambition to reduce the number of rail accidents to zero. Safety is determined by a combination of engineering, systems and human behavior. Through the Safety Management System (VMS) managing the security risks and meeting the company safety objectives is embedded in the daily business processes. ProRail is increasingly drawing attention to the behavior of people, because also without major investments in technology the security can increase. Employees are therefore even more aware of the risks and more focused on continuous control. **2. 20 % reduction of lifecyclecost per trainkilometre** Improvement of professionalism, efficiency and responsible use of public funds **3. 50 % more trains on the busiest corridors** The ambitions of the government and the railsector for growth on the track and the realization of high frequency traffic on the main corridors in the country are great. To enable train operators this growth in the short term, where possible, ProRail creates the possibility that more trains can run at high punctuality and where possible shorter travel times. On behalf of the Minister of Infrastructure and Environment ProRail works (from 2008) together with the train operators on the High Frequency Rail Program (PHS) to facilitate "timetable free travel". In the Longterm Program Infrastructure and Transport (MIRT), the Central Government funded the program for more than EUR 4.5 billion until 2020.



4. Satisfied customers

ProRail wants satisfied customers - both passenger and freight train operators and governments. In the medium term the ambition of ProRail is to get an 8 out of 10 of its customers and relations. The target for 2011 is average of 7. We hope to achieve with services tailored to specific needs, business and market dynamics of our customers, and transparent pricing and quick delivery. Specifically for the freight train operators, we aim to ensure that the 2011 freight arrival punctuality on the main corridors improve, and working to improve communication about train free periods and a better process for ad hoc requests for rail capacity. In addition, we provide more transparency into the process of the application of environmental permits.

From the perspective of corporate social responsibility ProRail intends to be a good neighbor to the millions who daily as traveller, user of roads or neighbor to the track have to do with passing trains and / or construction. Therefore ProRail aims for a greater satisfaction of the customer group "Public".

To establish, maintain and protect the interests of local governments within ProRail our relationship managers increased contacts with our public partners. Priorities for 2011 are: fast response times, the exact articulate questions, needs, accurate offers and realistic
leadtimes for projects.

The KPI's related to these strategic ambitions are mentioned with question 1.4.

NR	Network Rail is established as a not for dividend company, as the owner of the UK railway infrastructure. The goals of network rail are to operate and maintain the railway infrastructure to meet the demands of our customers the rail and freight operators and the travelling public. Network Rail's strategic goals are set through an agreement with the Office of Rail Regulation for a control period of 5 years. The Office of Rail Regulation is the independent safety and economic regulator for Britain's railways. The high level strategic goals are set based on benchmarking data and a drive to improve efficiency, safety and comfort, minimise disruption and improve capacity. These are influenced by the Strategic Rail Agenda 2020 (2007), a cross-industry TSLG (Technical Strategy Leadership Group) define future Rail Technical Strategy and has developed technology roadmaps

(http://www.futurerailway.org/Pages/home.aspx).

The Office of Rail Regulation then monitors Network Rail's performance against their targets and budgets on a quarterly basis these monitor reports are publically available from (http://www.rail-reg.gov.uk/server/show/nav.2280).

The present control period CP4 (2009-2014) has the high level targets to:

- Improve efficiency – reduce costs by 22% over the 4 year period
- Increase safety – reduce the safety risk factor by 3% (the risk factor is made up from statistics
- Maintain capability (eg line speed, gauge etc) at April '09 level
- Increase capacity – Improvements in capacity are defined by planned projects (eg. Thameslink project, Reading projects, Airdrie to Bathgate re-opening, Felixstowe-Nuneaton line upgrade for increased freight traffic).
- Improve availability – increase availability of the railway (keeping the railway open when people want to use it) by 37% for passengers and maintain current levels of availability for freight traffic
- Asset stewardship index – the ORR has an asset stewardship index using a large range of KPIs to measure the long sustainability of the management of the railway infrastructure ensuring that the assets are not degrading over each control period.
- Improve customer satisfaction – This comes from passenger satisfaction surveys

The goals that have the greatest impact on AUTOMAIN are improving efficiency, safety, performance and availability.

The responsibility for translating these high level targets into company goals and changes in working practice is the responsibility of Network Rail and these are cascaded down into the Network Rail Route Utilisation Strategies (http://www.networkrail.co.uk/aspx/4449.aspx) where the strategy is specifically tailored to routes and investment work. Within Network Rail's Engineering group, there are also technical strategies written for each of the asset types to define the future needs and what technology developments and research are required to meet the global objectives.

The KPIs related to the strategic goals upon which Network Rail is monitored and assessed include:

<u>Network availability</u>
- Passenger Disruption Index (PDI-P)
- Freight Disruption Index (PDI-F)

<u>Train performance</u>
- PPM (Passenger performance measure)
  - Total PPM
  - Long Distance
  - London and South East
  - Regional
- FPM (Freight performance measure)
- CaSL – Cancellations and Significant Lateness
  - Long Distance
  - London and South East
  - Regional
- Delay minutes (actual delay minutes)
  - Passenger (1000s of minutes)
  - Freight (Normalised by per 100 train km)

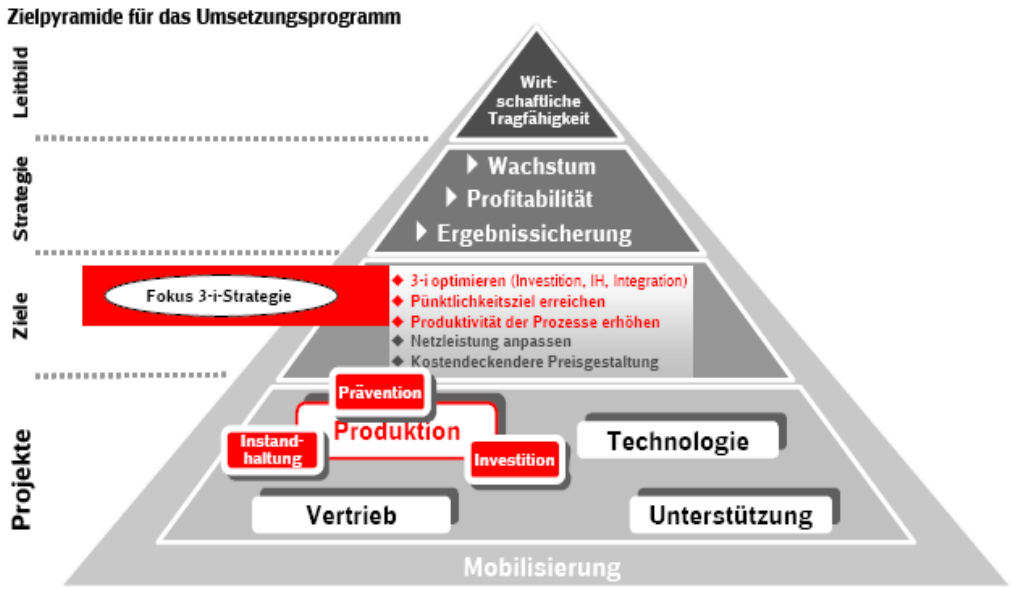
<u>Infrastructure</u>
- Number of asset failures

<u>Customer satisfaction with Network Rail</u>
- Train Operating Company (mean satisfaction score)
- Train Operating Company (mean satisfaction score)

<u>Finance</u>

	Controllable Opex Non-Controllable Opex Renewals Maintenance <u>Station Stewardship index for different station categories</u>
DB	*Safety* KPI's according to draft version of "Definition of common safety indicators and common methods to calculate economic impact of accidents" CSIsWG-SD – Annex 1-ver0.7, European Railway Agency 2007 Increase of safety at railroad crossings number of people involved in accidents *Climate protection* • Carbon emission – tons per year for infrastructure • Reduction of noise – installation of noise barrier • Management of vegetation – amount of herbicide and treated area *Reduction of LCC* LCC of new components, modules or systems, Operating profit *Management of dependencies* No direct KPI *Economic implementation of new laws and regulations* No direct KPI *Increase of quality and capacity* • Increase of reliability - Number of speed reductions • Increase of track performance and availability - Delay minutes • Increase of competitiveness - Operating profit • Punctuality of trains - 81,5% for long-distance trains - 92,5% for regional trains - 80,0% for freight trains At DB Netz, we have a 3-i-strategy, which directs the management processes of the investment and maintenance planning and control. The guideline for the 3-i-strategy consist of more than 150 pages and describes the bases of the strategy, the planning and the control of investment and maintenance for different assets like track, construction engineering and control and safety technique The strategy also directs the interface between the operation/construction and time table

ProNetz Projekte in Produktion, Vertrieb, Technologie und Unterstützung stellen die Zielerreichung der strategischen Stossrichtungen sicher



The 3-i-strategy is based on 10 core elements which are shown in the next figure (sorry in German). The goals are

- to reduce the costs
- to keep the planned dates and
- to increase the quality.

10 Kernelemente der 3-i-Strategie

	In the Service level and funding agreement (Leistungs- und Finanzierungsvereinbarung) between Deutsche Bahn and the government strategic goals with respect to the quality and the development of the infrastructure are described and KPI identified. For detailed information look at page 29 ff in the following document http://www.eba.bund.de/nn_804166/DE/Fachthemen/LuFV/IZB/IZB__2010__Kurzfassung,templateId=raw,property=publicationFile.pdf/IZB_2010_Kurzfassung.pdf Quality indicators related to the funding by the government are: • Theoretical loss of travel time (Theoretischer Fahrzeitverlust) • Number of defects of the infrastructure (Anzahl Infrastrukturmängel) • Functionality of train platforms (Funktionalität Bahnsteige height of platforms, accessibility without stairs, weather protection • Assessment of asset quality (Bewertung Anlagenqualität) quality and visual appearance of platforms • Supply guarantee of power (Versorgungssicherheit Bahnenergie) Additional quality indicators are: • Number of faults and time for repair (Anzahl der Störungen und Störbestehenszeiten) • Mean age of important assets (Durchschnittliches Alter von wichtigen Anlagenarten der DB Netz AG) • Condition categories of bridges and tunnels (Zustandskategorien Brücken und Tunnel) Assesment indicators are: • Delay minutes (Verspätungsminuten) • Total track kilometre of trains (Trassenkilometer) • Number of train stops in platforms (Zughalte) • Traction energy (Traktionsenergie)
SNCF	On 3 November 2008 the State and Réseau Ferré de France signed a performance contract covering the main commitments from the Grenelle Environment Forum. This contract defines the infrastructure modernisation objectives and the methods for developing a new commercial offer for the network, in order to improve quality, services and safety as much as possible. With this contract, we make 33 commitments, progress on which will be monitored by a series of indicators. Making a commitment today… for tomorrow's network The company is preparing the conditions for the opening up of the passenger market from 2010 and **puts the customer at the heart of its concerns:** to provide fair access to the network; to improve the quality, flexibility and relevance of its "train paths" offer; to improve the performance of its services; to innovate in order to encourage new activities using rail transport; to develop sales revenues for a "fair price"; to modernise infrastructure. Making a commitment to… a better performing network €13 bn between 2008 and 2015 will be invested to renew 6,400 km of tracks and almost 2,500 line points. Réseau Ferré de France is committed to the management of costs and deadlines and also to project visibility so as to allow the companies carrying out works to anticipate needs and better respond to infrastructure development challenges. The French network will be equipped with the most recent technological advances (centralised control or

telecommunications) developed in partnership with the European infrastructure management groups.

Making a commitment to… a balanced, shared, sustainable business model

The customers of the network and of its services will pay the "fair price" based on the full cost of the network, incorporating current operating charges, financial amortisations and return on capital.

The company is committed to developing its sales revenues: the proportion of the infrastructure cost financed by revenues will thus increase from 48% in 2008 to 60% in 2012.

We are strengthening our land and property policy to the benefit of local authorities, urban development projects and housing, especially social housing.

Making a commitment to… sustainable, local transport

The network must be used more intensively: this is the assignment given by the State to Réseau Ferré de France, to find answers to the mobility needs of all members of the public and companies.

To translate the commitments of the Grenelle Environmental Forum into action, we are committing ourselves to developing regional access points, adapting the network to lifestyles, introducing modern industrial practices, asserting ourselves as demanding, environmentally aware owners, and operating the railways within a sustainable business model.

Report on activities in 2010

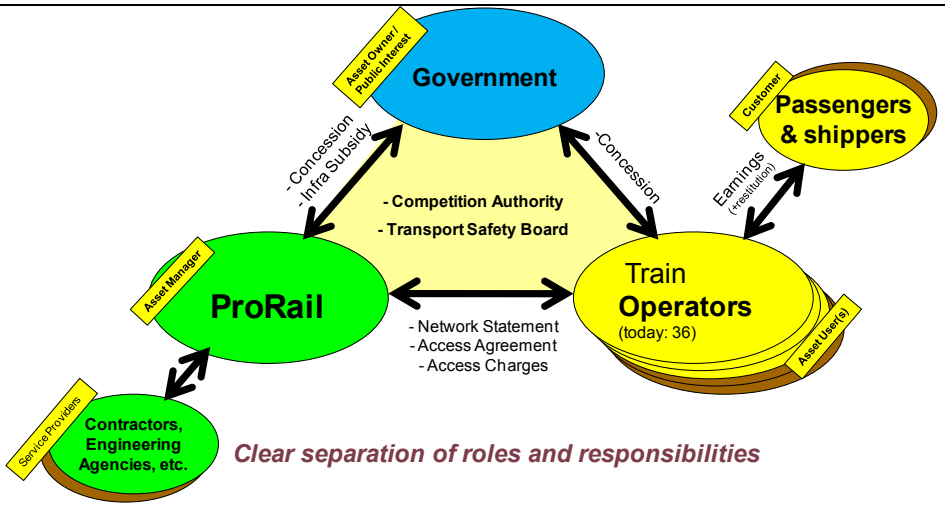
- Improving territorial accessibility
  - Proportion of clockface train path applications
  - Volume of freight traffic on the freight-oriented network (in millions of train path/km)
  - RFF response rate to late train path requests within the deadlines promised to the client
  - Number of train path-days affected by unscheduled works possessions
  - Punctuality to within 5 minutes
  - Length of unused lines targeted by conservation projects in the year of their closure to traffic (km) (tourist trains, cyclo-rail, greenways, cycle tracks)
  - Number of stations accessible to people with reduced mobility (PRM)
  - Sum invested (in millions of €)
  - Number of last minute train paths created
- INTEGRATING THE NETWORK INTO LOCAL LIFESTYLES
  - Number of railway accidents
    - Deaths (other than suicides and attempted suicides)
    - Injured (other than suicides and attempted suicides)
    - Number of suicide “events”
  - Number of accidents on RFF worksites
    - Deaths
    - Seriously injured
  - Dangerous level crossings closed
  - Dangerous level crossings improved
  - Total investment in safety (in millions of €)
  - Number of noise black spots processed as part of the elimination programme
  - Population affected by noise black spot improvements
  - Aggregate investment in noise black spots (in millions of €)
- USHERING THE RAILWAY INTO THE MODERN INDUSTRIAL ERA AND FOSTERING INNOVATION
  - Cost of renewal on main track (k€/km)
  - Quality of contract management: percentage of operations completed on schedule, to time and standard

	• EMERGING MORE STRONGLY AS AN ENVIRONMENTALLY-FRIENDLY LANDOWNER - Purchase of phytosanitary products (kg) - Conversion of equipment containing PCB (Number of items brought up to standard) - Quantity of asbestos eliminated (T) - Percentage of train-km with electric traction - Percentage of diesel hauled trains on the electrified network (regular train path-km) - Direct energy consumption per primary energy source (MWh) - Total weight of timber sleepers removed and treated • CREATING A SUSTAINABLE BUSINESS MODEL FOR THE RAIL MODE - Revenue from sales (in millions of €) - Proportion of all costs covered from sales revenues - Percentage of investment on the existing the network (other than new development as a % of spend) - Length of line renewed (equivalent in km) - Amount spent on renewal (in millions of €) - Cost of train-km for maintenance (€/Train-km) - Land and property business plan (in millions of €) ▪ Property disposals ▪ Rental income • OPENING TO COMPETITION AND STAKEHOLDERS - Proportion of freight revenues from new clients - Proportion of operations conducted by contract/project managers selected through competitive bidding

- **How strict do you use the separation between the Asset Owner, Asset Manager and Service Provider?**
  - Describe who has the role of Asset Owner, Asset Manager and Service Provider
  - What are your major stakeholders
  - Explain the advantages and disadvantages of this role model related to the allocation of train free periods

  Additional questions
  - Who are the main stakeholders, and what influence does each one have on determining the location and length of train-free periods in the timetable?
  - How does the IM optimize the planning of maintenance possessions?
  - How are the needs and wishes of the passenger and freight carriers taken into account?
  - How could collaboration on maintenance plan development be improved between stakeholders (Infrastructure managers, maintenance providers, train and freight operating companies)?

IM	***Answer***
TV	The complexity of railway maintenance demands a holistic approach to both internal and external factors and processes that have direct or indirect influence on the operation and maintenance of railway infrastructure. While forming the maintenance strategy for railway infrastructure the manager most take in consideration the interacting parts in the maintenance systems, i.e. between wheel and rail, between pantograph and catenary, between signaling systems (on board and way side) and train control systems. The manager also have to consider if the methodology or strategy he/she chooses will put demands on the contractor to enhances her/his competence or invest in new machines or instruments. When the infrastructure manager enters into an operation and maintenance contract, he commits funds for three to five years for payment to contractor against executed work as agreed in contract. Infrastructure manager (IM) must also have a flexibility to cut down on the maintenance activities because sudden unexpected events such as extreme weather conditions and decreases in the government grant owing to political resolutions. While the IM is responsible for the asset, rail traffic possession time on track (track capacity) is sold out to the train operators. Trafikverket maintenance strategy is condition based maintenance in combination with predetermined maintenance. However, by using functional maintenance contracts, only the function of the track is measured and not how the maintenance is executed. The structure for the control system is based on the European standard EN 133306:2001. Problems are caused by lack of good functioning control systems. Systems to measure the assets condition and where the condition is on the degradation curve. The infrastructure manager is working in an organization for continuous improvement and increases the activities for elimination of failures especially those causing train delays. A forum for decreasing train delays are set up in Stockholm and Göteborg and Malmö regions (In Swedish Kraftsamling Mälardalen, Väst, Syd). Groups with key personnel from the traffic operators, infrastructure managers, contractor and traffic control comes together in meetings to discuss and solve problems that causes train delays. These working groups are focusing on re-investment priority actions and not so much on daily maintenance actions in the contracts. Regarding the maintenance contracts, the infrastructure manager and contractor often only meet to discuss changes or activities that must be addressed in order to fulfill their contract. This type of relationship has often been called “arm’s length” contracting and implies that each party is free to act independent of each other. Since 1998 several types of contacts has been tested on the railways, for example buying with fixed prices and specifying every work, buying a function.
PR	In the Netherlands a very strict separation is created between the asset owner, asset manager and the service providers. But also the asset users (train operators) is a separate entity with its own “contract” with the government (consessions) and access agreements with ProRail.



Having 4 parties makes it difficult to get consensus on the possession times (train free period) for doing the maintenance activities. The asset users have a large influence on the planning of the train free periods. In some occasions the asset user even can uses a veto. In the Netherlands the safety regulations lead to an very high safety standard. Together with a rail infrastructure that reaches its maximum capacity this explains why reaching consensus on the balance between driving trains and maintenance / renewals is always difficult.
For the new performance based contracts (small scale maintenance) the contractor has to claim the needed possessions before he gets the contract. After award of the contract he gets the time he claimed to do the activities he thinks are needed to meet the specifications. The advantage is that this procedure provides clear agreements on possessions needed for small scale maintenance. But the disadvantage is that the flexibility is less.

To achieve a good balance between the running of trains (passenger and freight) and performing maintenance a formal agreement between ProRail and the train operators is necessary. In these consultations, the interests of the Asset Manager and Asset user are equal.

NR

Network Rail has the role as asset owner, asset manager and asset maintainer.
This does have the advantage of a single organisation planning possessions in conjunction with our customers (train and freight operators). Some maintenance tasks, renewal and upgrade work is carried out by sub-contractors but remains under Network Rail's planning.

Who are the main stakeholders, and what influence does each one have on determining the location and length of train-free periods in the timetable?

The primary stakeholders involved in the determination and location and length of train-free periods in the timetable is mainly Network Rail and the passenger train operating companies and freight operating companies. The negotiations for access begin with the 26 key route strategies, these strategies have been formulated between Network Rail and the train operating companies and freight operating companies, the "Rules of the Route" also define the levels of access that the TOCs and FOCs have to the infrastructure and the access that Network Rail has in order to carry out maintenance and renewal work, this is communicated to the TOCs as part of their bidding for a franchise. The National Access Unit which is part of Network Rail then negotiates with the TOCs and FOCs of the actual timetables of when these activities take place.

Meanwhile, the Network Rail track engineers create a national plan of required work for the year, which is based partly on experience of required maintenance volumes of previous years and also expectations of changes and infrastructure renewal projects. These are then submitted to the National Access Unit, which is part of Network Rail, 95-80 weeks before the timetable is set. Network Rail's National Delivery Unit then co-ordinated and optimises the maintenance requirements and produces a

	working time table . Then 60-45 weeks before the timetable is set the National Access Unit negotiates the access with the TOCs and FOCs. Weeks 38-26 before the possession the NAU confirms the Period Possession plan with the TOCs and FOCs for them to plan their services. **How does the IM optimize the planning of maintenance possessions?** Network Rail optimises the planning of maintenance possessions by have a central team to look at the national work plan, they can plan machine movements and possessions on a national basis to ensure optimum utilisation of machines. All the optimisation is currently done manually. **How are the needs and wishes of the passenger and freight carriers taken into account?** The needs and wishes of the TOCs and FOCs are considered at various stages during the planning process, however, access is largely defined as part of the Route Utilisation Strategies and the Rule of the Route. **How could collaboration on maintenance plan development be improved between stakeholders (Infrastructure managers, maintenance providers, train and freight operating companies)?** Collaboration on the maintenance plan could be improved by much closer working between Network Rail and the TOCs and FOCs from the earliest stages of the planning process, this will allow much better optimisation and planning of work to best suit the end users. It is expected that as Network Rail goes through devolution, each of the regions will work much more closely to the TOCs that operate on that route and the planning process is likely to become much more decentralised. This may create difficulties in the planning of large machines, but should make the planning much more closely aligned the needs of the TOCs and FOCs.
DB	*Roles:* Asset owner DB Netz Asset Manager DB Netz Service provider DB Netz and external companies Major stakeholder German State The planning of the maintenance and the allocation of the train free periods is independent of the asset owner and manager and service provider. The asset manager is responsible for identification of the maintenance requirements and commission of internal or external service provider. The external service provider will get the same possession time. **Assumption:** the train free periods are periods with respect to the number and types of trains and a result of the original planning of timetable without maintenance • Stakeholders and their influence on location and length of train free period - German state, the owner of the infrastructure, has no influence on the train free period - IM, responsible for the quality of infrastructure, has influence on the train free period in the case that the IM reports the need of maintenance to the creator of the time table - Maintenance provider (internal or external) has no marginal influence on the train free period - The creator of the time table takes into account the long- and mid-term need for maintenance • The optimization of the planning of maintenance possession is done by a special educated assistant of the IM. The planning will be done with software and takes into account individual boundaries and tries to group maintenance activities in a region. • Extensive maintenance activities will be published long time before the activities starts and will be included in the time-tables. Short-term maintenance activities that results in a disturbance of the trains are published for a three month period. DB Netz marketing supports the train operators during the booking of lines in case of heavy maintenance activities. • In Germany as a transit country it is very difficult to improve the planning process in general. In

<table>
<tr><td></td><td>
general DB Netz marketing knows the requirements of the train operators and tries to take them into account.

The following table summarizes the different responsibilities of the stakeholder:

<table>
<tr><td>Production performance</td><td>Overall responsibility and coordination of planning and control process</td></tr>
<tr><td>Section manager</td><td>Support of production performance and link between supply management and 3-i-strategy</td></tr>
<tr><td>Planning and control</td><td>Coordination of the regional process for validation of proposed measures</td></tr>
<tr><td>Maintenance and asset manager</td><td>Prioritisation of technical demands on the basis of 3-i-strategy</td></tr>
<tr><td>Technical expert</td><td>Support asset manager to validate the measures</td></tr>
<tr><td>Coordinator for construction and operation</td><td>Integration of validated measures in the time tables</td></tr>
<tr><td>Asset planning</td><td>Planning of measures and project coordinator for investments</td></tr>
<tr><td>Controlling</td><td>Financial issues</td></tr>
<tr><td>…</td><td>…</td></tr>
</table>
</td></tr>
<tr><td>SNCF</td><td>
The list and roles of the stakeholders is described on this web page:
http://www.rff.fr/en/our-company/who-s-who-in-the-railway-sector

The French railway network is structured around a group of companies and bodies that cater to the various organisational requirements: administration, management, operation, renovation, safety, development, etc. As the network owner and manager, Réseau Ferré de France plays a pivotal role among these organisations.
The liberalisation of the railway market in terms of freight and passenger transportation has altered how the system is organised. To ensure a wider range of services, new organisations tasked with overseeing safety and the correct functioning of competition have emerged as part of a rationale of neutrality and transparency.

• Structuring of the network
- The government defines the network’s general orientations, makes decisions on major works, participates in the financing of projects and the renovation of the network, etc.
- The regions are taking on a growing number of responsibilities in the area of public transport. On 1 January 2002, they became regional transport organisation authorities. They make a significant contribution to defining transport policies and financing the development of the network, particularly under State/Region Strategic Plans (CPER).
• Network operation and management
- Réseau Ferré de France plays a key role within the railway system. As the owner and manager of the French railway network, it decides what targets to apply in terms of traffic management and how the network is run and maintained. Its main commercial activity consists of selling slots, i.e. allotting time periods during which trains can transit from one point to another.
- The Department of Railway Circulation (DCF) has since 1 January 2010 been responsible for traffic and circulation management on behalf of Réseau Ferré de France. This independent entity, which forms part of SNCF, guarantees fair and completely transparent access to the network for all railway companies.
- Railway companies are responsible for the transportation of passengers and goods. They pay fees to Réseau Ferré de France in order to be able to run their trains on the network. Since the network was opened up to competition, new passenger or freight transportation companies have been given approval to operate on the French railway network. RFF, the network
</td></tr>
</table>

manager, provides them with the slots and infrastructures that allow them to operate, in the same way as the SNCF.

- Network maintenance and development
  - As the project owner supporting network amendments and development, Réseau Ferré de France delegates construction and modernisation work on its infrastructures to representative companies (SNCF, SCET, XELIS, SYSTRA, SETEC, etc.), which must meet its sustainable development requirements.
  - Réseau Ferré de France also employs companies that specialise in large infrastructure projects to carry out major construction work. As such, Eiffage, Vinci and Bouygues are involved in partnership or concession contracts, notably involving construction projects on high-speed railway lines (LGV).
  - Delegated by Réseau Ferré de France, activities involving the maintenance and renovation of the existing network are, by law, carried out by SNCF Infra.
- Safety and free access to the network
  - The Public Establishment for Railway Safety (EPSF) works on behalf of the Minister for Transport to ensure compliance with safety rules and consistency in technical conditions and operational safety for all railway companies.
  - The Railway Activities Regulatory Authority (ARAF), created by the Act on the Organisation and Regulation of Railway Transport in 2009, is an independent administrative authority tasked with guaranteeing equal treatment for all organisations involved in the railway system. It ensures that access to the national railway network is provided under equal conditions for all railway companies, and that the development of competition is not hindered by rules governing the pricing of infrastructures in particular.
  - European organisations (Commission, Parliament, Railway Agency) also help to define and ensure compliance with the rules imposed on all national companies.
  - European Infrastructure Managers (or EIMs) are also working on the gradual creation of an interoperable European network. The EIM Association is currently chaired by Mr Hubert du Mesnil, Chairman of RFF.

How does the IM optimize the planning of maintenance possessions?
In order to optimize the planning of maintenance possession, RFF fixes some rules in section 4.5 of the National Rail Network statement in order to schedule the cooperation between both the maintenance providers and the Train and freight operating companies. To build 2012 timetable, RFF introduced the project “WINDOWS OF AVAILABILITY 2012” to enhance the planning and scheduling of works.

RFF (National Rail Network statement – Annex 8.4 about “Windows of availability 2012”):
A substantial amount of work of different kinds has to be conducted on the national rail network: maintenance, renewal or modernisation. This vital work forms part of ambitious programmes (renewal plans under the performance contract signed with the State, central-regional government project contracts, national commitment to rail freight, etc.).
In the current context (growth in passenger demand, opening up to competition, large quantities of works, late requests for works possessions, proliferation of the network, etc.) RFF has decided to introduce a clear and well-structured capacity allocation policy easily understandable to its customers and partners and designed to boost network productivity.
Windows of availability for works operations are the counterpart of clockface timetabling for train paths. Both are designed to enable capacity to be allocated on a systematic basis and, thereby, enable timetables to be compiled well in advance in complete transparency, ensure that train paths offered meet optimum standards and improve works possession scheduling.
"Windows" are constructed on an "all inclusive" basis. The different types of works are identified for each corridor then reclassified according to type in relation to their nature and the type of traffic expected. The timetable slots thus identified and available for reservation will be windows of availability for works. Outside these periods, capacity will be fully reserved for revenue service operations. The resulting train paths will therefore be one hundred percent certain.

Established track possessions (see section 2.1) for a line do not vary much from one year to the following. They can be revised when RFF or SNCF Infra show that a change can decrease the global cost (Reference document on infrastructure capacity sharing, section 5.4.3)

	RFF optimizes all the track possessions required for maintenance (including also speed limits) by favouring main lines. **How are the needs and wishes of the passenger and freight carriers taken into account?** Framework agreements can be contracted between RFF and operating companies. Moreover, in relation to the National Commitment to Rail Freight (ENFF), whereby the impact of works possessions on paths on the freight-oriented network (ROF) must not exceed four hours. RFF informs passengers and freight carriers of the track possessions scheduled as of January 15th Y-1. During the construction of the timetable, there is a coordination procedure Once the timetable is scheduled, RFF Service Centre (CDS) takes part in the timetabling process, in addition to the work already done in this connection by the Rail Traffic Department (DCF). The CDS' target is to resolve any conflicts between works possessions and train paths on certain days that may have come into existence since the preparation of the annual timetable. The Service Centre works in association with customers to find solutions and will offer proposals for each two-month period between 4 and 6 months in advance. Customers will be informed of progress in the train path-day allocation process for each two-month period via the GESICO application. **How could collaboration on maintenance plan development be improved between stakeholders (Infrastructure managers, maintenance providers, train and freight operating companies)?** -

- Effect of flexible maintenance on the relation with service provider

One of the goals of Automain is flexible maintenance with a minimal effect for the train service. This will influence the relation with the Service Providers.

- Explain how the Service Provider gets the possession time for doing the work in the current situation.
- What does flexible maintenance mean for the relation with the Service Providers and for the process of getting the possession time on the right moment?

What effects do you predict for:

- the amount of outsourced work
- the type of outsourced work
- the type of contracts (think of balancing financial aspects, incentives and processes)
- costs per activity
- workforce of the IM
- workforce of the Service Provider

Additional questions

- explain how the service provider gets the possession time for doing the work in the current situation;
- what impact does flexible maintenance have on the relationship between the IM and the train operator
- what impact does flexible maintenance have on the ability to get a possession when required?

IM	***Answer***
TV	1. Explain how the Service Provider gets the possession time for doing the work in the current situation. The role model related to the allocation of train free periods are a process that take 18 month in planning. Budget and procedures/priorities for maintenance project (grinding) selections, act as input for this process. Tamping needs are included and decided by the maintenance contractor, Trafikverket only measure that the track condition is according to the track classes. This gives the network statement (EC-directive 2001/14/EC) and act as input for the train table construction, see BAP planning. In Sweden, TV is commissioned by the Swedish government to issue the Network Statement (JNB) according to the Railway Act 2004:519 (Näringsdepartementet 2004). The aim is to have a single source of relevant and non-discriminating information of railway networks. In the Network Statement one finds the principles governing the right to operate traffic, infrastructure information, regulations governing applications for capacity and fees related to operation of traffic. Major Engineering Works (PSB) are also found in the Network Statement, which is a part of the planning of engineering works. The annual planning has to be finished before the Network Statement (JNB) so it can be published together with it, which is one year before the final Annual Time Table. Before signing a traffic contract with the operator, Trafikverket has to negotiate with the train operators for putting in time for maintenance, rebuilding and renewal work. This is called BAP – plan for all activities on track. The plan includes all activities except snow clearance and running or urgent repairs tasks. On the other hand, the infrastructure manager (if functional contract, the contractor self) have to put this plan BAP into their maintenance contract document so that the contractor can get an estimate of maintenance time available for each maintenance activity (tamping). Therefore the strategy for budget, maintenance and procurement selections must be closely linked (And also linked to “selling” strategy). Trafikverket has put both “selling of train traffic” and maintenance planning under the same organizational unit. It is now easy to realise that all maintenance, performance measuring and other procedures most be planned and decided in an early stage. See Figure 4.

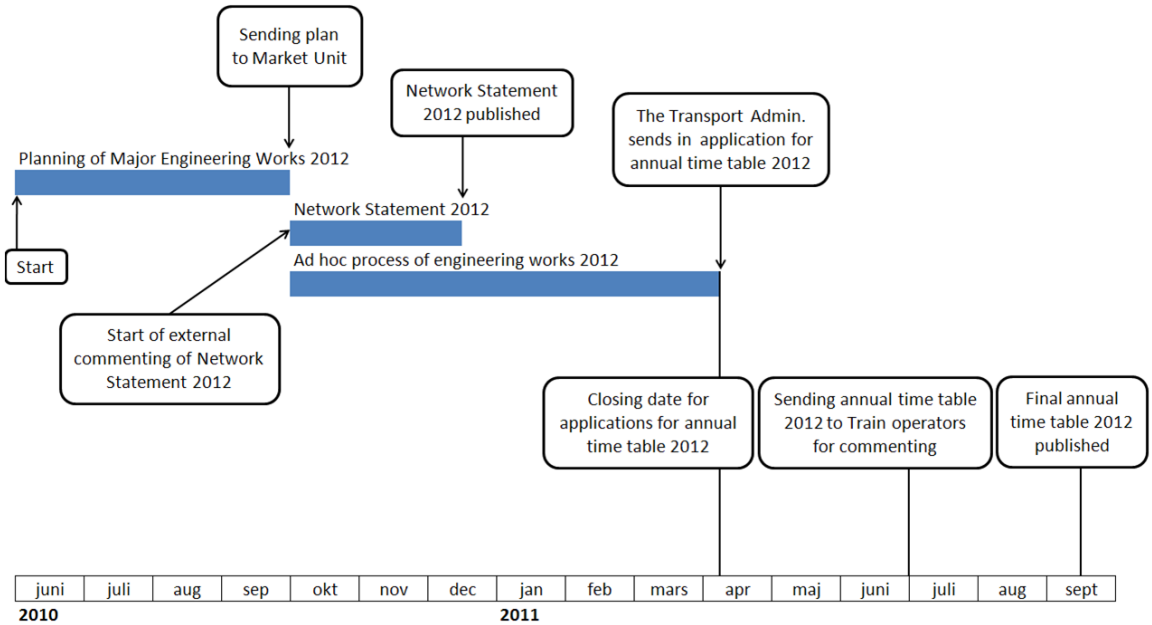


Figure 4: Sketch of the Planning of Engineering Works by TV. Planning starts one and a half year before Annual Time Table starts. Exact dates are left out.

The planning of engineering works is a main part of the organisational planning of TV. It is carried out on a yearly basis. Before the planning can start one has to collect data, analyse the infrastructure state, needs and requirements. The output from that analysis is the Maintenance Need Analysis (UBA), semi-literal translation. The Operation Department is responsible for the planning of engineering works. Within the Operation Department the Railway Division, Road Division and Technology Division assembles the need for reinvestments, maintenance and operation. The inquest is handed over to the Tactical Planning Division in the same department, whom does prioritisation of the engineering works. After prioritising, the former three divisions mentioned carries out optimisation of their future work according to the new plan and hands over the resulting plan to the Tactical Planning Division. The Tactical Planning Division does final prioritising and financial calculations. The output is a one to five years list of reinvestments, maintenance and operation work.

2. What does flexible maintenance mean for the relation with the Service Providers and for the process of getting the possession time on the right moment?

In order to achieve an efficient, flexible and effective maintenance decision support system, all involved parties must be included and fully updated in the whole process. This includes the main contract issues to be discussed, key factors such as safety, punctuality, availability, governmental (Trafikverket) goals and variables etc. and also presumed relationship amongst them. All this must be decided on and accepted by all involved parties along the maintenance planning process, see figure 5.

The methodology used is to inform and get clear about Trafikverkets goals and how Trafikbverket handles the different interrelationships and clarifies them and try to solve them in a good way. It is vital to be selective and to decide which variables are most important, which contract actions are likely to be most meaningful, and as a consequence, what information should be collected and analyzed to verify the selected and performed actions. This feedback is to be reported back to IM.

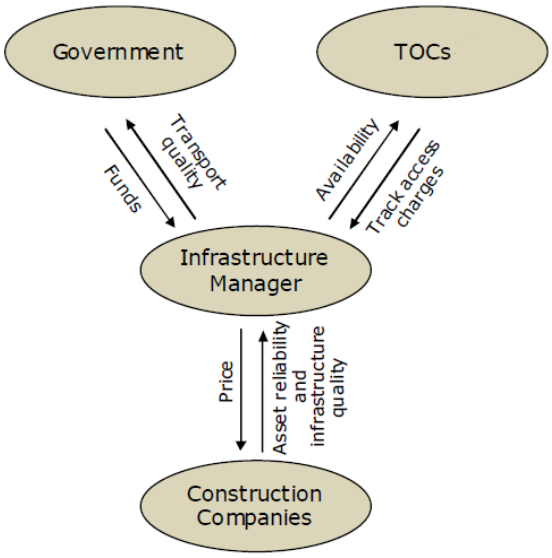


Figure 5. Parties involved in the process. TOC – Train Operating Companies

In these complex maintenance contracts, of interrelated engineering systems environment, with a number of different businesses constrains, large a large number of factors have to be considered, updated and distributed among involved stakeholders. This is an ongoing process for an 18 months planning period. Due to the actual traffic situation on the final day of planned maintenance execution, corrective daily maintenance planning usually take place by the train control centers.

Different planning decision support system helps to facilitate the management to be flexible in planning, however, the logistic, traffic situation, interlinked engineering systems, involvement of different organizations, budget updating etc. etc. gives almost no flexibilities left for maintenance actions.

What effects do you predict for:

- the amount of outsourced work
  In Sweden, 100% of train traffic and maintenance work are outsourced. The flexibility is then believed to be achieved in that the operator and the contractor, on an open market, is set under pressure to come up with new ideas and to find new ways of increasing its flexibility. Each company then increases its own flexibility in constrain and frame of its own business goals. Hence, 100% outsource level should then give an increase flexibility. However, the increased number of contractors and operators needs to be synchronized in some way so that the *system flexibility* is achieved. Flexible system logistic synchronization with increased number of parties is very hard to achieve, leading to that the maintenance providers, in the process of getting the possession time on the right moment, is hard to fulfill with an increased amount of outsourced work.

- the type of outsourced work
  Long technical life of rail assets need long time engineering strategy and safety condition control of the assets, in-between renewing and changing the maintenance contracts over time. Also, comparing costs of corrective and preventive maintenance, corrective maintenance cost is much higher and expensive than preventive maintenance due to loss of train “production” and higher labor cost. The potential for transferring “capacity killing” corrective maintenance to planned and predictive preventive maintenance is therefore high and must then be, in some way controlled by the IM to fulfill long term life, safety and cost management. Therefore, it is desired that the infrastructure mangers should focus on a balanced combination of predictive and corrective maintenance strategy. However, today only rail grinding is controlled by the IM. All other work is decided by the contractor.

- the type of contracts (think of balancing financial aspects, incentives and processes)
  See above text. The idea is that the market will give the lowest price with the highest quality.

	• costs per activity See above text. The idea is that the market will give the lowest price with the highest quality. • workforce of the IM Trafikverket have personnel for long/mid/short term strategies and planning, monitoring, procurement, contract managers and engineers. • workforce of the Service Provider Contractors have personnel for mid/short term planning, monitoring, contract managers and machines.
PR	1. Explain how the Service Provider gets the possession time for doing the work in the current situation. For the new performance based contracts (small scale maintenance) the contractor has to claim the needed possessions before he gets the contract. After award of the contract he gets the time he claimed to do the activities he think that are needed to meet the specifications. This results in a maintenance regime with a fixed timescale. The contractor gets and uses the slots he asked for. Renewal or new infra often leads to long possessions of frequently short possessions. The possessions are asked in advance (1,5 – 2 year). 2. What does flexible maintenance mean for the relation with the Service Providers and for the process of getting the possession time on the right moment? Flexible maintenance has no effect on our relation with the Service Providers. The process of planning a possession does not change. We expect that flexible planning of the possessions leads to an increase of the cost. The longer the planning horizon the lower the prize. So there must be relevant cost benefits for the Asset User to compensate for the increase of cost for the Asset manager (maintenance) due to flexible planning of the possessions.
NR	At present maintenance is carried out by Network Rail, who are also the infrastructure manager. Changes to working practices and hours would need to be managed, but this will be internal to Network Rail and should not alter commercial arrangements other than in the hire and operation of certain machines. **Explain how the service provider gets the possession time for doing the work in the current situation?** At present Network Rail gets the possession access as part of agreed access set out in the Route Utilisation strategy and the Rules of the Route. This is then defined in the time table with negotiation with the TOCs and FOCs. **What impact does flexible maintenance have on the relationship between the IM and the train operator?** There is a possibility to negotiate extra access to the track for more flexibility and this can be done up to 26 weeks before the possession, however, Network Rail will have to pay more to take access after the timetable has been set. There is also the possibility to take access to fit in around the white space in the timetable at much shorter notice. **What impact does flexible maintenance have on the ability to get a possession when required?** The current system is not very flexible, however, it expected that as part of the restructuring and devolution of Network Rail there will be much closer planning between Network Rail and the TOCs, this is expected to lead to less rigid systems and greater flexibility in planning and obtaining possessions as required.

DB	The possession time for the different maintenance activity are related to the type of work and the planning processes and handling time: • In case of a long planning period and handling time (up to 48 month) the non-availability of the track or track section is included in the timetable. Therefore long possession times days/weeks etc are possible. • In case of very short planning periods and handling time (days or weeks) the possession time is adjusted with the timetable. In case of double tracks the possibility of changing the track will be taken into account. In general all possession are at night. The problem of the right maintenance at the right moment is not only related to the track possession but also to the availability of the resources (machines, workers, etc). Therefore the planning of the maintenance activities is very important. Especially in big networks like DB the distribution of resources is a fundamental question. Most effects are difficult to predict. A flexible maintenance allows complete different strategies, approaches and processes. The cost per activity should go down to get the acceptance of IMs. Only in case of increase of availability, which is really needed by train operators, the cost per activity could increase. But in this case the IMs have to take into account also the life time of their assets.
SNCF	1. Renewals are scheduled three years earlier and the free periods for other maintenance operations are fixed one year earlier. The maintenance volume is assessed for each line. 2. Flexible maintenance cannot be applied without globally rethinking the maintenance policy. Contracting would be more difficult because flexibility induces more lead times. Therefore cost and complexity of the system are expected to increase. **Explain how the service provider gets the possession time** Windows of availability are finalized in April of year Y-2 and the schedule of the possession times is completed one year in advance. Therefore, all is discussed in an early pre-production phase. Preparatory work on requests for possessions is conducted in meetings organised by SNCF Infrastructure in year Y-2 also attended by RFF, and track possession applicants. These provide an opportunity for: • the applicants to comment on the potential alternatives; • RFF to put forward its first thoughts as regards the position it will adopt in reply to the formal applications it is likely to receive. **Flexible maintenance** Since the current policy is works to schedule the maintenance possession times as early and as “massively” as possible, effects of a really flexible maintenance are very hard to assess because all the process should be changed. However, a significant increase of costs is expected by both RFF and SNCF Infra.
Strukton	• We use the possession schedule as set up by ProRail. In this schedule each track or emplacement has a minimum possession time of 5½ hours for regular (small) maintenance activities. This schedule is fixed approximately 2 years in advance. Work which requires a longer possession time (cost-benefit analysis) will be discussed, requested and fixed 1½ to 2 years in advance. • This will result in variable workloads with peaks and troughs. More resources (both labour and equipment) will be needed in the peaks; and underuse of resources will occur in the troughs. This will inevitably result in poorly spread resource usage.

- Key Performance Indicators

What Key Performance Indicators (KPI's) do you use related to planned and unplanned unavailability and possession time?

Give for each KPI the following information:
- Algorithm, how is it calculated
- On which level of detail is it used (object, region, country, track, corridor etc.)
- What are the mechanisms to control the level of each KPI?
- Do you use any incentives, bonuses or penalties regarding to the level of the KPI's?

Additional questions
- The IMs seem to have a lot of things that they call key performance indicators; but are they all really key? Please differentiate between key and non-key performance indicators.
- TV has different KPIs for different line categories. Do the IMs have similar arrangements?
- Can the IMs describe the main function of the KPIs? Are they for monitoring asset condition, or for helping to make decisions about what maintenance should be done, or a mixture of the two?
- When an IM has to make a decision about what maintenance to carry out, how does it decide which KPIs to use?

IM	***Answer***
TV	Broadly, PIs classified by Trafikverket are leading or lagging indicators. A leading, lead, or prospective indicator is a performance driver, i.e. a measure that drives the performance of the outcome measure. The outcome measure itself is simply the lagging, lag, or retrospective indicator, e.g. different financial measurements. Leading and lagging indicators are relate to strategy/goals, and therefore it is important not to mix means and ends. When Trafikverket develop PIs, the PI characteristics are: • For railway-the-shelf or Trafikverket tailor-made indicators: an important distinction when the indicators are to be used in benchmark, inside or outside Trafikverket organisation • Long- or short-term indicators: an important distinction when deciding how long a time the indicator measures have to be stored • Slow or fast changing rate indicators: an important distinction when performing trend calculations or deciding if slower/faster redundant indicators must be used or developed, often the case for environmental issues The relation between different PIs can be studied from three different perspectives, namely relationships through signal characteristics, decision characteristics, or signal and decision characteristics. PIs used by Trafikverket are scalable; i.e. it must be possible to use them locally at the same time as they can be aggregated and used globally or vice versa. Since the development process for PIs follows a top-down approach where Trafikverkets overall business objectives are cascaded down to specific PIs to be measured in the organization, the reporting and aggregation of PIs follow a bottom-up perspective. This approach also makes it possible to integrate fully the PI system into other performance management systems in use, for instance balanced score cards that Trafikverket use. (See Thomas Åhrén "Maintenance performance indicators (MPIs) for railway infrastructure: identification and analysis for improvement", Doctorial Thesis, ISSN: 1402-1544, ISRN: LTU-DT—08/19 – SE, 2008:19 Luleå University of Technology, (2008)) The KPI has a differentiation and use when it comes to different line categories. The KPI is based governmental agreements and interfaces and internal KPI are broken down in the organization using BSC. Interfaces to internal systems support IM in translating top-level KPI-agreements into daily business planning. The internal KPI-systems are instruments to monitor and control the assets' performance development considering also local conditions since approximately half the budget is spent for maintenance and renewal of superstructure. KPIs for track are of highest importance. See Figure 6 and 7.

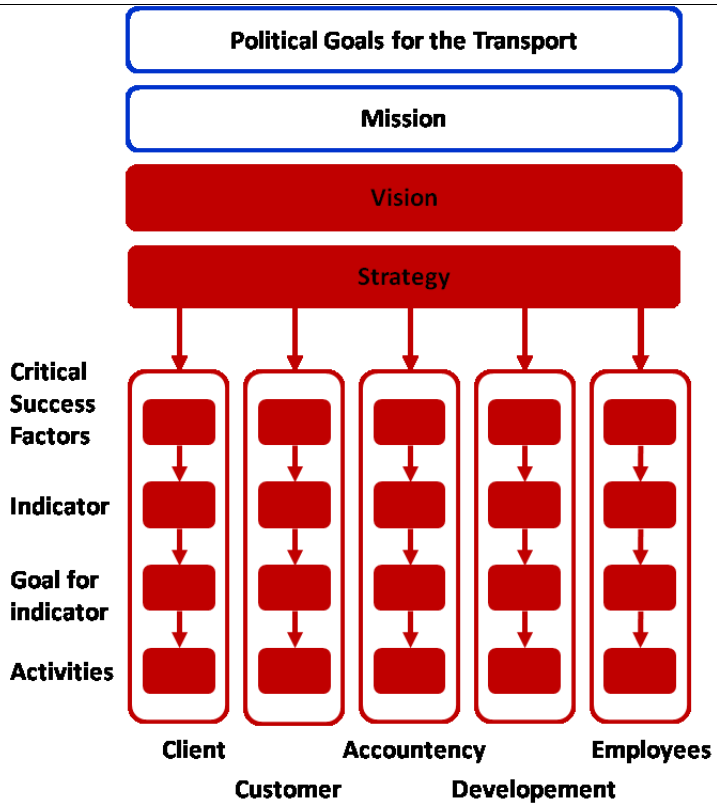


Figure 6: Overall sketch of the scorecard used by TV.

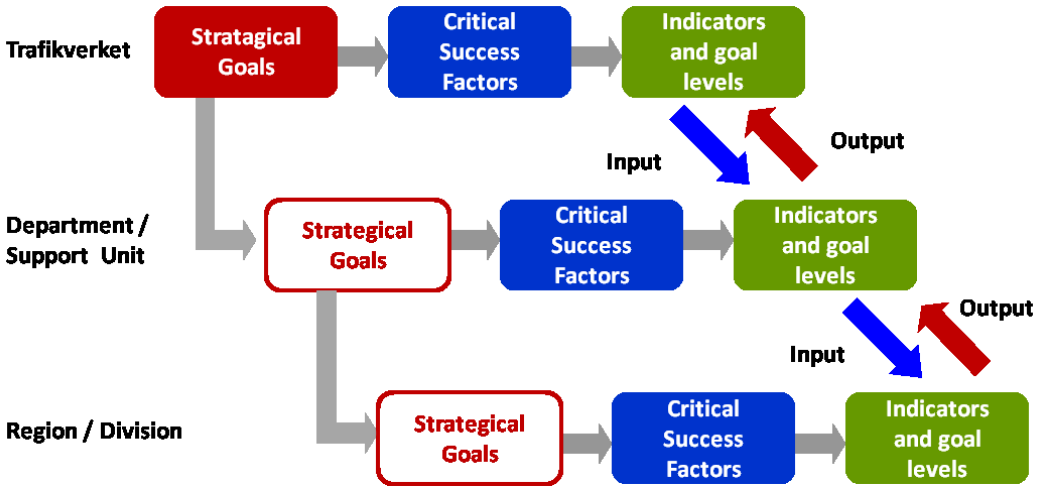


Figure 7: Overall sketch of the scorecard used by TV.

Trafikverket use 5 different line categories (1 – 5) to differentiate and prioritize the railway network, see figure 8. The criteria's are; traffic flows, number of trains per day, type of traffic and relative importance to society functions. Trafikverkets KPI breakdown and prioritization of activities are mostly differentiated according to the 5 line categories and then linked to maintenance and renewal prioritization. The five line class classification criteria are: economic importance, sensitivity to disruptions, ability to restore traffic after delays, regularity and frequency of traffic, established to support decision making and finally failure related target values linked to lines to manage maintenance activities.

Figure 8. The five different rail line categories in Sweden.

KPI differentiation according to line categories are presented in figure 9.

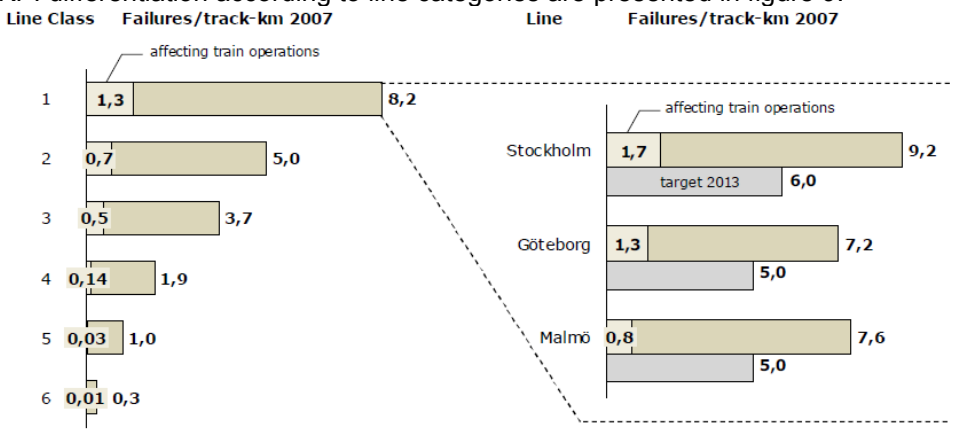


Figure 9. KPI differentiation. (5 and 6 are same classes from 2011)

Categories of top-level KPIs agreed with the government are: safety, network availability, asset reliability, quality and condition, finance, customer orientation and finally environment. See table 2.

Table 2. Categories of top-level KPIs.

First level sub-goals	Second level sub-goals	Maintenance performance indicators	Relationship BSC
An accessible transport	Improve the use of state infrastructure	- Capacity utilization - Capacity restrictions	Customers Customers

system			
A high quality of transport	Decreased train delays Decreased freight traffic disruptions Increased rail network maintenance efficiency	- Train delays due to infrastructure - Hours of freight train delays due to infrastructure - Number of delayed freight trains due to infrastructure - Number of train disruptions due to infrastructure - Q-factor (degree of track standard) - Markdowns in current standard - Maintenance cost per track kilometer - Traffic volume	Processes Processes Processes Processes Processes Processes Processes Financial
Safe traffic	Reduced number of killed and injured persons	- Number of accidents involving railway vehicles - Number of accidents at level crossings	Customers Customers
A sound environment	Reduced energy consumption Effective natural resource consumption	- Energy consumption per area - Use of environmental hazardous material - Use of non-renewable materials	Financial Innovation Innovation

From 2011 we use operational quality as in table 2.

Track Class	Punctuality	Robust	Traffic information	Comfort	Safety	Usefulness
1	++	++	++	+	++	Base
2	++	++	++	++	++	Base
3	+	+	+	+	++	Base
4	Base	+	Base	Base	++	Base
6	Base	Base	Base	Base	Base	Base

From the table above, Table 2, it is found that the operational qualities punctuality, robustness and usability, or usefulness, are related to punctuality. The underlying indicators is found in the table below, Table 3.

Table 3**:** Delivery qualities, or operational qualities and their underlying indicators used by Trafikverket.

Delivery Quality	**Performance Indicator (KPI)**	**Unit**
Punctuality	- Arrival Punctuality - Train Delay	% h/Million-train-km
Robustness	- Downtime, or Restoration Time	h/days

Traffic Information	- Availability of the traffic information system - Passenger Satisfaction (NKI) - Trip-planner	% % Quantity
Riding Comfort	- Q-value - Passenger Satisfaction (NKI)	- %
Safety	- Kills and Injuries - Vehicle damages	Quantity Quantity
Usability	- Availability of Infrastructure	%

The indicators related to availability from Table X above is:

- Arrival Punctuality [%]
- Train Delay [h/Million-train-km]Downtime [time]Availability of Infrastructure [%]

KPIs Related to Punctuality and Availability

In TV's, or former BV's annual report of 2009 one finds indicators of punctuality, delay and regularity.

Punctuality

A punctual train is no later than five minutes to its end station. The punctuality is presented over three and five years as the percent that is punctual for different types of traffic and different line classes. The traffic types are Passenger Trains, Freight Trains, Long Distance Trains, Express Trains, Regional Trains, Commuter Trains and Arlanda Line. And the line classes are City, Major Lines, Other Important Lines, Minor Lines and No or Little Traffic. (Banverket 2010)
The indicator used by TV is called Arrival Punctuality and is one of the underlying indicators for the six deliver qualities of Trafikverket with quantitative objectives for the different railway lines. Punctuality is presented in the latest strategic plan 2010-2021 of Trafikverket with objectives up to year 2021 (Banverket, Vägverket et al. 2009). Similar presentation over a five years period is found in the annual report of 2009 (Banverket 2010).

Train Delay

In the Swedish network, Train Delays due to Infrastructure can be found as an index over an eight years period and as an indicator in hours for passenger and freight over a three years period (Banverket 2010). Delay data can also be found in the monthly reports of TV, as well as punctuality, traffic volume and regularity. In TV's monthly report of December 2010, delay is presented over three years, in hours, with the owner of the cause to failure. The owners of the cause to failure are Operation Centrals, Infrastructure, Train Operator, Accidents & Mishap and Secondary Delays (five in total). Secondary delay occurs when a delayed train affects the next coming trains. (Trafikverket 2010b) Another work where the owners of train delay were examined was carried out by Nyström Delay hours due to failures in infrastructure for different geographical regions for 2002-2005 can be found in the maintenance handbook of TV. TV stresses on the issue that this indicator does not take into account which time on the day the delay occurs and therefore it does not show the effect on passengers on there way to work in a good manner. Another issue to keep in mind is that the indicator does not take into account the cancelled trains. Indicators of regularity measure this issue. (BVH 800 2007)
Timetables are constructed with some slack so that trains can take back small delays that can occur during travelleing. This slack affects the delay, depending on how large it is, and should therefore be measured and compared with the delay. An indicator for measuring the timetable slack is the Slack over Total Travel Time (Goverde, Odijk 2002). This indicator has been redefined by Nyström to measure the availability due to slack, i.e. 1 – Slack/Total Travel Time. It is then straightforward to

	define an indiactor for planned slack by using the planned travel time instead of the total travel time, i.e. Slack over Planned Travel Time and 1 – Slack/Planned Travel time. **Regularity** Regularity can be presented as the number of trains in percent that travels the whole planned distance, or as the number of cancelled train departures. The regularity indicator is found in TV's monthly report of December 2010 for passenger and freight over three years (Trafikverket 2010b), and cancelled train departures are found in TV's annual report of 2009 for passenger and freight over three years (Banverket 2010). These indicators are called Train Regularity and Cancelled Trains. **Availability** Availability of railway infrastructure is used as an indicator in the operation and maintenance scorecard Delivery Qualities by Trafikverket, called Availability (Banverket, Vägverket et al. 2009). Availability is defined as: $$A = \frac{Uptime}{Uptime - Downtime} = \frac{MTBF}{MTBF + MTTR} \quad (1.1)$$ Where: MTBF = Mean Time Between Failures MTTR = Mean Time to Recovery (or restoration) Note that TTR can stand for Time to Recover or Time to Repair. See Section 2.1 for TV's operation and maintenance scorecard Delivery Qualities. Reliability is related to availability and is the ability of an item to perform a required function under given conditions for a given time interval, i.e. a measure of probability (SS-EN 13306 2001). The reliability cannot be measured by any indicator but can be calculated for specific times by the use of failure data. Availability is a function of reliability, maintainability and maintenance supportability (SS-EN 13306 2001). **Conclusion** Availability is a function of Uptime and Downtime and is therefore related to the indicators Train Delay per Item and Downtime. It is possible to calculate various availabilities of different items but does not necessarily give any additional inputs than the related indicators, besides normalizing the range to zero and one. Nevertheless, one indicator has been identified: • Availability of Infrastructure [%] (or Network Availability, used by TV and SBB) • MTBF [h] • MTTRecovery [h]s • MTTRepair [h] Give for each KPI the following information: • Algorithm, how is it calculated. These are current developed during 2011. • On which level of detail is it used (object, region, country, track, corridor etc.) These are current developed during 2011. • What are the mechanisms to control the level of each KPI? These are current developed during 2011. • Do you use any incentives, bonuses or penalties regarding to the level of the KPI's? These are current developed during 2011.
PR	In the contract 2011 ("Beheerplan 2011") between the asset owner (government) and the asset manager the following top KPI's are mentioned. **KPI Capacity distribution** The extent to which ProRail is capable to honor the requested train paths by the asset users

KPI Delivered trainpaths
The percentage of the original planned train paths that ProRail allowed the asset users the use for their operation.

KPI Partially delivered trainpath
The percentage of the not realized trainpaths where the passenger train has passed a part of the planned the time table checkpoints.

Trainpath quality (all passenger carriers) (new)
This is the arrival punctuality of all trains on all scheduled passenger arrivals.

Punctuality (5 minutes, Main routes) (new)
This is the punctuality that the main passenger carrrier (NS) has agreed to the ministry of transport

Major disruptions (main routes) (new)
The number of emergency days per year: This is the number of days per year that the main routes punctuality is below 75% and the main routes ridden trains drops below 90%.

Top 5 least performing train series from last year (new)
For top 5 least least performing train series the trainpathquality is multiplied by the % delivered train paths. Here, only the series of train passenger carriers is considered with a minimum of 20 rides a day and not transnational. The KPI is the average of these five Lines.

Major disruptions (new)
The number of infrastructural disasters that result in the failure of a node. These are the number of infrastructure failures (no collisions and collisions).

KPI Passengers satisfaction on the cleanness of transfer
The percentage of the train passengers of NS that gives the cleanness of the transfer a rating of 7 out of 10 or higher.

KPI Passengers satisfaction on social security (daytime and evening)
The percentage of the train passengers of NS that gives the social security on the stations a rating of 7 out of 10 or higher.

KPI Passengers satisfaction with travel information during disruptions
The percentage of the train passengers of NS that gives the information supply to the passengers a rating of 7 out of 10 or higher.

KPI Accessibility
The extent to which Prorail delivered the accessibility measures, as described in the implementation plan “Accessibility”, conform to plan.

KPI Availability
The availability of the infra during opening hours.

KPI Maintenance time
The percentage of time the infrastructure is not available for the trainservice, due to possessions for planned maintenance

KPI Downtime
The percentage of time the infrastructure is not available for the trainservice, due to a disturbance

All of the mentioned indicators are introduced to manage the contract between ProRail and the government. So they are all key performance indicators.

Up to now Prorail does not use different levels of the KPI's for the different type of lines ("infra concepts"). We intent to do so in the future and are working on it. In this project the main focus is on defining the infra concepts and the level of the performance and cost KPI's.

The 2011 targets for the KPI's:

Tabel 2: Overzicht Beheerconcessie met dienstengroepen en KPI's ProRail

Zorgplichtgebieden Conform artikel 6, lid 1, Beheerconcessie	Diensten Conform Netverklaring 2011	Prestatie-indicatoren Conform artikel 6, lid 1, Beheerconcessie	Grenswaarde 2009	Grenswaarde 2010	Grenswaarde **2011**	Streefwaarde 2012	Streefwaarde 2013 e.v
Kwaliteit van de capaciteitsverdeling	Treinpaden	Capaciteitsverdeling	99,5%	99,6%	**99,6%**	99,6%	99,6%
Beschikbaarheid en betrouwbaarheid van de hoofdspoorweg-infrastructuur		Geleverde Treinpaden	-	97%	**98%**	98%	98%
Kwaliteit van de bijsturing		Deels gerealiseerde treinpaden	-	40%	**60%**	60%	60%
		Beschikbaarheid:	99,49%	99,53%	**99,45%**	99,45%	99,45%
		Storingstijd	0,21%	0,21%	**0,21%**	0,21%	0,21%
		Onderhoudstijd	0,30%	0,26%	**0,34%**	0,34%	0,34%
Reinheid, toegankelijkheid en sociale veiligheid van transfervoorzieningen	Transferdiensten	Reizigerstevredenheid over reinheid	55%	55%	**55%**	55%	55%
		Reizigerstevredenheid over sociale veiligheid:					
		overdag	86%	89%	**90%**	90%	90%
		's avonds	58%	58%	**58%**	58%	58%
		Toegankelijkheid	56%	71%	**86%**	96%	>96%
Kwaliteit van de informatievoorziening	Informatiediensten	Reizigerstevredenheid over reisinformatie bij ontregelingen	53%	56%	**56%**	57%	57%

ProRail has been translated its company goals into a balanced scorecard (BSC). In this BSC the objectives from different perspectives are translated into performance indicators and measures. ProRail deliberately chooses to steer on a combination of performance indicators and actions because the only steering on 'numbers' gives a one-sided focus. ProRail also works continuously to further develop his dashboard to ensure that the output and performance that we deliver matches with the expectation of the customers and our financiers.
Besides the key performance indicators (KPIs) with min – max values that are represented in the figure above ProRail also uses a number of internal KPIs. These KPIs are also used to support and measure our strategic goals.

Tabel 1: Interne afspraken

	Waarde				
	2009	2010	2011	2012	2013 e.v
Klanttevredenheid					
Reizigersvervoerders (reg., kernnet)	n.v.t.	7	7	>7	>7
Goederenvervoerders	n.v.t.	7	7	>7	>7
Regionale en lokale partners	n.v.t.	7	7	>7	>7
Publiek	n.v.t.	7	6,6	7	>7
Punctualiteit < 5 minuten	93%	93%	93%	93%	93%
Realisatie infraprojecten					
Functiehandhaving	n.v.t.	10%	10%	10%	10%
Overige werkstromen	n.v.t.	20%	17,5%	15%	15%
Aantal botsingen trein-trein	3	3	2	2	2
Aantal ontsporingen	5	3	2	2	2
Aantal arbeidsveiligheidsincidenten	3	2	1	1	1
Life Cycle Costs (LCC) per treinkilometer	€ 9,58	€ 9,54	€ 9,25	€ 8,96	€ 8,65
Arbeidsmarktimago	72%	Top 50	Top 50	Top 50	Top 50
Medewerkerbetrokkenheid- en tevredenheid	75%	80%	80%	80%	80%
Contractopvolging omgevingswerken*	n.v.t	n.v.t.	-	-	-

* In het Beheerplan 2011 zijn geen waarden vastgesteld voor de KPI Contractopvolging omgevingswerken. De komende tijd zal ProRail deze KPI volgen en na het eerste halfjaar 2011 nader evalueren.

PR also uses KPI for safety (see next figure), some examples are:

- Collision train – train
- Derailment
- Accidents when on duty
- Electrocution
- Transfer incident
- Collision on level crossing
- Suicide

KPI - Ongevallen volgens ERA kwalificaties (afgesproken met I&M)

Domein		ERA / Ernstige ongevallen	Aantal 2010	Doel 2011 ≤	Doel t/m apr	Aantal t/m apr	DS 2011	ZS 2011
Veilig Reizen		Botsing trein-trein	1	2	0	2	0	0
		Ontsporing	1	2	0	3	0	0
Veilig Werken		Aanrijding baanwerker	0	0	0	0	0	0
		Elektrocutie	0	0	0	1	0	1

KPI - Ongevallen volgens ProRail kwalificaties (interne sturing)

Domein		Ongevallen	Aantal 2010	Doel 2011 ≤	Doel t/m apr	Aantal t/m apr	DS 2011	ZS 2011
Veilig Reizen		Botsing trein-trein	17	9	3	5	0	0
		Botsing trein-trein CBG	8	3	1	4	0	0
		Botsing trein-trein NCBG	9	6	2	1	0	0
		Ontsporing	23	22	7	16	0	0
		Ontsporing CBG infra/mat	1	0	0	1	0	0
		Ontsporing CBG overig	5			5	0	0
		Ontsporing NCBG	17	22	7	10	0	0
		Transfer ongeval	300			24	0	0
Veilig Leven		Aanrijding overweggebruiker	32	50	16	11	2	1
		Suicide (incl. poging tot)	275			109	67	2
Veilig Werken		Aanrijding baanwerker	0	0	0	0	0	0
		Elektrocutie	1	0	0	1	0	1
		IF-rate spooraannemers						
		IF-rate kabelbedrijven						
		IF-rate werkplekbeveiliging						
		Ongeval personeel op bouwplaats	51			36	0	2

NR

TV has different KPIs for different line categories. Do the IMs have similar arrangements?
The KPIs are split up into the routes for performance comparison of one route to another. However, they are not divided up into line categories.

Can the IMs describe the main function of the KPIs? Are they for monitoring asset condition, or for helping to make decisions about what maintenance should be done, or a mixture of the two?
The performance KPIs have the main function as business tool for Office of Rail Regulation to assess Network Rail's performance and also for Network Rail to assess it's own performance and compare that across the routes.

Monitoring data from track recording cars and other measurement systems is used to decide which maintenance activities should be carried out and prioritised. This data is subject to limits of criticality which define what maintenance is required and how soon it should be carried out. Some KPIs will have an indirect impact on decision making in that routes will want to maintain high levels of Passenger Comfort levels, minimal numbers of rail breaks and other incidents. These asset condition KPIs are also recorded on a route basis and reported to the Office of Rail Regulation

When an IM has to make a decision about what maintenance to carry out, how does it decide which KPIs to use?
When maintenance is carried out all of the KPIs below are relevant to ensure that the possession is carried out with minimal interruption to traffic. But it is the Asset Condition KPIs that will have a greater influence on the decision of what maintenance is to be carried out.

KPIs - Performance

KPI	**200**	**PPM**	Percentage of franchised operator trains that arrive 'on time' at their destination (10 mins for Long Distance, 5 mins for Regional and London & South East)	Number of trains arriving within 5/10 minutes divided by total number of planned trains	Punctuality on the network; are we getting passengers to their destinations at the scheduled time
PI	201	Passenger Lateness	Average weighted lateness for passengers at their final destinations (taking into account cancellations and missed connections)	(Minutes late at each stop x number of passengers alighting from train) + (Minutes impact of cancelled trains and missed connections x number of passengers affected)	What is the actual impact of delays on the network to passengers arriving at their final train destinations
PI	202	Right Time	Percentage of trains arriving exactly on time or early at their final destinations	Number of trains arriving on time or early divided by total number of planned trains	Punctuality on the network; are we getting passengers to their destinations at exactly the scheduled time (or before)
PI	203	Delay Minutes	Accumulated loss of time compared to scheduled running times by individual trains at set monitoring points	Sum of minutes lost by all trains between monitoring points	Representation of how delay incidents impact on train services
PI	204	Cancellation and Significant Lateness	Percentage of trains cancelled or running 30 minutes or more late at their destinations	(Number of trains arriving 30 minutes or more late plus number of trains cancelled) divided by total number of planned trains	Severely disrupted services (although in a minority) have the greatest impact on people travelling and leaves a strong negative impression of the railway

PI	205	Cancellations	Percentage of trains which are cancelled	Number of trains cancelled divided by total number of planned trains	Cancelled services create a big disruption to passenger journeys and leave a strong negative impression
PI	247	Freight PPM	Percentage of freight operator trains that arrive 'on time' at their destination (ranging from 5 to 20 minutes depending on type of commodity being transported)	same as PPM	It is necessary to have separate PPM measure for frieght
PI	252	Non-Franchised Cancellation and Significant Lateness	Percentage of non-franchised operator trains cancelled or running 30 minutes or more late at their destinations	Same as Cancellation and Significant Lateness	
PI	248	Non-Franchised PPM	Percentage of non-franchised operator trains that arrive 'on time' at their destination (10 mins for Long Distance, 5 mins for Regional and London & South East)	same as PPM	It is necessary to have separate PPM measure for non-frachised operators
PI	431	Public Performance Target (PPT)	PPT is a weighted average of PFM (Freight Performance Measure) and PPP (Public Performance Measure)	The basic calculation (expressed as a percentage) is (PPM % x 0.9) + (FPM % x 0.1)	It is intended to be a measure which more fully encompasses performance achievements by Network Rail, rather that individual elements of Passenger or Freight performance. As such, it is potentially a better indicator for bonus calculations.
KPI	226	Network Availability	Measures the % of train schedules ran and disrupted (cancelled or replaced by buses vs. the permanent timetable) per weekend, per TOC	WTT compliance = (total no. of schedules planned and run as trains / (total no. of schedules planned and ran as trains + bus schedules vs. the permanent timetable + cancellations vs. the permanent timetable)) * 100% Class 1 and 2 services, per weekend, per TOC as reported in Trainplan	WTT compliance is the KPI aimed at measuring the reduction in usage of the replacement bus services and cancellations disrupting the railway during weekends. In order to incentivise better planning and delivery resulting in reduction of the disruption in the short term, it excludes long-term disruption (e.g. a 6 month replacement bus service introduced for a major renewal work) and focuses mostly on the effect of the typical maintenance and renewals possessions.
PI	227	Possession Disruption Index for Passengers (PDI-P)	The economic value of the impact of possessions on excess journey time as experienced by passengers as a result of disruptive possessions	(Excess Journey Time x Busyness Factor) x (# Passengers x Time of Day Weighting x Economic Value of Time) divided by (Total Scheduled Passenger Km	Incentivise Network Rail to minimise possessions which have the biggest value impact on passengers

		PI	228	Possession Disruption Index for Freight (PDI-F)	Track Kilometre availability weighted by relative levels of freight traffic operated over each ELR	(Average freight tonne km per SRS divided by Average freight tonne km for network) x (Track Km Available divided by Total Track Km)	Provides network availability measure with relative importance to freight operators	
		PI	229	Rail Replacement Bus Hours	Measures the rail replacement bus service hours operated due to possessions	(Scheduled departure time - Scheduled arrival time) using TSDB code 'BR' summed over all TOCs	Bus hours not captured in excess journey time so this will ensure the impact of bus substitutions are minimised	
		PI	244	Possession Notification	Percentage of disruptive passenger possessions notified prior T-12.	Number of disruptive passenger possessions that were entered into National Timetable database within 12 weeks before the date of the possession. Further splits for number of disruptive possessions that were: • incorporated in First Working Timetable • entered into National Timetable database within 12 weeks before the date of the possession • entered into National Timetable database within 12 weeks before the date of the possession divided by total number of disruptive passenger possessions	Network Rail should be incentivised to plan possessions as far in advance as possible Improves the planning of journeys by passengers as changes made before T-12 are not seen by the travelling public	
		PI	245	Late Possession Cancellations	Percentage of possessions that were cancelled after issue of the Weekly Operating Notice (WON).	Number of possessions per period that were cancelled after issue of the Weekly Operating Notice (WON) divided by the total number of possessions recorded in the relevant period	Cancellations published after the WON do not allow train operators time to re-schedule services that were previously cancelled	
		PI	246	Possessions Involving Whole Line Block	Expresses the number of possessions recorded as 'whole route blockage' as a percentage of the total number of possessions.	Number of possessions recorded as 'whole route blockage' divided by the total number of possessions	Network Rail should be incentivised to take partial line blocks to allow more services to take place	
		PI	232	Delay Minutes Due to Possession Overrun	Delay minutes per scheduled train kilometre due to possession overrun	Total delay minutes attributed to possession over-runs divided by scheduled train-km	To incentivise Network Rail to not simply take longer possessions with a greater chance of over running	
		PI	233	Cancellation Minutes Due to Possession Overrun	% of trains cancelled due to possession overrun	Number of trains cancelled due to possession overrun divided by number of trains	To incentivise Network Rail to not simply take longer possessions with a greater chance of over running. (Using % of trains cancelled aligns with Cancellations and Significant Lateness performance measure)	
		IPI	**308**	Maintenance Planning Efficiency	Percentage planning level multiplied by percentage plan attainment (i.e. how well we are planning our available resource, and how well we are then delivering our plans)	Planned Delivery Efficiency % = % planning level x % plan attainment	This is as measure of how well we deliver plans that fully utilise the available resources.	

			% planning level = norm hrs planned in 4 wks/maximum hrs available for the same 4 wks % plan attainment = norm hrs of planned work delivered in 4 wks/norm hrs of work planned for delivery in the same 4 wks			

Infrastructure Condition KPIs

Asset Group	Category	ICR Code	Measure
Track	Performance	Delay 1	COT TSRs
		Delay 2	Track Faults (including Broken Rails)
		Delay 3	Points Failures
	Asset Condition	Track 1	a. Track Geometry: Poor Track Geometry
			b. Track Geometry: Poor Track Geometry - S&C Eighths
			c. Track Geometry: Good Track Geometry
		Track 2	a. Track Geometry: L2 Exceedences
			b. Track Geometry: L2 Exceedences on lines over 40mph
		Track 3	Track Geometry: TGI (and SDs)
		Track 4	Track Geometry: Super Reds
		Track 8	Number of Broken Rails
		Track 9	a. Number of Rail Defects: Isolated Defects Discovered
			a. Number of Rail Defects: Remaining Isolated Defects
			b. Number of Rail Defects: Continuous Defects Discovered
			b. Number of Rail Defects: Remaining Continuous Defects
		Track 10	Number of Track Related Derailments (Running Lines)
		Track 11	Number of Track Buckles
		Track 13	Number of Points Failures
Civils	Performance	Delay 4	Bridge Strikes
		Delay 5	Lineside Structure Failures
	Asset Condition		c. Additional Inspections
		Civils 4	Number of Earthworks Failures
Signalling	Performance	Delay 6	Track Circuit Failures
		Delay 7	Signalling System and Power Supply Failures
		Delay 8	Signal Failures
		Delay 9	Cable Faults (Signalling and Telecoms)
		Delay 10	Level Crossing Failures
		Delay 11	Other Signal Equipment Failures
		Delay 20	Axle Counters
	Asset Condition	Signal 1	Signalling Condition Index (YTD is last available annual return)
		Signal 2	a. Incidents of Signalling Failure Causing Delays
			b. Incidents of Signalling Failure Causing Delays in Excess of 10 minutes
		Signal 3	Number of Track Circuit Failures
		Signal 4	Number of Category B Technical SPADs
		Signal 5a/b	Signal Failures with a Hazard Rating of 20+ (by Type)
		Signal 5c	Signal Failures with a Hazard Rating of 50+
Operational Property	Asset Condition	Op Property 1	Station Stewardship Measure (YTD is last available annual return)
		Op Property 2	Light Maintenance Depot Condition Index (YTD is last available return)
Electrification and Plant	Performance	Delay 13	OLE/Third Rail Faults
	Asset Condition	E&P1	E & P Condition Index - AC Feeder (ytd is last available annual return)
			- AC Contact
			- DC Substation
			- DC Contact
		E&P8	Signalling Power Supply Failure Causing Delays in Excess of 10 minutes
		E&P5	Number of Signalling Power Supply Failures
		E&P7	Traction Power Failure Causing Delays in Excess of 10 minutes
		E&P6 AC	Number of AC Traction Power Supply Failures >300 mins
		E&P6 DC	Number of DC Traction Power Supply Failures >300 mins
		E&P4	Number of AC & DC Traction Power Supply Failures >500 mins
Telecoms	Performance	Delay 14	Telecoms Failures
	Asset Condition	Telecoms 6	Incidents of Telecom Failure Causing Delays in Excess of 10 minutes
		Telecoms 4	Safety Related Telecoms Failures with a Hazard Rating of 20+

DB	KPIs *Number of speed reductions* • Only counting Database • From region to whole network • This KPI will also be monitored by the government *Number of delay minutes* • We asked for the algorithm. • From region to whole network *Number of delayed trains (unplanned availability)* • Delayed trains will be monitored individually for long-distance, regional and freight trains • See section 6 in “Schienennetz-Benutzungsbedingungen 2012” (SNB 2012) for the algorithm. Service providers have to pay a penalty if they don’t meet the possession time. Normally the SP breaks the maintenance to allow train operation. In case the SP can’t break the activity (e.g. heavy maintenance at a bridge or renewal of track) the SP has to pay for the delay minutes. The penalty depends on the train type and delay. DB Netz has to pay penalties to the train operators if the assured percentage of punctuality will not keep during the year due to infrastructure reasons (see also 1.1 for assured punctuality). The basis of the funding by the government are the following indicators, which are monitored by DB and the government; ***Quality indicators*** *related to the funding by the government:* • Theoretical loss of travel time • Number of defects of the infrastructure • Functionality of train platforms height of platforms, accessibility without stairs, weather protection • Assessment of asset quality quality and visual appearance of platforms • Supply guarantee of power ***Additional quality indicators****:* • Number of faults and mean time to repair • Mean age of important • Condition categories of bridges and tunnels ***Assesment indicators*** *are:* • Delay minutes • Total track kilometre of trains • Number of train stops in platforms • Traction energy Additional the *delay minutes for the different train operators* will be monitored and compared with predefined limit values. DB has no different indicators for different lines. The maintenance of an asset is triggered by the inspection results and prioritized by the significance of the asset. The significance is build of income and actual/future traffic volume and influence of KPIs

	like delay minutes.
SNCF	To evaluate a tentative schedule: • The number of track possessions • The total volume (in km.h) for each line A posteriori evaluation of the maintenance efficiency : the train tardiness caused by infrastructure Performance indicators of RFF are derived from the performance contract between RFF and the state (see question 1.1). Four high-level performance indicators are given in the infrastructure management agreement between RFF and SNCF (CGI 2007-2010, article 27): • Quality, track geometry → Track level • Reliability → Number of train delays caused by the infrastructure • Reactivity of maintenance and exploitation (both under the responsability of SNCF Infra) → Total delay in minutes (sum of the length in minutes of the train delays caused by infrastructure • Reactivity of the maintenance → (Mean?) duration to repair infrastructure failures Maintenance is now mainly scheduled for each of the main axis (the rest of the network is divided into subset of lines). The decisions about what maintenance should be done are based on indicators based on models or inspections. For example, the time periods between some periodic operations change in function of the UIC group of the line.

- Trends, developments or opportunities for train free periods

What trends, developments or opportunities do you see in the length or the effectiveness of the train free periods?

- What innovations are used at this moment?
- What are the results on performance and costs?

Additional questions
- Could all IMs please check that they have answered the question about trends?
- Most IMs foresee an increase of the maintenance costs. Please explain.
- How do IMs balance the demands from train operators for more track access, with the increased maintenance cost that will result?
- What cost increase is acceptable to decrease possession time by 1% / 10% / 50%?

IM	***Answer***
TV	• What innovations are used at this moment? With the current procurement strategy using functional contracts with little or less impact from IM, regarding the decision making process of choosing activities, the trend must be to develop train free periods. This is to get at better logistic forecast to allocate time and resourses to perform preventive maintenance actions. It is too complex to work with a dynamic planning self updating process with all involved parties as we do today. • What are the results on performance and costs? Performance might go up and maintenance cost might also go up. This is all linked to how much profit the contractor is willing to get and how good the IM is to manage and control the situation. If successful, the LCC per train kilometer might go down.
PR	• Within ProRail we see a trend called “more for less” (also known as “simple track”). This means we want to create more capacity and functionality using less infra. This means we have to maintain less infra. A disadvantage can be the accessibility of the infra to be maintained. • We use a method (TRS) to optimize the effectiveness and costs of the trainfree period. We optimize between the Life Cycle Costs and the social benefits for the passengers and freight trains. We use a self developed calculation tool to do the calculations (LCM tool). In this tool we calculate the prize of planned unavailability (a train free period) and unplanned unavailability (errors). The prize depends on the number of trains, number of passengers, time of day etc.. • We want less people on the track during opening hours. We achieve this by using an other maintenance regime and making more use of dedicated measuring trains: - ProRail is developing a new maintenance planning (Maintenance Planning 2020) in order to facilitate future developments concerning maintenance and traffic. The most important developments are: ▪ Increasing traffic demand (High Frequency Programm to be implemented in 2020) ▪ Increasing maintenance activities ▪ Increasing complexity of safety measures resulting in more out of service hours The new planning will be based upon another frequency of service hours with an adjusted time slot. At the same time it will optimize the service hours needed for projects and systematic maintenance. Major benefits will be an increase of capacity needed for traffic and a decrease in cost. - We changed from inspecting the switches and crossings by men force to inspection with a dedicated inspection train. - The use of specific measuring and inspecting trains increases. This has a big advantage for the safety and the required train free periods. Cost benefits depend on the type of measurement. - We want to make a switch from using specific measuring and inspection trains to normal

	passenger trains equipped with measuring devices. • With equipment build in in the infra we monitor the condition of the trains (e.g. Quo Vadis, hotbox detection). **Most IMs foresee an increase of the maintenance costs. Please explain.** We expect that flexible planning of the possessions leads to an increase of the cost. The longer the planning horizon the lower the prize. So there must be relevant cost benefits for the Asset User to compensate for the increase of cost for the Asset manager (maintenance) due to flexible planning of the possessions. The increase of cost is caused by: • Fragmentation of the work and the late fixation of the date and time of the possession leads to inefficient use of man and machine force resulting in higher absolute price and probably a higher price per trainkilometre (increase in cost is more than increase in tonkilometre!) • Flexible maintenance leads to more space for passenger and freight trains. So the track is used more intensive resulting in a high demand for maintenance. This will lead to a higher absolute price and a lower price per trainkilometre (increase in tonkilometre is more than increase of cost!). **How do IMs balance the demands from train operators for more track access, with the increased maintenance cost that will result?** Up to know the (increased) cost of maintenance is not an issue during the negotiations between the infra manager and the asset users (train operators). We negotiate only about the time available for riding trains and time for maintenance
NR	Current work streams now used or in planning: In-service train and measurement train monitoring and inspection Line side intelligent infrastructure monitoring including S&C remote condition monitoring Modular S&C for quick renewal High volume track renewal trains New road-rail vegetation clearance machines The results of all of these initiatives will result in reduced possession time and reduce numbers of people out on track. **Could all IMs please check that they have answered the question about trends?** It is expected that there will be a growing trend for the maintenance to be fitted into shorter slots, the current use of longer maintenance slots at weekends is likely to be pushed as much as possible into mid-week night time slots in order to provide a full timetable service at weekends and on public holidays. This will be especially true on the main routes. **Most IMs foresee an increase of the maintenance costs. Please explain.** Maintenance costs are expected to rise due to increasing numbers of staff working unsociable hours, but there is also a reduction in the utilisation of machinery if it is only used in the night time. **How do IMs balance the demands from train operators for more track access, with the increased maintenance cost that will result?** Maintenance will need to be fitted into the shorter slots, but improvements in efficiency and carrying out more work and inspection away from the track is expected to drive through cost reductions as well as meeting the train operators demands. Also efficiency improvements in the opening and closing of possessions such as ensuring that the possession is clear of plant will have an impact. **What cost increase is acceptable to decrease possession time by 1% / 10% / 50%?** The acceptable increase in costs to decrease possession times will depend upon the track and the

	current capacity constraints on that track. For many rural lines there is probably no incentive to increase costs to reduce possession times. However, for a major route that is capacity constrained such as the West Coast Mainline in the UK the business case will be in favour of spending more money on maintenance in order to free up capacity. For example in Network Rail's 2007 Strategic Business Plan for a Seven Day Railway, http://www.networkrail.co.uk/browse%20documents/strategicbusinessplan/other%20supporting%20documents/seven%20day%20railway%20(final).pdf, identifies that estimates from EWS and Freightliner predict that a seven day railway would add £105m pa of freight revenue to the UK railway and by 2030 the additional freight earnings would be as high as £210m pa, The same report estimates that to achieve this maintenance costs would need to increase £90m pa and significant enhancements would be required including remodeling and adding additional cross-overs, bi-directional signaling, modified isolation and earthing arrangements on electrified routes.
DB	DB changes the percentage between corrective (condition based) maintenance with short-term planning (handling time) and preventive maintenance with mid- and long-term planning to preventive maintenance. These increase the efficiency of maintenance activities due to longer possession times, grouping of maintenance activities and better pre preparation. **Most IMs foresee an increase of the maintenance costs. Please explain** The increase of maintenance costs is related to more or new traffic. For example the increase of head checks (all over Europe) results actual in higher maintenance costs for the rail. But the 3-i-strategy at DB has the goal to reduce the maintenance and investment costs in long-term at higher track quality. **How do IMs balance the demands from train operators for more track access, with the increased maintenance cost that will result?** The train operators have to pay a track access charge that is based on the infrastructure costs. **What cost increase is acceptable to decrease possession time by 1% / 10% / 50%?** Only in the case the IM can sell more slots (more trains on a line) an increase of maintenance cost is acceptable. But in case of highly loaded tracks you have to take into account the reduced life time of the assets and the related interruption time for renewal.
SNCF	Maintenance by night with single-line working may increase maintenance cost by a factor of 2. Innovations • Gates between track to increase the safety of the workers • Train announcement by radio. **Trends:** The infrastructure management agreement is to be renewed in 2012 and will fix the trends for the coming years. Since, much maintenance and works are planned in the next years, the trend is to combine as much work as possible in somehow large possession times. This process is called massification. **Most IMs foresee an increase of the maintenance costs. Please explain.** - **How do IMs balance the demands from train operators for more track access, with the increased maintenance cost that will result?** The maintenance cost per train-km was 3.55€/train-km in 2008, 3.66€/train-km in 2009 and 3.84€/train-km in 2010.

	What cost increase is acceptable to decrease possession time by 1% / 10% / 50%? -
Strukton	Through the use of measurement and video trains and measurement systems like POSS, the need for staff presence on the tracks will be significantly reduced.

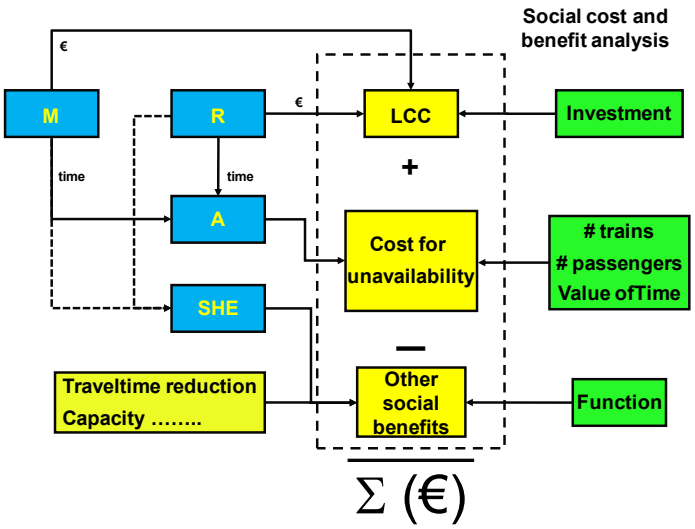
- Good practices and benchmarks

What good practices / benchmarks do you know about how individual infrastructure managers in Europe translate their company goals (such as punctuality) to asset management strategies?

- Mention the relevant situation and explain briefly why this is a good practice.

Additional questions
- Could each IM say what technique or process they have seen used by other IMs, which has impressed them sufficiently to want to try it on their own network?

IM	***Answer***
TV	In 2007 Banedanmark, the Danish rail infrastructure operator, commissioned BSL to conduct an international study on asset management practices in railways. For that project eight European railways in total contributed to the study and met in several workshops to discuss their good practices in areas such as organizational structures, core processes and information management. As a result the complete peer group agreed to continue working together in a so called "club project" to explore several issues more in depth and to take advantage of the project as a platform for networking and further exchange. In the course of this club project the railways openly provided dedicated experts and comprehensive information on the defined work packages, held presentations during the workshops in London and Bern and vitally exchanged ideas. Mention the relevant situation and explain briefly how to find good practice.
PR	The punctuality is now used as a KPI for the asset user. The IM (asset manager) can only affect a portion of the punctuality. We mention some developments that can be relevant for other IM's: • more capacity and functionality using less infra • we use more and more partial lifetime extension instead of complete renewal • new maintenance contracts are performance based, this means that the contractor decides what maintenance is needed to meet the specifications (kind of maintenance and the frequency is not prescribed by Prorail) • many initiatives to reduce the LCC with 20 % in projects for renewal, small maintenance (e.g. performance based contracts), new functionality • due to recent accidents the focus of the asset owner, asset manager and asset user is more and more on the customer (= passenger) • many project are started to reduce the number of incidents with casualties • ProRail has a new management which focuses more on the translation of the company goals to activities for each department and individual • ProRail succeeded to make the connection between RAMSHE performance and the economic value.



- We are starting projects to change the position of the signals. One of the consequences is that the distance between the signals will decrease. This must result in a quicker reduction of the train delay minutes following to a disruption. In Japan this is proven method to optimize the punctuality.
- ProRail is impressed by the way NR translates company goals (business objectives) to AM Strategy
- ProRail is impressed by the performance dashboard of NR
- Prorail is impressed by the Infrastructure detoriation models for maintenance planning used by SNCF. We learned about these models during the UIC study "Line Comparison Study"
- Recently ProRail was impressed by the usage of SAP for asset management by RFF. After 10 years work they have achieved a level of automation that is the benchmark for ProRail. The situation of both infra managers is different (RFF is their own service provider and ProRail outsources everything) but many subjects are eye openers for ProRail.

NR

All of Network Rail company goals are translated into asset management policies and are monitored by Office of Rail Regulation through the KPIs and define the asset management strategies.

In terms of benchmarking studies there is the Asset management Club Project, which Network Rail participated in.

Could each IM say what technique or process they have seen used by other IMs, which has impressed them sufficiently to want to try it on their own network?
Network Rail has been very impressed with the KPIs developed by ProRail and Trafikverket and the cost savings derived from negotiation of maintenance supply contracts. The use of KPIs is of interest to compare and monitor the performance of the different routes although Network Rail carried out the maintenance activities in-house.

DB

DB AG:
- Use of high performance maintenance machines like
  - Four sleeper tamping machine 094X inclusive high speed ballast plough (?) (Pflug in German)
  - High performance grinding and milling machines with up to 64 grinding stones
  - High speed grinding
  - Two-Pass-Grinding
- Preventive maintenance (grinding, tamping)
- Use of optimised track components and track construction (rail, rail fastening, under sleeper pads, under ballast mats, slab track, …)
- Maintenance groups for switch maintenance

	High performance maintenance machines ensures longer maintenance sections during a given possession time. Preventive maintenance enables longer possession times, grouping of activities and reduction of machine movements. An optimised track reduces the need of maintenance due to an decrease of deterioration and harmonises the maintenance cycles.
SNCF	Macroscopic degradation laws are useful to evaluate the required volume of maintenance. Systematic renewals of long line sections at fixed time-intervals makes the network more efficient.

- Available data on performancekillers and overruntime

Do you have data available concerning:

- Performance killers:
- The planned activities that have the most effect on the unavailability KPI.
- Data about the overruntime of planned activities
- The time for each sub-activities of the performance killers?

Additional questions

- Please could the IMs say what are their top three performance killers and why? The answer should be on the basis of 'gut feeling / experience'; there is no need to do a data analysis to find the answer. We can then compare the IM answers with our own analysis of the data

IM	***Answer***
TV	• Performance killers: Yes and No First of all one need do define a performance killer. These are current developed during 2011. • The planned activities that have the most effect on the unavailability KPI. First of all one need do define an unavailability KPI. These are current developed during 2011. • Data about the over runtime of planned activities These are current developed during 2011. • The time for each sub-activities of the performance killers First of all one need do define a performance killer. These are current developed during 2011.
PR	• The planned activities that have the most effect on the unavailability KPI: we do not know what activity the small maintenance contractor executes in a planned possession. For renewal and new infra we have more knowledge about the activities in a possession. • Data about the overruntime of <u>planned</u> activities: we have data of the overruntime of a possession. We have no data to relate specific activities to overruntime. • The time for each sub-activities of the performance killers: The contractor has this information but he only askes us permission for the total time. Prorail has no detailed information.
NR	• The planned activities that have the most effect on the unavailability KPI: Yes we can obtain this data from our possession plans • Data about the overruntime of <u>planned</u> activities: Yes, we can obtain this data from the possession data and our penalty payments • The time for each sub-activities of the performance killers: Data is not recorded in this much detail, but we have standard task times for planning purposes **Please could the IMs say what are their top three performance killers and why? The answer should be on the basis of 'gut feeling / experience'; there is no need to do a data analysis to find the answer. We can then compare the IM answers with our own analysis of the data** Experienced gut feeling of the top 3 performance killers are: Tamping Wet bed removal OHL maintenance As these are felt to be the top 3 activities which impact on the availability of the track to train operators.

DB	Performance killers: • The planned activities that have the most effect on the unavailability KPI. YES. This question is difficult to answer (please explain in more detail). Do you mean the activity itself or do you mean the influence of the activity on failure that causes unavailability. • Data about the overrun time of planned activities No - we have to check • The time for each sub-activities of the performance killers Yes – hopefully we can take this at least from time and motion studies Top performance killers, based on possession time: 1. Renewal of track and components 2,Grinding Tamping
Strukton	Currently, it is not possible to work according to safety regulations outside possession times. Fail-safe detection equipment might enable maintenance outside possession times.

• Maintenance and inspection processes

- Processes to plan a possession

Explain the processes, involved parties, decision moments and criteria that are relevant to decide whether or not a possession will be planned.

- What determines when a possession is carried out?
  - MGT – scheduled into campaigns (e.g. tamping campaign for a whole route) or individual sites.
  - Inspection data
  - Availability of plant
  - Timetable availability
  - Public holidays/low traffic
  - Availability of budget
  - Pre defined maintenance intervals preventive/prognostic) maintenance
  - Other things ….
- Who is in charge of the decision?
- Who is the owner of the processes?

Additional questions
- How do IMs decide what work should be done?
- How do IMs 'bundle', group, or package together the tasks?
- How do IMs decide what length of possession would be best?
- Who measures the status of the infrastructure?
- Can NR system provide more information about "Modelled prediction of wear and crack growth"?

IM	***Answer***
TV	All inspections are performed by the maintenance contractor according to the stipulated safety regulations. The contractors also decide on witch action that is needed to take after the inspection, depending on the results of the inspection. Regular track patrolling frequencies take place every second month. Regular frequencies for measurement trains take place every 6 months. Regular frequencies for ultrasonic measurement trains are based on line categories. Usually it inspects all rails one to two times per year. All inspected data are reported in IM own data bases BESSY and in OPTRAM. Trafikverket have detailed regulations for condition assessments and it differs according to line categories. Inspection frequencies for measurement trains also vary according to line categories. Trafikverket's contractors can use several modern and multi-functional measurement trains that are utilized for condition assessment. In order to control the development of KPIs, frequent and systematic condition assessments are regulated by Trafikverkets different inspection regimes. In recent years Trafikverket invested a lot in technologies to improve the accuracy of measurement results and to optimize the need of human resources for condition assessment. Appropriate evaluation processes and new developed computer software are necessary to sort the benefit from the terabytes as input for condition based activity planning and handling raw data from the inspections. Trafikverket's Infrastructure system for assets is called BIS, corrective (emergency) maintenance report failure data system is called 0felia, the preventive and safety Inspection System is called BESSY. Track quality measured data are analyzed in OPTRAM and data can also be found from safety way side monitoring systems for wheel flats and hot bearings.

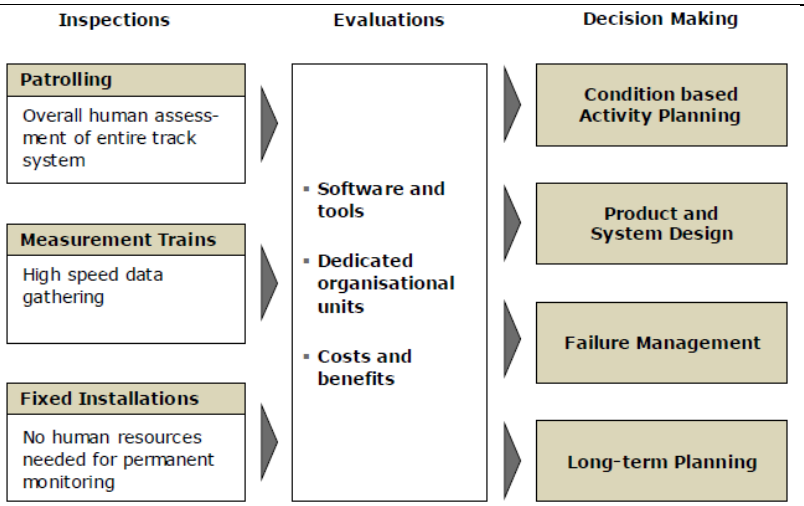


Figure 5. Inspection process chain from inspection via evaluation to decision making.

Trafikverket use both mind-based knowledge inspections to IT-based condition assessments such as HI tech video recording systems and laser measurements from measurement trains. Information on historical and current asset condition is also stored in order to support decision making and to improve knowledge on asset degradation and its behavior. Inspection regimes – especially for visual inspections – are sometimes not so updated. Potential and possibilities of modern information technology that results in high expenditures for human resources might be used in future. Video inspections play more and more an important role in condition assessment, in parallel reducing safety risks for track patrolmen. Still, the general opinion is that automated inspections will not fully substitute human assessments fully.

What determines when a possession is carried out?
Due to seasonal changes in frost and winter conditions, the Swedish philosophy on tamping is “if it lies still inside its limits, do not fix it”, meaning that if the tack is stable, do not tamp and adjust. Also, due to the frost problems, most of the tamping must take place during the summer months. In spring the measurement train gives data on places that needs tamping. Tamping is then performed during summer and in the autumn the contractor validates the track position using the measurement train. The grinding campaigns are planned according to data on corrugation, NDT train measurements and visual inspections.

- MGT – scheduled into campaigns (e.g. tamping campaign for a whole route) or individual sites. See above explanation.
- Inspection data. See above explanation.
- Availability of plant. It is up to the contractor. See above explanation.
- Timetable availability. It is up to the contractor. See above explanation.
- Public holidays/low traffic. It is up to the contractor. See above explanation.
- Availability of budget. It is up to the contractor. See above explanation.
- Pre defined maintenance intervals preventive/prognostic) maintenance. It is up to the contractor. See above explanation.
- Other things ….

Who is in charge of the decision?
All decisions are taken by the contractor, except for grinding.

Who is the owner of the processes?
IM in close corporation with the contractor.

PR	Involved parties in possession planning: Asset manager (maintenance and traffic) and (sub)contractor (responsible for small maintenance). The asset manager plans the possessions.

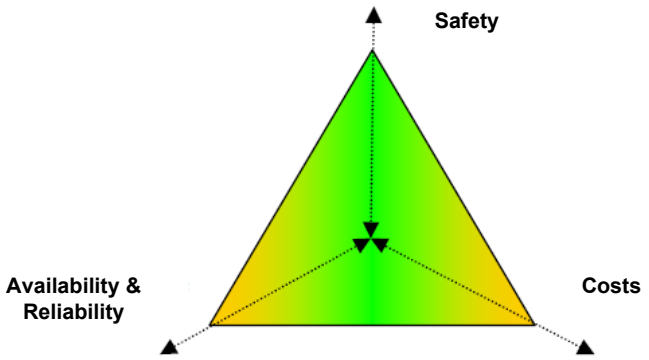
The planning horizon (normal process):
Year N+2 and further: long-term series (planning on year-level)
Year N+1: finalize maintenance planning (planning on day-level). The N+1 planning is adjusted to the needs of train operators in order to come to an agreement on maintenance vs train operations (In Dutch: Net declaration).
Year N: keep planning actual. In year N we make a distinction between small and large maintenance. Slots for small maintenance (at most several hours possession time) need to be requested 11 weeks in advance to the possession. Slots for large maintenance activities (renewal, grinding, tamping) need to be requested by contractors 21 weeks prior to the moment the possession is needed.

Planning horizon in case safety of the track is at stake:
Repairs need to be carried out within 6 weeks (small issues that cannot wait 6 weeks to be repaired, not safety related)
Repairs need to be carried out immediately or within 48 hours (small issues, safety related)

Relevant milestones in the planning process:
Long term planning (year planning / timetable):
- 2nd Monday in April: Closing date maintenance slots (year N+1)
- 3rd Monday in August: Timetable approved (trainpaths as well as maintenance slots)
- 2nd Sunday in December: Start new time table

Decision for maintenance is based on:
- Costs (minimal costs)
- Safety (sense of urgency)
- Manufacturability
- Necessity (what kind of work should be done)
- Duration / (un)availability of infra

ProRail uses the following model for maintenance:



How do IMs decide what work should be done?
- At the beginning of a contractperiod the contractor asks the possessions to do the “small scale” maintenance in his contract area. Bases on the status of the infra the contractor decides to do the work or to postpone.
- For the condition based maintenance, predetermined maintenance and complete renewals we make every year a production plan. When the money is available and the priority of the activity is high enough the activity is included in the plan.
- Based on questions from national or local governments ProRail changes the existing infrastructure of build complete new infrastructure.

Based on the capacity of ProRail and the contractors the activities 2 and 3 are planned in time.

How do IMs 'bundle', group, or package together the tasks?
We use a method (TRS) to optimize the effectiveness and costs of the trainfree period. We optimize between the Life Cycle Costs and the social benefits for the passengers and freight trains. We use a self developed calculation tool to do the calculations (LCM tool). In this tool we calculate the prize of planned unavailability (a train free period) and unplanned unavailability (errors). The prize depends on the number of trains, number of passengers, time of day etc..
When we combine tasks the tool also calculates the volume purchase discount and the discount due to the use of longer possessions instead multiple short possessions.

How do IMs decide what length of possession would be best?
When combining possessions we use the ProRail LCM tool to calculate the optimum length.

Who measures the status of the infrastructure?
Prorail is responsible for measuring the status of the infrastructure. We contract specialized companies for doing the measurements. The output data is available for both Prorail and the contractors. The data is analyzed mainly by the contractors and sometimes for specific reasons by ProRail.

NR

Answer to 2.1 and 2.2 - Infrastructure Maintenance Delivery Managers submit their requirements for maintenance possessions based on their planned campaigns, past data, track data and modelled predictions of wear and crack growth. The National Delivery Service (NDS) will then co-ordinate and optimise these requirements and schedule with the availability on-track machines and haulage as required.

Timescales:

Time Table/Time	Description
TT-95 – TT-80	Maintenance informs NDS of requirements for T3 access, on-track machines and engineering trains. NDS commences integration of access requirements and initiates negotiations with NAU (National Access Unit).
TT-80 – TT-65 (80-65 weeks before the timetable is set)	NDS co-ordinates and optimises maintenance requirements. This includes allocating follow-up possessions to track recording trains. The outputs of this are the draft versions of Rules of the Route (RotR), which is base annual access plan and establishes the frequency, amount and type of access required over the year. The WTT (Working Time Table) is also produced at this stage.
TT-65 (65 weeks before the timetable is set)	"PPS freeze date". Further requests for changes to Rules of the Route are no longer accepted.
TT-60 – TT-45 (60-45 weeks before the timetable is set)	NAU negotiates RotR and WTT with TOCs (Train Operating Companies) & FOCs (Freight Operating Companies). NDS publishes RotR at TT-44.
T-38 (38 weeks prior to possession)	Last opportunity to request low cost track access (input to the DPPP[Draft period possessions plan]). The DPPP firms up the T3 possessions and confirms specific locations, dates and durations. NB- A period is a 4 week long period of time, Network Rail splits a year into 13 four week periods.
T-38 – T-26 (38-26 weeks prior to possession)	NAU negotiates and confirms Period Possession Plan with TOCs & FOCs.
T-26 (26 weeks prior to possession)	NDS publishes CPPP.(Confirmed Period Possession Plan) which is the final agreed track access plan agreed by all stakeholders including the TOCs and FOCs
T-12	NDS confirms provision of additional (high cost) track access

(12 weeks prior to possession)	requested after publication of CPPP
T-7 (7 weeks prior to possession)	"PPS (Possession Planning System) lock-down" – further changes to work site information are no longer accepted.
T-5 (5 weeks prior to possession)	NDS / Maintenance "T-5 review meeting" held.
T-8 days (8 days prior to possession)	Draft WON (Weekly Operating Notice) is published, which is a weekly notification of all possessions and speed restrictions

Possession types:

1. *Absolute Possession* ("T3"). These are green zone possessions where lengths between signals or junctions are totally blocked to the passage of trains and controlled by a PICOP who has ownership of the line until it is handed back. They are commonly divided into a number of worksites, or can be used to allow bigger items of work to be carried out.
2. *Protected Possessions* ("T2"). These are usually short-duration possessions that are ideally taken between trains in quieter times of the day. T2 possession arrangements prevent train movements to protect a worksite using a number of protection arrangements.

How do IMs decide what work should be done?
The maintenance work that should be carried out is decided by the track engineers based on anticipated work based on previous years, known problem spots and need for renewals or enhancements. Work is prioritised based safety, then based on cost and whole life cycle asset management and ability to gain access to the track.

How do IMs 'bundle', group, or package together the tasks?
Work is bundled and planned, based on a primary task for the possession around which everything else is planned. Typically the principle task is planned from 95-80 weeks before the timetable is set, whilst other activities a planned around this, additional activities can be added into the possession up to 8 days before the possession as long as they don't impact on the possession length.

How do IMs decide what length of possession would be best?
The possession length depends upon the location. The physical length of the possession can depend upon the rate at which work can be carried out at eg tamping or grinding processes. The physical length of a possession typically is between switches or based on signalling block lengths.

The time length of a possession is typically based on the white space in the timetable, unless the activity needs requires a longer possession.

Who measures the status of the infrastructure?
Network Rail measures the status of the infrastructure and this is reported to the Office of Rail Regulation through the infrastructure condition metrics. Please see question 1.4 for details of the infrastructure condition metrics used.

Can NR system provide more information about "Modelled prediction of wear and crack growth"?
Network Rail has developed a tool called TrackEx which is designed to be simple to use and is written in visual basic in Excel so it can easily be used by track engineers for planning grinding and renewal work. TrackEx can model the impact different types of rolling stock on individual routes.

DB	**What determines when a possession is carried out?**

	• MGT – scheduled into campaigns (e.g. tamping campaign for a whole route) or individual sites. Partly in conjunction with preventive maintenance but not only the MGT is considered but maximum speed of track, radius, … • Inspection data YES – basis for corrective/condition based maintenance • Availability of plant YES, especially in case of preventive maintenance, grouping of activities to ensure availability and short transportation distance of plant • Timetable availability Partly, weekend, night, Monday (less freight trains), … • Public holidays/low traffic • Partly, low traffic, the timetable does not consider public holidays • Availability of budget Yes, the responsible asset manager has to look for the budget and makes a prioritisation of the maintenance activities (shift of activities (next year), grouping of activities, …) • Pre defined maintenance intervals (preventive/prognostic maintenance) Yes, DB uses more and more a mid-term planning of maintenance (preventive tamping and grinding) based on load, speed radius, … • Other things …. **Who is in charge of the decision?** In detail a lot of different peoples are involved. In either case the local asset manager, local head of maintenance and the local scheduler of construction phases are in charge. Also the internal or external service provider is in charged in the process to guaranty the availability of the plant and experts. In case of preventive maintenance activities experts from general office of DB Netz are involved. These experts elaborate the proposals for the maintenance activities. In case of activities, which have a big impact on the train operation a central scheduler of construction phases and people making the time table are involved in the process. In some cases the EBA (Eisenbahn Bundesamt) has to be involved. This may be necessary if DB gets a funding from the government or a new method apart from the regulation is used. **Who is the owner of the processes?** Local asset manager.
SNCF	SNCF and RFF are currently experiencing a major change in the process of track possession demands, allowances and planning. According to the maintenance needs expressed between 18 months and 2 years in advance by SNCF, RFF defines on each track segment a possession window typology (number of hours per day or night, number of weeks per year, single or double track possession, …) and allows an maximum amount of possessions corresponding to the amount of planned maintenance. **“Established track possessions”** Established possessions allow the completion of preventive and corrective maintenance as well as works suitable with their dimensions. The periodicity and schedule of these possessions are defined considering the particular situation of each track : • daily possessions - 1 hour during day time every day (for inspection and patrolling) + 4 to 6 hours at night for a limited number of weeks during the year + 3 hours minimum during low traffic time (week-end nights). - 1h50 at day time or 4 hours minimum at night from Mondays to Fridays. • variable possessions - maintenance is then performed during at a regular time, but on a varying locations, resulting in a limited flow and a fixed transit delay during the considered time.

“Special track possessions”
Selective possessions can be allocated to specific works such as investment works, renewals or major maintenance operations, for which RFF is looking the best technico-economic solution: i.e. possession for 8 hours a day on one or two tracks, line closure, etc.
Such special possessions are scheduled within a five-year sliding scheme, for the major routes.

The scheduling of these possessions is planned in several steps :

- Identification of main capacity options, 3 years before, on structuring axis and for major works.
- Planning of required possessions start from 2 years earlier. Close collaboration between RFF and SNCF. Planning sent to TOCs at the end of this step.
- Derogatory and late possession applications

The schedule of these possessions is negotiated between SNCF, RFF, train operators, and regional transport authorities, according to the needs of each, high and low traffic periods, planned renewal works, availability of plants, etc.

Dispensatory possessions can be allowed up to 35 days in advance, after negotiation within “capacity committees” where RFF, train operators, SNCF Infrastructure and scheduling office are represented.

This new process is still generating a large number of dispensatory and late applications. Under the pressure of the French Ministry of Transports, RFF and SNCF have created common coordination structures to optimize their cooperation.

Main axis and regional routes are to be considered differently according to the needs for anticipation and the capacity of negotiate dispensatory possession.

How do IMs decide what work should be done?
Renewal and investment works are decided by the IM (RFF) at the delegate IM’s (SNCF) instigation, based on the assessment of the infrastructure condition and on the expected life time of the components.
The IM decides to undertake the works according to its investment capacity and its strategic choices regarding impacted the line.

Planned maintenance operations are decided according to the maintenance needs expressed by the DIM, following the infrastructure monitoring and assessment and in accordance with maintenance rules.

Corrective unplanned maintenance works might be justified by the knowledge of the track condition and the compliance with safety standards

How do IMs ‘bundle’, group, or package together the tasks?
Possessions are decided and dimensioned for main structuring tasks (renewal works, sleeper replacement campaigns…). Secondary tasks are combined and integrated with the main ones by the Maintenance Production Territories, on the request of Maintenance business units (Infrapôles) and according to the availability of human and technical resources and operational compatibilities.

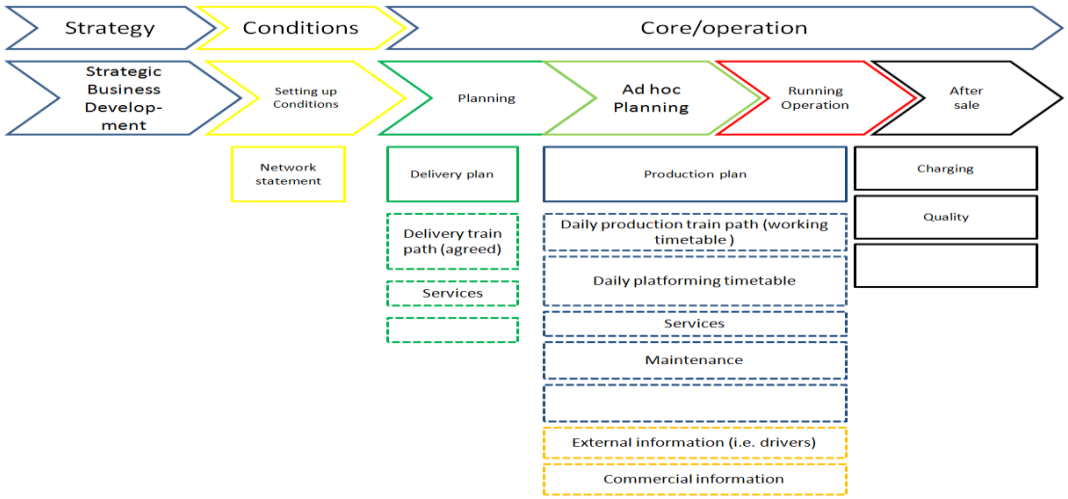
How do IMs decide what length of possession would be best?
RFF looks for an technico-economic optimum between the preservation of a maximal traffic capacity and the possession length needed by SNCF to perform the work.

Who measures the status of the infrastructure?
The condition of the infrastructure is measured and analysed by SNCF, as delegate infrastructure manager, who maintains the control over the measurement tools and process and who regularly

	reports to the infra owner on agreed indicators.
Strukton	For the dutch practice possessions can be characterized as • planned in a repeating roster (available for multiple contractors to carry out maintenance tasks), • as dedicated planned for multi-possession tasks (possibly combined with compatible other tasks), • as dedicated planned for specific tasks and as unplanned (break down service).

- **What are the relevant time-scales for booking a possession?**

Additional questions
- Please describe in more detail the process for setting up a possession?

IM	***Answer***
TV	It is up to the contractor. See above explanation. The contractor is a part of the overall process, see figure 6.  Figure 6. Time table process planning.
PR	In general for maintenance slots: Long possessions: 21 weeks in advance Short possessions: 11 weeks in advance Safety/reliability issues on the track: issues need to be solved within 48 hours See also 2.1
NR	See answer 2.1
DB	Depending on the scale of activity • maintenance, • heavy maintenance (noticeable impact on train operation), • renewal or • rebuilding a time scale between 14 weeks and 2 years is necessary.
SNCF	2 years before: • Expression of maintenance needs on each line segment • Definition of possession window typology • Negotiation and allocation of possession times from 2 years to 6 month before: • Continuous adjustment process • Bundling of tasks from 6 months to 35 days before : • Derogatory requests, submitted to a Capacity Committee

	From 34 days to 1 day before : • Late requests within the residual capacity
Strukton	It is possible to use mainly the available possession schedule, except for incidents which need to be solved within two weeks.

- Incentives, bonuses or penalties for possessiontime

Do you use any incentives, bonuses or penalties regarding to the use, overrunning or under running possession time?

- Describe the incentives that are in use.
- In what way are they part of the contract?
- Do they stimulate the right culture and results or do they occasionally turn out to be counter-productive?

Additional questions
- Please could the IMs give examples of the size of the financial penalties?
- Please could the IMs say whether they have bonus systems in place, as well as penalty systems; and if they do, what size is the bonus?

IM	***Answer***
TV	No, but Trafikverket is planning for this in future. Describe the incentives that are in use. In what way are they part of the contract? Do they stimulate the right culture and results or do they occasionally turn out to be counter-productive?
PR	Yes, there is a bonus/malus system for contractors. There is also stimulation for contractors who minimize the number of possessions and for innovations (like mobile worksphere) to decrease total downtime of the infra due to maintenance. For the new performance based contracts we use incentives for the different KPI's. When train passengers have more than 30 minutes delay they get a refund. This is paid by the largest passenger train carrier (NS) and ProRail. **Please could the IMs give examples of the size of the financial penalties?** For the new condition based contracts one of the criteria to get the contract is the number and length of the possessions. Depending of these numbers the value of the contract is adjusted. So a contractor with an offer of € 5.000.000 with 500 hours cumulative possession has a better offer than a contractor with an offer of € 5.000.000 with 750 hours cumulative possession. We have an algoritme to compare both offers. **Please could the IMs say whether they have bonus systems in place, as well as penalty systems; and if they do, what size is the bonus?** ProRail has a bonus/penalty system for small maintenance work following Output Controlled Contracts (± 15 % of all activities are output controlled now). The goal of ProRail is to change old maintenance contracts into new OPC-contracts within the next years. Subcontractors get a bonus of 0 – 5 % for minimizing the total TVP-time / number of TVP's. In case a subcontractor exceeds the given TVP-time the penalty will be of 0 – 5 %. Tamping / grinding / large maintenance works (i.e. renewal): There is no bonus/penalty system. The planning for these works is optimized by ProRail. The number of TVP's that was planned, but not used is very little. TVP's will be rescheduled and this will be communicated with train operators in an early phase. This makes it still possible for train operators to run their services. However, rescheduling TVP's should be minimized in order to unburden the planning department.
NR	Delay minutes and cancellations from overrunning possessions are both monitored KPIs. Network

	Rail must also compensate the train operating companies for any overrun of possession resulting in service delays and cancellations. Network Rail must also pay for access for the possession length, however, if the possession is booked more than 38 weeks before the work there is a lower cost for access to the track, so over booking possessions still costs Network Rail, but the incentive overall can be book longer possessions than required to avoid the expensive delay minute and cancellation compensation. **Please could the IMs give examples of the size of the financial penalties?** The financial penalties for interrupting traffic due to unplanned maintenance, infrastructure failures and possession overruns, these come under Network Rail's schedule 8 payments, the scale of these payments depends upon the route and train operating company. Traffic interruption due to planned maintenance comes under Network Rail's schedule 4 payments and again is based upon the route and train operating company. During 2009-2010 Network Rail paid a total of £149m in schedule 4 and schedule 8 payments. **Please could the IMs say whether they have bonus systems in place, as well as penalty systems; and if they do, what size is the bonus?** There is no bonus system in place for completing possessions early.
DB	Service providers have to pay a penalty if they don't meet the possession time. Normally the SP breaks the maintenance to allow train operation. In case the SP can't break the activity (e.g. heavy maintenance at a bridge or renewal of track) the SP has to pay for the delay minutes. The penalty depends on the train type and delay. Contractual details are not public. Yes they stimulate the provider to finish their work in time.
SNCF	There is currently no incentives, bonuses or penalties regarding to the use, overrunning or under running possession time, by the delegate IM. However, a global bonus/penalty arrangement between RFF and SNCF exists over track availability and train delays, which is partly impacted by possession time overrunning. Statistics on the use of possession are however recorded by both parts. Contracts between delegate IM and work contractors may include clauses on the respect of possession times.

- **Does the involved equipment affect the decision making?**

  - Types of worker protection applied – e.g. signal protection, detonators etc
  - Type of maintenance machine used
  - Shift length

  Additional questions
  - How do you decide what method of working to use?
  - Can the IM influence the optimization of pre and post-possession activities?

IM	***Answer***
TV	Yes, especially on single tracks and if we are running near capacity limits on the track section. It is up to the contractor. See above explanation. • Types of worker protection applied – e.g. signal protection, detonators etc Yes, always due to safety. It is done by a certified personal that always travels with the machine. • Type of maintenance machine used It is up to the contractor. See above explanation. • Shift length It is up to the contractor. See above explanation.
PR	• Types of worker protection applied – e.g. signal protection, detonators etc Yes. Mobile worksphere creates possibility to make use of very small time slots for maintenance Videotrain / inspection train: helps to inspect the infra in a safer way compared to personal, visual inspections. Use of remote controlled detonators • Type of maintenance machine used Mostly that's up to the contractor, but innovations are stimulated: Grinding machine: Using higher grinding speed 7 km/h instead of 5 km/h (reduces track possession or less possessions that • <u>Shift length</u> Shift length is important. For grinding / tamping longer shifts than usual (5.5 hours) are needed, because the used machinery is very expensive. For controlling switches small(er) slots of at most 5,5 hours can be used. **How do you decide what method of working to use?** This is up to the contractor, but during planning (1 year in advance) a rough estimation is made on what kind of working method will be used. For example when special work trains are needed the planning department should take into account that these trains are able to reach the spot where the work has to be carried out. **Can the IM influence the optimization of pre and post-possession activities?** ProRail does not do that at the moment. This is up to the contractor.
NR	Yes – requirements for engineering trains and labour are made to NDS (National Delivery Service) with the initial possession request. NDS will then optimise possessions based on the availability of equipment. **How do you decide what method of working to use?** The methods of protection used in possessions are defined in the Rule Book which can be found on the RSSB website: www.rssb.co.uk

	There are two types of possessions – Absolute possessions – which are green zone possessions where the work site is protected, either by closing all lines to traffic; workers are protected from traffic by a fence; or the use of warning systems and look outs. These are typically larger possessions with multiple work sites. - Protected possessions – are protected by signals and are typically used for short work tasks. Addition protection devices such as detonators should also be used if: • you are working on a single or bi-directional line • single line working is in operation on the line concerned. Emergency protection can be applied by use of track circuit operating clips and detonators Lines need to be blocked if: • The work group are at risk from trains • Work affecting the safety of the line - Carrying heavy or awkward equipment or materials across or along the line. - Work that will affect the condition of the track. - Digging a hole or stacking material or equipment close to the line or near the edge of a platform. - Placing a hand trolley on the line. - Using plant within 2 metres of the line. - Using a road vehicle within 2 metres of the line. - Using on-track plant (OTP) that will foul the line. - Using a crane or other lifting equipment that will foul the line. - Attaching anything to a railway structure, such as a bridge, a station roof or building, a signal post or gantry, or electrical equipment. - Using a ladder, unless secured so that it cannot fall towards the line. - Using scaffolding or a climbing tower, unless secured so that it cannot fall or move towards the line. - Felling or trimming trees. **Can the IM influence the optimization of pre and post-possession activities?** Network Rail aims to optimize the pre and post-possession activities, however, the RSSB Safety Board are the custodians of the safety case and therefore own the process for the safety related activities and the Rule Book.
DB	• Types of worker protection applied – e.g. signal protection, detonators etc No information, only a small influence expected • Type of maintenance machine used Yes. In case of preventive maintenance and the grouping of activities the type of machine is very important. Also for longer maintenance sections the type of machine influences the number or duration of possession • Shift length Yes, very important
SNCF	Involved equipments might affect the need of derogatory possessions, such as double track possession, when only a single track possession is planned. High output equipments allow more work to be done within the allocated possession. Innovation is highly encouraged towards higher output and alternative techniques allowing a reduction of possession needs.
Strukton	The choice of equipment and work method will of course influence the required length of possession time. It is therefore necessary to include start-up and clear-up time (e.g. equipment readiness time eating into the possession time).

- Involvement of IM in efficiency of use of possession time

- Possession pre-possession and post-possession tasks and timings
- Regulations and standards
- Experiences of IM
- Is there a central database for experience/knowledge about maintenance? This could help a new one to start working faster.

Additional questions
- Do you have a well defined process (LEAN, for example) for driving up the efficient use of possession times?
- If so, what is it, and what problems does it have?

IM	***Answer***
TV	The software Trainplan presented on a graphical time/distance graph and the graphs are re-planning manually by drawing in graph. Steering order is manually typed in to the central control system. The result manually recorded in the paper graph. In Sweden we are now testing STEG – Controlling train traffic trough a computerized time-distance graph. It´s the Swedish National Railway Administration:s project for development and implementation of an interactive prototype system based on traffic management rules and user interface researched. • Possession pre-possession and post-possession tasks and timings Yes during the BAP process see above. • Regulations and standards Yes during the BAP process see above. • Experiences of IM Yes during the BAP process see above. • Is there a central database for experience/knowledge about maintenance? This could help a new one to start working faster. No we do not have such database in Sweden.
PR	IM is involved. There are dashboards for reporting about efficient use of possessions. IM is involved by joining programs like mobile worksphere and for the planning of grinding machines. (see also 2.4) There is no central database for experience/knowledge about maintenance. Probably contractors have. **Do you have a well defined process (LEAN, for example) for driving up the efficient use of possession times? If so, what is it, and what problems does it have?** See also 2.3 answer first additional question See also answer 1.5 second bullit
NR	Network Rail is directly involved in improving the efficiency of possession times and is heavily incentivised to do this to increase the availability of the track, this optimisation is part of the possession planning process. Network Rail maintenance improvement teams have also been working on optimisation of the pre-possession and post-possession tasks subject to RSSB Safety Board approval. Network Rail has several databases which hold details of the task and sub-tasks carried out within each possession within the Ellipse database and the details of the possession and timings within the PPS database. **Do you have a well defined process (LEAN, for example) for driving up the efficient use of possession times? If so, what is it, and what problems does it have?** Network Rail have previously employed six sigma personnel to optimising and carrying out process improvement. However, there is currently no well defined process for driving up efficiency.

DB	• Possession pre-possession and post-possession tasks and timings Yes • Regulations and standards Please explain this question. Do you mean that IM give an input for regulation and standards? • Experiences of IM Yes • Is there a central database for experience/knowledge about maintenance? This could help a new one to start working faster No
SNCF	RFF is engaged with the French State through a Performance Contract, and is bound to improve the global efficiency of maintenance and the availability of good quality train paths. RFF is then working in close cooperation with SNCF to control and measures the efficiency of possessions, to assess the results of maintenance, to improve and adapt the maintenance and inspection policies and techniques and to keep an optimised balance between renewal, modernization and maintenance in order to minimize the maintenance needs and maximize the availability for traffic. **Do you have a well defined process (LEAN, for example) for driving up the efficient use of possession times? If so, what is it, and what problems does it have?** No permanently/globally defined process. Some optimized processes are being tested for particular conditions (heavy duty and suburban lines).

- External regulations

To what extent does external regulation (safety rules, law) affect the organisation of possessions?

- Regulations and standards
- Access to track and use of bi-directional running, single line closed, etc – does this depend upon line speed and track category?

IM	***Answer***
TV	It effects, but it is needed to fulfill its purpose, a safe working place for the personnel. If we had a "smarter" planning tool it might be helpful. Today we are using TrainPlan software for the planning and simulation. The contractor use an in data planner called "Trans" to plan their work and then this data is uploaded to TrainPlan for the IM to use as a maintenance tool. • Regulations and standards No impact – it is the safety frame that we need to work within. • Access to track and use of bi-directional running, single line closed, etc – does this depend upon line speed and track category? Yes, speed and safety regulations. Some contractors also have an open wagon that they can work in, see figure 7.   Figure 7. Maintenance vehicle providing protection from traffic and harsh weather conditions.
PR	Safety is the most important factor. The short process in 2.1 is partly enforced by law: Net-declaration. There a standards on safety (enforced by law). For every possession the contractor develops a safe work spot. The safety measures are checked by ProRail. Single track possessions are rare, more and more double track possessions are used.Innovations like mobile worksphere make single line possessions possible.
NR	Standards / 'The Rule Book' (an industry wide set of rules for accessing and using the track, http://www.rssb.co.uk/RGS/Pages/RULEBOOKANDOTHERPUBLICATIONS.aspx) dictate the types of protection required for different work activities and the use of barriers, detonators and other worksite protection. Network Rail's commitment to safety is also driving more work into green zone worksites, where the task is carried out within a protected possession.
DB	• Regulations and standards Noticeable extent for high speed lines, inspections and maintenance only possible at night when train operation ends or if the track is the blocked also the neighbour track Small extent for other line, speed reduction on neighbour track • Access to track and use of bi-directional running, single line closed, etc – does this depend upon line speed and track category?

	Yes, see above
SNCF	Performance Contract between the French State and RFF?
Strukton	Increasing safety levels makes it more difficult to create a workable day/night/weekend balance for staff. Safety is actually the most important factor in work planning and execution. However, the balance between safety and delivery must be continuously maintained. Sometimes during single track possessions, the other track is not used. In this case the contractor should be informed and a double track possession ensured.

- **What good practices / benchmarks do you know for maintenance and inspection processes?**

  Mention the relevant situation and explain briefly why this is a good practice.

IM	***Answer***
PR	Internal projects to improve processes / save costs: • OHR 2020 (developing the maintenance regime for 2020) • Mobile Worksphere • Contactors contracts: from predetermined maintenance to condition based maintenance • Planning inspection trains/services in-house with dedicated software
NR	Network Rail has a number of projects to optimize maintenance and inspection as part of the 7 day railway strategy. Developments have included the development of modular S&C for rapid renewals, improved inspection techniques such as plain line pattern recognition systems and image based S&C inspection and increasing the speed of ultrasonic inspections. Where appropriate technologies have presented themselves from other railways Network Rail has looked at implementing them, for example Network Rail has implemented the Dutch wheel impact measurement system.
Strukton	Manual inspection using hand-held computers with direct on-the-spot analysis will enable direct response (maintenance actions).

- Available data for possessions

Do you have data available concerning:

- The distribution of the overall length of possessions.
- The distribution of possession lengths based on weekday/weekend/public holiday.
- Information about the time of the day in which possession carried out – overall
- Time of day in which possession enforced – split by weekday/weekend/public holiday

Additional questions

- Please ask for the data
- Please ask how long it will take to get the data

IM	***Answer***
TV	Yes to all questions. It is possible to extract from TrainPlan.
PR	All answers are: Yes. We already send data from Jan Swier to Jon Paragreen
NR	Yes to all questions. Network Rail collects data against each possession of the start and end time of each possession from which it is possible to plot these distributions.
DB	All answers are: Yes
SNCF	Existing data make it possible to provide the required information, but a few weeks needed to proceed.
Strukton	ProRail has all data, Strukton as a contractor has only limited information available.

• Integration of maintenance in the timetable

- **Do you use planning/scheduling software for maintenance activities?**

Describe the systems / databases that you use for:
- Maintenance activities to be planned
- Resources availability
- Process standards

Additional questions
- What problems, if any, do you have with maintenance planning/scheduling software?
- How could it be better?
- Is the planning/scheduling software developed in-house, or commercially available?

IM	***Answer***
TV	It is up to each contractor to plan their own work. Time plan for 2011 is presented below. • January – International train traffic corridors are planned into the Swedish time table. • April – Supplemental application for maintenance activities are to be delivered by the contractor for maintenance activities not included in PSB application (Planned Substantial maintenance work) • July – First version of train plan (trains and maintenance work) for 2012 are public published. • July – Committee reports are collected from involved parties. • August – Last date for acceptance, train plan committee reports. • August – Co-ordination period starts with all involved parties. Parties can send a contention regarding the suggested train plan • September – Contention period is over and solutions must be agreed on. One solution might be that the track is "over charge" with too much maintenance work and train traffic. If so, we have capacity (maintenance and traffic) priority principals to be used, for solving the "over charge". 16th of September – The official train plan for 2012 is published. Describe the systems / databases that you use for: • Maintenance activities to be planned – TrainPlan database • Resources availability – It is up to the contractor how to solve this • Process standards – See above explanations.
PR	Yes. Maintenance activities are planned with help of software packages: there are different software packages for long term, mid-term en short term planning Most packages are based on MS Access / SQL server. Resource availability: IM is responsible for infra availability planning, contactor is responsible for material and human resource planning. **What problems, if any, do you have with maintenance planning/scheduling software? How could it be better?** Problems in planning: ProRail lacks the overview of the relationship between all planned maintenance activities. The planning/scheduling software is mainly based on MS Access. Recently ProRail started a project to build a software package where the main functionality is to visualize the relationship between all possessions at a certain location / time period. This makes it possible to see the impact of a possession. **Is the planning/scheduling software developed in-house, or commercially available?** The planning / scheduling software is commercially developed.

NR

Data system	Description
Ellipse	The data system used to store record and progress all maintenance work. Used mainly by the Section Planners who enter all work arising and reactive works into Ellipse and then utilise it to plan the delivery of all the work items stored in it.
Geogis	The system that stores all information regarding the topography of the Track infrastructure. Maps on the layout, buildings and equipment
PPS	Possession Planning System. The system used by NDS to review Possession and Worksite requests. The IMSM Team enter requests into PPS and receive conformation from it.
Visible plan (PossMan/WAR/ARP)	This is the local section visible plan that identifies the RotR T3 access footprint. It shows cyclical and inspection requirements, large maintenance blocks and projects. Available for Sections to identify worksite opportunities within the existing T3 plan
P3	Project planning tool used by Infrastructure Projects to plan the delivery of their projects. Does not interface directly with the work planning process
NROL	Network Rail On-Line. The system used to order plant, materials and resources. Usually operated by the Resource Planner
NEONs	Data system used to review the progress and delivery of S&C, etc. Used by Resource Planner to identify progress and plan delivery to site.
RDMS	Rail Defect Management System. The system that stores information on defects that have been discovered and reported.
SSoWP	Safe System of Work Programme used to put together all relevant information for establishing a safe working environment for operatives working in a site of work
TrackEx	Track Engineers tool to predict rail wear and crack growth rates for the planning of grinding and rail renewal

What problems, if any, do you have with maintenance planning/scheduling software? How could it be better?
The current databases are not fully compatible and often data has to be manually transferred between databases. Also most of the systems are purely databases with any optimisation still being carried out manually. A better system would integrate all of the data automatically and provide some intelligent optimisation and planning systems.

Is the planning/scheduling software developed in-house, or commercially available?
Most of the systems have been developed or customised for Network Rail.

DB	DB uses software for planning and scheduling of maintenance activities. There are three different systems/databases in use: 1. SAP R3: financial/technical database with failure indications and required maintenance activities (kind, time and place) 2. BBP: planning tool for building/maintenance activities upon traffic (regional planning and scheduling) 3. Granit: financial planning of maintenance activities These three systems are not compatible and can not change the data automatically. For planning of availability of maintenance machines DB uses just simple Excel-tables. DB has extensive process standards for planning of maintenance activities under traffic: “Planquadrat” is a main standard and there are recently new created standards from the innovative cost saving maintenance strategy “3i”.
SNCF	SNCF (in its role of delegated IM) uses software to plan between Y-3 and June Y-2. This includes not only maintenance activities (including renewal), but also those related to development and investment, and those related to other activities. SNCF wants to develop software to plan precisely at later stages (from 6 months to 8 days prior to activities) all types of activities (maintenance, investments, and other works). This software should enable a better use of both human and mechanized resources. Availability of these resources is considered in the previous stage (Y-3 to June Y-2). For the most relevant maintenance operations, SNCF built up a “work catalog”, both at national and local levels (meaning adapted to local work conditions on each line segment) : preparation, realization and finalization, including work speeds and required resources. RFF (the Infrastructure Manager) also uses an IT system to plan the use of the network capacity (track possession used to perform maintenance and other types of works on the network). **What problems, if any, do you have with maintenance planning/scheduling software? How could it be better?** The planning system could be improved by integrating many sources of data and automatic decision support. Several schedules are still manually generated which could be improved by new software tools. **Is the planning/scheduling software developed in-house, or commercially available?** The software is developed in-house but most of the tools are derived from commercial software.

- **Do you think automated planning and scheduling tooling would be useful?**

  - How is your current process of planning and scheduling automated?
  - Describe the main benefits of an automated planning and scheduling tool compared to your current situation?

  Additional questions
  - Do you think that better management/scheduling of logistics trains could shorten possession times?

IM	***Answer***
TV	We already have a planning tool that the IM uses – what we need is also a simulation tool that simulate the actual situation and is able to do prognostics. How is your current process of planning and scheduling automated? – No atomization Describe the main benefits of an automated planning and scheduling tool compared to your current situation? It could help the planner with some good judgments in the beginning of the process. Today it is up to the individual personnel skills to do these judgments and hence, years of experience is vital for this work.
PR	Yes. An automated planning tool could help to calculate different scenarios. Tooling could help to calculate different scenarios for now and in the future. A tool could give an overview of all activities. **Do you think that better management/scheduling of logistics trains could shorten possession times?** Tooling could also be helpful to propose combinations of possessions and to increase the occupancy of machinery. This could minimize the total downtime of the tracks and the degree of occupancy of expensive machinery.
NR	Yes an automated planning and scheduling tool which optimises work within a possession, the track maintenance machinery as well as optimising possessions for the least impact on the timetable has the potential for optimisation beyond what is currently possible. **Do you think that better management/scheduling of logistics trains could shorten possession times?** Better management of the logistics of maintenance trains would help to improve possession times, however, there are also a number of other issues regarding logistics including available stabling locations and the safe management of the trains within the possession.
DB	The current process of maintenance planning and scheduling at DB is not automated. Interconnection of our existing systems and a possibility of automated planning of maintenance activities would open new options for saving time and money.
SNCF	Yes. Some optimization should be performed to take into account simultaneous multiple resource usage: any activity uses several types of resources, and its shifting in time to optimize a given resource might degrade the use of other resource types. This cannot be managed by a simple, off the shelf, planning tool, as the following aspects must be considered : • A real-time view of the workload of all the resources must be available • Some decision support must be proposed through the use of a powerful dedicated optimization engine. The expected benefits are a better reactivity in decision taking (with a faster convergence to an

	acceptable solution) and an optimization of the required resources through a better balance of the workloads over time. **Do you think that better management/scheduling of logistics trains could shorten possession times?** Scheduling of logistics trains could be improved for complex track possessions where several tasks are combined. By the way, robust scheduling of logistics trains between commercial trains is necessary so that works can start with no delay. The quality of logistics train paths is also important for SNCF Infra even if it has no direct impact on possession times.

- **Estimation of track possession for each maintenance strategy**

Make a rough estimation of the percentage of track possessions used for:
- Condition based maintenance
- Predetermined maintenance
- Corrective maintenance
- Inspections
- Complete renewal (done at the end of the lifetime of object)

- Focus on heavy maintenance activities addressed in Automain (grinding, tamping and renewal)
  - Condition based maintenance
  - Predetermined maintenance
  - Corrective maintenance
  - Inspections
  - Complete renewal (Total of the 5 factors is 100%)

- How will the future situation differ from the current situation?
- Is there a differentiation of planning horizon for those maintenance activities?

Additional questions
- Explore the differences between the numbers quoted: for example, ProRail has 70% predetermined maintenance, while Network Rail only has 10% - why?
- Some of the IMs failed to provide numbers. Please ask them to complete their answers to the original question
- There is considerable variation in the estimates. Could this be because the IMs are using different metrics; for example, percentages of: possessions, the cumulative length of possessions, or something else?
- Can the result also be affected by the method of contracting?

IM	***Answer***
TV	• Condition based maintenance – No • Predetermined maintenance – No • Corrective maintenance – No • Inspections – No • Complete renewal (done at the end of the lifetime of object) - No Focus on heavy maintenance activities addressed in Automain (grinding, tamping and renewal) • Condition based maintenance – It is up to the contractor how to solve this • Predetermined maintenance – It is up to the contractor how to solve this • Corrective maintenance – It is up to the contractor how to solve this • Inspections – It is up to the contractor how to solve this • Complete renewal – It is up to the contractor how to solve this • How will the future situation differ from the current situation? It is up to the contractor how to solve this • Is there a differentiation of planning horizon for those maintenance activities? It is up to the contractor how to solve this
PR	Based on <u>total number</u> of possession: • Condition based 70 % (yearly maintenance scheme: planned 11 weeks in advance) (after infra inspections by train or hand • Predetermined 20 % (yearly maintenance scheme: planned 11 weeks in advance) (especially tamping and grinding is planned one year in advance, based on use figures of the infra (i.e number

	of trains that run on a specific track)). • Corrective 5 % (ad-hoc, as fast as possible) • Inspections 4% (planned one year in advance) • Complete renewal less than 1 % (planned 1 year in advance, but combinations of renewal activities are already made 2-10 years in advance) <u>Planning horizon</u>: In brackets above, planning need to be updated at all time. In the future more and more possessions are condition based instead of predetermined. Another change could be innovations like mobile workspheres, more use of inspection trains instead of human inspections, more use of switches with remote sensors signaling the status of the switch. Note: When possessions are ranked based on total duration, the figures will be different, but not easy to collect on a short term. **Can the result also be affected by the method of contracting?** More and more possessions are planned for condition based maintenance, at the expense of predetermined maintenance. ProRail sees a shift from a fixed determined maintenance planning to a more flexible (condition based) maintenance planning. In the new contracts contractors are stimulated to use as little possessions as possible and do more work in a single possession.
NR	• Condition based maintenance 17% • Predetermined maintenance 10% • Corrective maintenance 20% • Inspections 25% • Complete renewal 28% How will the future situation differ from the current situation? • It is expected that in the future more of the inspections will be carried out from in-service, inspections vehicles and remote condition monitoring sensors. Corrective maintenance should be reduced and condition based and predetermined maintenance increases with improved remote condition monitoring and asset condition models. • A tool that would allow us to model the different options, give us a first cut optimization and allow us to alter the variables to generate alternatives that we could then decide on would be very useful indeed.
DB	How will the future situation differ from the current situation? Is there a differentiation of planning horizon for those maintenance activities? *Answer* Answer is still open yet. We will deliver more verified data if available. My (Burchard Ripke) rough estimation: • Condition based (short-term planning) 2,5% • Predetermined (mid-term planning) 1,5% • Corrective maintenance (immediately) 5,0% • Inspections ~ 0% (in relation to all five activities) • Complete renewal (long-term planning) (renewal of switches, rail and track) 91% Most possession time is required for renewal or reconstruction of bridges, switches, rails and tracks. But these activities are planned for longer times and in general included in the time table.

	Most inspection activities are done in the train free period or with high train speed e.g. track recording car runs with up to 200 km/h.
SNCF	This point should be more carefully investigated. There are two ways a organising possession times : In the “weekly model” model (over old lines, including condition-based maintenance, predetermined maintenance and corrective maintenance, excluding renewals) : 4 day * 1.9h/day * 200 days = 1600 hours per year Massified maintenance model: 300 to 400 hours per track Predetermined maintenance : 5 to 6 weeks a year * 5 hours a day = 125 hours per year Condition based maintenance + corrective maintenance + inspections : 1 hour a day = 200 hours per year Renewal : 15 hour per km of track every 30 to 40 years In euros: 60% for maintenance and 40% for renewals.

- **Are tasks combined in order to reduce possession time?**

  - Describe whether activities are combined in one possession in order to reduce possession time
  - Are there different approaches for:
    - short / long possessions
    - main track on lines/station yards/side tracks

IM	***Answer***
TV	• Are activities combined? Yes; we do try to find combined possessions when the contractor is applying. That is taken care of when the IM is doing its total planning from the different contractors; however, we need to develop some penalties and rewards to find these combinations with the contractors. • Are there different approaches for: - short / long possessions – No - main track on lines/station yards/side tracks – No
PR	Yes, tasks are combined in order to reduce possession time. For larger possessions we see more tasks combined. There is more time and flexibility to combine tasks for long possessions compared to short ones. There is not a different approach for main line or side track (goal is to minimize the unavailability)
NR	Tasks are combined for maximum utilisation of the possession to reduce the costs of track access especially on the major routes. If timetable slots are required to carry out the maintenance on our heavily utilised routes a greater emphasis is put on maximising the effectiveness of the possession, whereas work in yards and low volume traffic lines is not subjected to so much pressure as there is less impact on the timetable for passenger and freight traffic and possessions can be fitted into the timetable.
DB	Yes, DB combines maintenance activities to reduce possession time. The new strategy “Integrative Bundling” postulates that generally all maintenance activities should be combined according to place and time as far as possible. In the case of renewal and preventive maintenance it is always possible to combine more activities in the same possession (vegetation control, catenary maintenance, drainage maintenance etc.). In the case of corrective maintenance and maintenance activities with short planning periods, it is unusual to combine more different maintenance activities at the same time. Generally, it is more difficult to bundle tasks on free lines of main tracks than in stations and on side tracks (because of difficulties of alternative routing).
SNCF	Massified maintenance: works on track, signalization, and catenaries performed simultaneously over a period of 2 to 4 weeks within intervals of about 5 hours over 50 to 100 km. In general, the limits of this approach lie in the use of maintenance-specific trains that must go through the different work sites. This model is used for main lines and on-line stations. For railway nodes, specific studies are carried out to build itineraries enabling the maintenance operations (some traffic can for example be switched from a line to another). SNCF would like to develop software to check the coherence between capacity usage by works on the network (maintenance and other types of possessions) and the traffic to go through a station, by modelling itineraries. This would also be useful for train operators willing to design new cyclic schedules, for example.
Strukton	Combining will definitely have an advantage, however requires a lot of discussion, negotiation and agreement. This might lead to delay of some activities during possessions with possible resultant overruns.

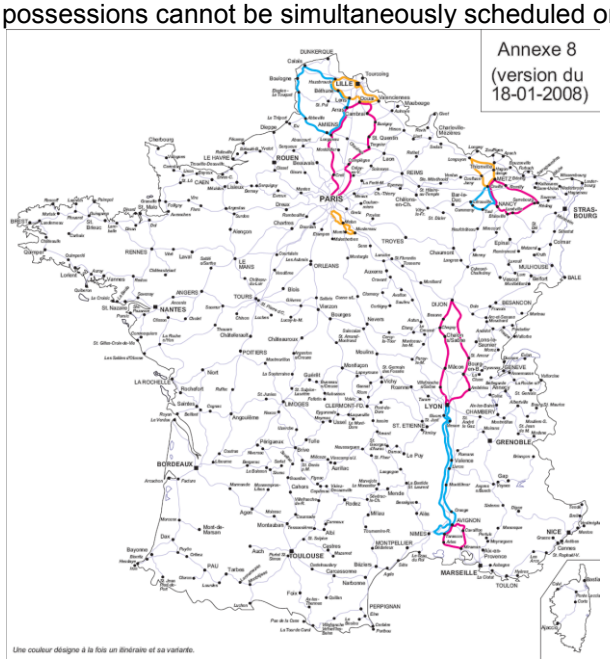
- **Are combined tasks successful in any case or most cases?**

Describe whether combined activities are successful or new problems raises due to:
- availability of maintenance machines
- reliability of maintenance machines
- performance of maintenance machines
- higher complexity of planning and maintenance processes
- …

Additional questions
- What are the problems combining tasks? How could things be improved?
- What is the role of the service provider / contractor in combining tasks?
- Some IM give the contractors much freedom in finding solutions (eg TV question 3.5). Please explain why and what are the benefits?
  Are there formal rules to explain to the maintenance provider how possessions can be planned (alternative routes, combination of tasks, night/day...)?

IM	***Answer***
TV	Describe whether combined activities are successful or new problems raises due to: • availability of maintenance machines – It is up to the contractor to find solutions • reliability of maintenance machines – It is up to the contractor to find solutions • performance of maintenance machines – It is up to the contractor to find solutions • higher complexity of planning and maintenance processes – It is up to the contractor
PR	Combined tasks are successful in most cases, but combinations of tasks makes possessions more complex. It's more the responsibility of the contractor to combine activities. Certain activities exclude each other, or certain activities have an overlap in time and location. ProRail has limited overview over the activities and little incentives to stimulate contractors. But this is starting to change by introducing a new application to help creating the overview of possessions shown on the infra network. Certain activities exclude each other (i.e. switch renewal and grinding). Example of combining tasks: Project Arnhem where the complete station/infra within 6 weeks was rebuilt during summer without running trains. **How could things be improved?** Overview in combination of tasks could be improved by using software packages that help to generate an overview of all planned possessions, plotted on the network. ProRail lacks this overview. **What is the role of the service provider / contractor in combining tasks?** For small maintenance: contractor is fully in control of planning and combining tasks. Incentive: Required level of quality needs to be assured with minimal possessions. Large maintenance (Grinding, tamping, renewal): Planning is made by ProRail and contactor has no influence on the planning which is made one year in advance. For the detailed planning (11 weeks in advance of performing the activities) there is some space to change the planning and combine activities. **Are there formal rules to explain to the maintenance provider how possessions can be planned (alternative routes, combination of tasks, night/day...)?** There are rules. The Dutch railway network is divided in so called corridors. At the moment a possession is planned on corridor A, it's not possible to plan another possession on corridor B (when corridor B is a bypass route for corridor A. Besides it's not allowed to plan several possessions on one corridor. Example (A2 corridor): Amsterdam – Utrecht – 's-Hertogenbosch – Eindhoven

	It's not allowed to plan at the same time a possession between Amsterdam-Utrecht and 's-Hertogenbosch-Eindhoven. As stated earlier for large maintenance activities ProRail is responsible for the planning of possessions.
NR	Generally the combining of tasks is planned as part of the possession plan, with maintenance machine availability part of the very early stages of possession planning and the actual possession is planned to ensure that the individual tasks do not interfere with each other. **What are the problems combining tasks? How could things be improved?** Problems with combining tasks are generally that it makes the possession more complicated and more difficult to manage, there can also be safety issues with more movements of plant on site and potentially incompatible tasks. Better planning and communication systems could improve this. **What is the role of the service provider / contractor in combining tasks?** Network Rail is the service provider as well as the Infrastructure Manager, so is wholly responsible for combining tasks. However, UK experience from when maintenance was sub-contracted out found that there was no incentive for a principle contractor in charge of the possession to incorporate other tasks by other contractors as any overrun would result in penalties. **Are there formal rules to explain to the maintenance provider how possessions can be planned (alternative routes, combination of tasks, night/day...)?** No formal rules other than the guidelines of the Rules of the Route which say how many possessions can be planned as service interrupting possessions and the maximum length of diversionary routes and compensation to be paid.
DB	Combined tasks are successful in many (most) cases. There are some differences upon different regional districts because of diverse infrastructure complexity and sometimes also because of diverse experiences / principles of infrastructure managers. The problems we don't see in availability, reliability and performance of maintenance machines or in complexity of planning, but more in unexpected situations that can occur, for example: bad weather, other soil conditions, accidents, machines out of order, human errors etc.
SNCF	Combined tasks work better when the following conditions are met : • Possession time is at least 5 hour long • Work train circulation constraints were considered well in advance • An assigned work manager designs the possession (long enough before the actual date) and manages all operations in space and time • A complete, detailed, space – time representation is made (that includes the paths of the commercial trains). However, the space-time graph is only partially available between Y-3 and Y-1. **What are the problems combining tasks? How could things be improved?** Combining tasks makes the scheduling of the maintenance tasks during a track possession more constrained, more complex, also less robust. Things could be improved with the help of dedicated scheduling software that are precisely informed of what is possible to combine and what is not. Maintenance process could be improved to make each maintenance operation less intrusive with respect to other maintenance operations. **What is the role of the service provider / contractor in combining tasks?** RFF lets SNCF combine and schedule the maintenance in order to minimize the total cost. **Are there formal rules to explain to the maintenance provider how possessions can be planned (alternative routes, combination of tasks, night/day...)?** • RFF gives a list of alternative routes (RFN-REF-Capa-REPART-V10 – Annexe 8). Two track

	possessions cannot be simultaneously scheduled on alternative routes.  • The minutes that can be lost due to speed limits is bounded between some pairs of stations (otherwise, timetable of affected trains must be changed).
Strukton	A large proportion of activities can be combined depending on location and the methods chosen.

- Influence on task duration and effectiveness

How do each of these factors influence task durations and effectiveness?

- Seasons
- Night/day
- Track topology
- Region
- Dedicated freight / passenger / mixed lines
- Single track / double track
- UIC class of track
- TEN / TSI
- Safety

Describe the influence of the characteristics on task duration (i.e. will a season influence task duration and to what extend?)

IM	***Answer***
TV	Seasons – In the north we only do maintenance work in the summer • Night/day – In the north we have daylight 24/7 in the summer • Track topology – No influence • Region – No general influence, but for single line traffic – yes • Dedicated freight / passenger / mixed lines – Mixed lines with limited places to wait for its possession is not so good. • Single track / double track – Lines with limited places to wait for its possession is not so good. • UIC class of track. ?? • TEN / TSI. ?? • Safety. ??
PR	The three most important factors are: • Safety: For every possession the right safety measures should be taken. This takes time which puts limitations on the net Train Free Period. • Seasons: Some activities are season-based and some activities cannot take place in a particular season • Day/night: There should be a right shift in work during day/night hours • Track topology: There are certain tracks and yards where's little capacity for maintenance. Smart planning is needed in order to carry out the maintenance activities. A mobile work sphere is a piece of equipment that helps to safely carry out activities in smaller slots.
NR	• Seasons weather conditions can have a large impact on the effectiveness of maintenance tasks potentially leading to requiring greater preparation times, especially in snow. Workforce • Night time Labour costs can be greater for weekend and night time work and tasks such as inspection are especially more difficult at night • Track topology and location will impact access to site and again have a large impact on pre and post maintenance tasks and logistics of getting materials and staff to the worksite • Mixed traffic lines present some of the largest problems in terms of access, especially for example our West Coast Mainline which has very little spare capacity.

DB	• Seasons characteristics like temperature, rain, frost can extend or even be a reason for failure or displacement of possession time. • Night/day: On the most lines there is more traffic during a day. Longer possessions are possible at night, on weekends and holidays. • Track topology: High gradients or small radius in curves can be reason for decreasing of performance and hence for longer required possessions times. • Region itself doesn't influence task duration, only through different regional seasons characteristics; different topology, soil conditions or different train mix. • Dedicated freight / passenger / mixed lines: - Pure passenger lines have normally very good possibilities for long possessions at night. - Task duration possibilities on pure freight lines depend on distribution of traffic. Most of them have also quite good possibilities for longer possessions either durin a day or during a night. - Mixed lines have a lot of traffic on daytime as well on night time, there are possibilities only for short possession times during a day and maybe a little bit longer possession at night time. • Single track / double track: - Logistic of material transport as well alternative routing for traffic is more difficult on single track lines. - Double tracks with traffic on the neighbouring track during maintenance need more time and effort for safety. • UIC class of track: there is no influence • TEN / TSI tracks require special regulations and maintenance, e.g. regarding noise, equivalent conicity or track equipment, TEN tracks are important lines for international traffic • Safety has especially for high speed lines an impact on task duration and effectiveness. On German high speed line from Frankfurt-Cologne the inspection and all maintenance (including very small maintenance) are only possible if the trains are stopped on both tracks. The visual inspection is carried out at night with an SKL and artificial light.
SNCF	• Season: cold and heat prevent specific operations (such as long welded rail maintenance). Rain can disturb some operations. • Night: decreases efficiency (by around 20%), it becomes difficult or even impossible to set up human announcement chains • Track topology: problem of visibility for human announcements, problems of access to track for human and mechanized resources, and for maintenance trains (including rail / road with specific devices to access the track) • Region: some mobility constraints for human resources • Freight / passenger lines : Freight is mainly operated at night, passengers during day : some constraints on planning day / night / both No impact on operation durations, but impact on frequency • Single / double track : potential problem on single track for some operations which need simultaneous possessions on the track and its contiguous track (size of devices, crosses of material and mechanized resources…) • UIC Class : impact on frequency of maintenance • Safety : the duration of safety procedures (no circulation periods, work train circulations, etc.) degrades efficiency in limited time possessions

- Effect of automatic planning

Where do you think that automatic planning can contribute most:

- Scheduling over one day in the future of the elementary maintenance tasks during a track possession
- Planning 1-3 months in the future of the operations assigned to track possession
- Planning over 1-3 years in the future of the operations in order to balance track possession and resource usage

Describe in what time window/interval you will expect most value of automatic planning tooling.

Additional questions

- For what planning horizon do you see the biggest potential when implementing an automated planning tool?

IM	***Answer***
PR	Automated planning will contribute in every phase of the planning, but will be most useful in planning and scheduling for the current year (bullit 1 and 2), while in the current year the changes in the planning are the biggest and have the largest impact on train service/other possessions. It would be very helpful to see the impact of the plan changes directly in the software tool. Planning for over 1-3 year in the future is very uncertain: there are a lot of plan changes. But maybe the tool could help to calculate different scenarios for future situations (taken into account the uncertainty of planning).
NR	**For what planning horizon do you see the biggest potential when implementing an automated planning tool?** The most useful stage to have the automated planning is in the 1-3 years to balance track possessions and resource usage, but potentially an automated planning tool could have it's greatest advantages for scheduling and optimising possessions on a very short term basis optimising possessions for corrective and condition based maintenance, which cannot be as well planned as the predetermined maintenance tasks. Major changes occur at the shorter timescales 1week – 3months can be particularly problematic. This is potentially where the modeling and selection of the best option will derive most benefit where many different scenarios and the necessary resources can be analysed quickly.
DB	Planning 1-3 months in the future of the operations assigned to track possession (Maybe also for long-term planning over 1-3 years)

- **What good practices / benchmarks do you know for the integration of maintenance in the timetable?**

  Mention the relevant situation and explain briefly why this is a good practice.

  Additional questions
  - Please could the IMs explain what they think of as good practice for short term rescheduling (especially for corrective maintenance or to adapt the planning to any area).

IM	***Answer***
PR	• Mobile worksphere • Software package for videotrain planning to optimize the planning • Inspection equipment on commercial trains (passenger of freight)
NR	**Please could IMs provide more detail in their answers to the original question?** **Please could the IMs explain what they think of as good practice for short term rescheduling (especially for corrective maintenance or to adapt the planning to any area).** Good practice for short term corrective maintenance in the UK is to as much as possible schedule this maintenance into possessions that have already been planned and if necessary delay some of the less critical activities that were planned during that blockade. If this is not possible the next best scenario is to plan the corrective maintenance between trains or within the white space within the timetable, with traffic only being interrupted in the cases where immediate action is required either due to safety or to preserve the running of services. A move away from corrective maintenance with improved preventative and prognostic maintenance is being adopted where possible, utilizing data from measurement trains, line side monitoring and other remote condition monitoring systems as well as models and algorithms to understand the rates of degradation, so that maintenance can be carried out in a well planned manner.
DB	**DB:** Preventive or prognostic maintenance increases the shift performance and reduces the cost per meter maintenance. The use of high performance maintenance plants to increase the maintenance length per possession. A Continuous track monitoring using a conventional train for evaluation of track degradation and the development of deterioration laws. These laws are used for prognostic maintenance procedure. **SNCF:** Stop of the train operation on the affected line and maintain the track in one possession; often over more then one day. Higher efficiency of maintenance and higher quality. **Heavy Haul**: Preventive grinding and tamping of track with plants exclusive available for the line. High quality of track, short transportation distances of plants, high availability of plants and therefore maintenance is easier to schedule.
SNCF	Good practices: integrate maintenance within circulations? Tracks in station: • adapt timetables in collaboration with operators, taking into account itineraries and possible postponement/rerouting of trains or passengers. Tracks out of station: • Permanent devices on the track to switch traffic from one track to another (single-line working) • Alternative itineraries enabling to free tracks for maintenance, switching traffic, and possibility of

	working on both itineraries when no traffic if planned • French “IRIS 320” train : high speed inspection between commercial paths • Mechanized resources able to drive both on tracks and on road to reduce transportation durations (hence increasing work speed), if specific devices are usable (parking locations, rail / road platforms…)
Strukton	Exploiting short gaps between trains (as possible before current safety regulations). With the use of modern techniques this might be possible again whilst still complying with current safety levels.

Appendix B: Innotrack innovation priorities.

Track Problem	Innovation Priorities
Rail: cracks and fatigue	• Wheel and rail profiles to minimise contact patch energy; • Friction management; • Resistance to RCF and wear; • Energy damping technology: e.g. better rail pads; • High speed rail re-profiling; • Monitoring systems.
Track geometry: poor support	• Ballastless track; • Novel track forms; • Self-adjusting rail support; • Better design of transitions; • New elastic fastenings; • Improved panel shift strength.
Sub-structure: unstable ground	• Geogrids; • Short piling in the ballast layer; • Improved ballast drainage; • Stone blowing; • Reduced formation stress/formation strengthening; • Hot-mix asphalt underlay.
S+C: wear, deformation and cracking	1. Designs for low wheel/rail stress; 2. Development of modelling guidelines; 3. Revised geometry; 4. Improved frog design; 5. Replaceable components; 6. Design for automated maintenance.
Rail: corrugation	1. More resistant rail steels; 2. Wheel/rail profile management; 3. Innovative rail support systems; 4. Friction management techniques; 5. Optimised grinding strategy.
Poor geometry: wrong stress free temperature	• Non-invasive measurement; • Improved repair guidelines; • Better SFT switch guidance; • On-train SFT monitoring; • Buckling-resistant rails and rail supports;
Rail welds	• More flexible electric flash butt weld equipment; • Improvements to heat affected zones.

Table 1 – Innotrack Innovation Priorities

Appendix C: Benchmark report on comparison of rail with automated maintenance in road networks.

Preface

Benchmarking is a process to measure products, services and practices of a company against those of the industry leader. It is the search for best practices in order to reach excellence. In this particular case, practices in maintenance for rail and road are being compared. Although both fields are of the transportation sector, processes and practices cannot be compared in detail. Therefore, the benchmarking is carried out on a functional level. The main topics to be focussed on are asset management strategies, policies and performance; maintenance and inspection processes; and planning and scheduling of the maintenance.

To gather the relevant information, three separate ways have been taken. First, the authority for road construction and traffic in Lower Saxony, Germany, was visited. The interview has then been used to design a questionnaire also based on the one sent out to the railway infrastructure managers. There have been replies by the road authorities of the Netherlands (Rijkswaterstaat) and of Sweden (Transverket). Finally, existing studies on road maintenance have been taken into account, especially the EU project ISTIMES (Integrated System for Transport Infrastructure surveillance and Monitoring by Electromagnetic Sensing).

Asset management strategies, policies and performance

The main objective of German road authorities to achieve is to keep the overall average quality of the complete national road network inside a given quality interval. The most significant parameter to measure the qualitative success of a constructional measure on road sites is the average substantial quality of the road itself. Values like financial benefit, national economic impacts or traffic densities are considered secondary. The KPI calculated as a weighted value of different measurements. In a first step, different values were accumulated to a substantial quality and a characteristic number for serviceability. The structural value is divided into concrete and asphalt driven roadbeds because some characteristics are not feasible to use on concrete and vice versa. Figure 1 shows a brief overview about how the values are brought together. The left boxes describe the parameters that got measured. Those values are categorized by grades from 1 (great condition) to 5 (bad or very bad condition) what can be seen in the next column of boxes. The small circles show the weights the values will have in the accumulated numbers listed in column 3. This is where serviceability (box on top) and structural qualities for asphalt (box in the middle) and concrete (lowermost box) are derived as partial indices. These two values are combined to the final KPI. During the interview it turns out, that this final KPI is less interesting compared to the single structural and service indices. Obviously, this is based on the engineer's practical experiences. Many of the criteria, e.g. grip, are safety relevant. If in those cases a quick correction of the failure is not possible, speed restrictions or restrictions of the allowed maximum weight of the vehicles are applied.

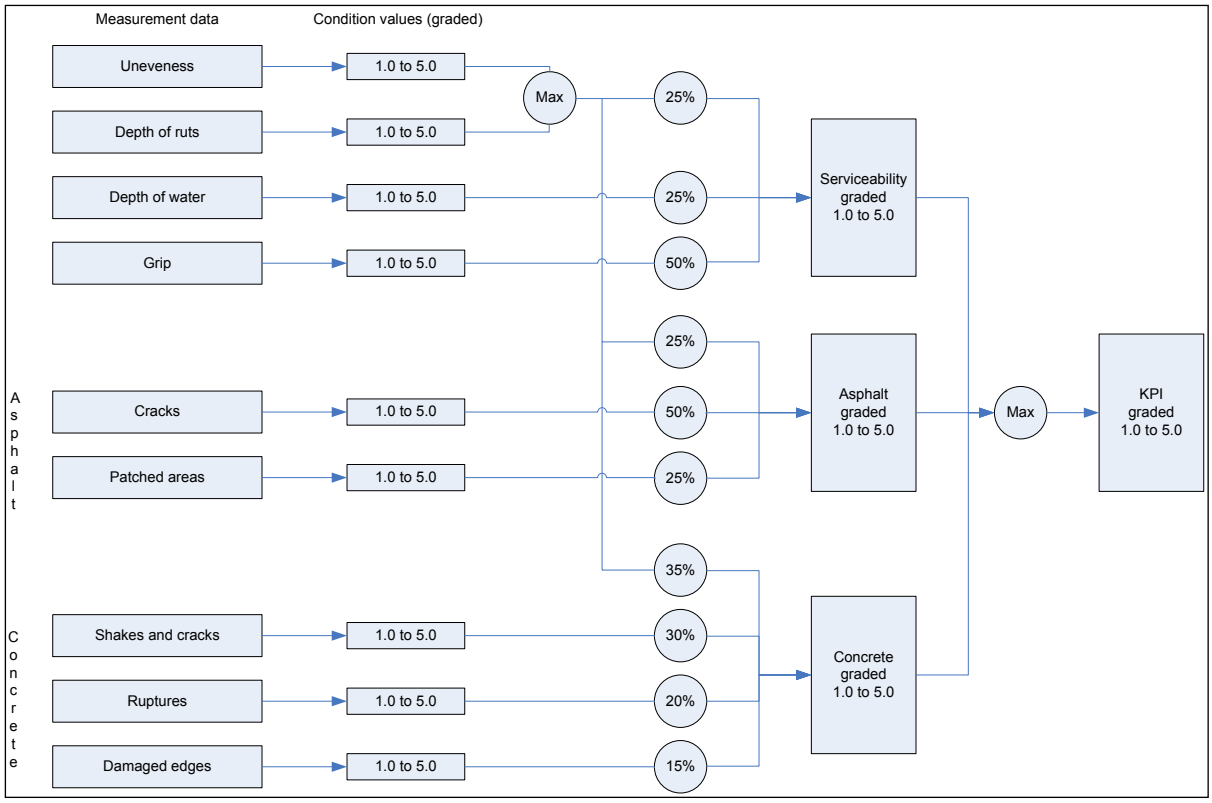


Figure 1: Rough overview of road quality KPI; Source: http://www.bast.de/

The generated KPIs can be visualised in different ways. One example of a map with the quality of the road's surface can be found in Figure 5, below.

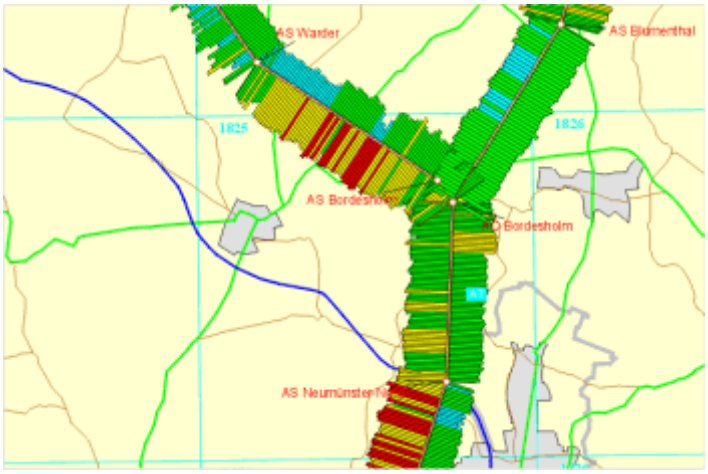


Figure 2: Map of the condition of the road surface; Source: http://www.bast.de/

After measuring and qualifying the partial index values engineers have to develop a plan of construction sites across the road network. The prioritization is secondarily influenced by the traffic density and the availability of funds. The Pavement Management System (PMS) as a part of the planning process makes suggestions on how to schedule the construction yards across the area of authority. PMS is widely used, in the Netherlands as well as in Germany and Sweden. There are huge amounts of publications concerning its functionalities.

There are public private partnership (PPP[5]) pilot projects for road construction and maintenance in Germany. The largest project so far is the renewal and operation of the A1 between Bremen and Hamburg. The consortium of Bilfinger Berger Project Investments, John Laing Infrastructure Ltd and Johann Bunte Bauunternehmung GmbH & Co. KG will be responsible for the 72,5km long stretch of the highway for 30 years. In 2008, the complete renewal started and it is supposed to be finished in 2012. If the schedule can be kept up, the construction would be finished much faster than comparable projects. The income of the consortium is a not published share the toll collected from freight traffic running over the particular stretch. Thus, the goal of the consortium is to maximise the revenue under the constraint to ensure the road quality guaranteed in the contracts with the responsible road authorities. The Bundesrechnungshof which examines federal financial management has published a study in which the economic efficiency of such PPP projects is questioned. First of all, the consortium will have to pay higher interest rates than the state. Therefore the share of the collected toll transferred to the consortium has to be increased. There is also a high risk concerning the prognosis of future freight traffic, which directly affects the income. The Bundesrechnungshof also points out that high costs for juridical, technical and economical consultancies appear preface. Those are likely to be higher than savings from gained efficiency. The highly efficient planning of the construction site also seems to have a stronger negative influence on road safety compared to usual projects. The highway police responsible for the stretch points out that in the first year of the construction, the number of accidents rose by 121%. The number of casualties rose from 2 in 2008 to 6 in 2009. In the first half of 2010, already 7 people died in accidents. Experts point out the small lanes and the driver-fatiguing length of the construction site as main reasons.

In the Netherlands, the strategic goals are accessibility (traffic circulation), i.e. preventing or limiting time lost on a journey, traffic safety, i.e. reducing the number of victims of traffic accidents and quality of life, i.e. limiting or compensating for the effect of the road on its environment. This concerns not only air, soil and water pollution but also nuisance caused by noise, vibrations, light and stench. KPIs used are availability during rush hours and total amount of loss of vehicle hours as well as safety, i.e. number of deaths and hospitalizations. The asset owner is the secretary-general of the department of infrastructure and environment. The asset is managed by Rijkswaterstaat. The service providers are contractors as almost all the work on the network is outsourced. The stakeholders are organized in interest groups such as ANWB. As a KPI, less than 10% of the traffic-jam may be caused by maintenance. There are no incentives, bonuses or penalties in the relation between Rijkswaterstaat and the department.

The Swedish Transport Administration is the asset owner and manager of the road and railway system. The overall goal is to safeguard the provision of socio-economically efficient and sustainable transport for citizens and the business community throughout the country. This is broken down into sub goals, i.e. functional goals and impact goals. The functional objective concerns accessibility for journeys and transports. The impact objective concerns health, safety and the environment. Details can be seen in the questionnaire in the appendix. Road maintenance and operations are provided by

[5] PPP: public private partnership.

different contractors. Traffic information is provided both by the transport administration and private companies. All maintenance and operation works are outsourced, mostly in 5 year contracts. Many authorities use total stoppages as a KPI, often in combination with stoppages during a time period.

Maintenance and inspection processes

The most common way of failure detection on pavements is based on a visual inspection by maintenance teams. Recent developments allow road managers to add technical support to those teams. Vehicles with measurement techniques like laser altimeters and video devices deliver detailed information about the surface of the roads. From this information, road engineers can create microscopic maps to pinpoint critical road segments.

The inspection frequency in Germany is given as a four year period per road type. When highways were inspected in year 1, interstate routes were monitored the next year while small to little streets are checked in the third year, etc. The coordination of those monitoring tasks is given by the German Ministry of Transportation which is the highest national transportation authority. The subordinated department responsible for streets in a broader sense is called the BASt (German: “Bundesanstalt für Straßenwesen”). This institution provides frameworks and contracts to the regional and local street administrations and agencies. That way they determine technical thresholds for road qualities as well as the money available for maintenance tasks. In Sweden, the condition of the road network is measured on regular basis every 1-3 years, depending on traffic. The Netherlands utilise similar measurement methods.

The following sections describe mid and long term maintenance. This process does not apply to e.g. accidents. The technical support to gather detailed information about the condition of the pavement surfaces is realized by different types of test and measurement cars. The first one is equipped with two arrays of upright aligned laser altimeters in crossways and longitudinal driving direction or the car. This laser sensing provides data to process a cross-section model of the roads.

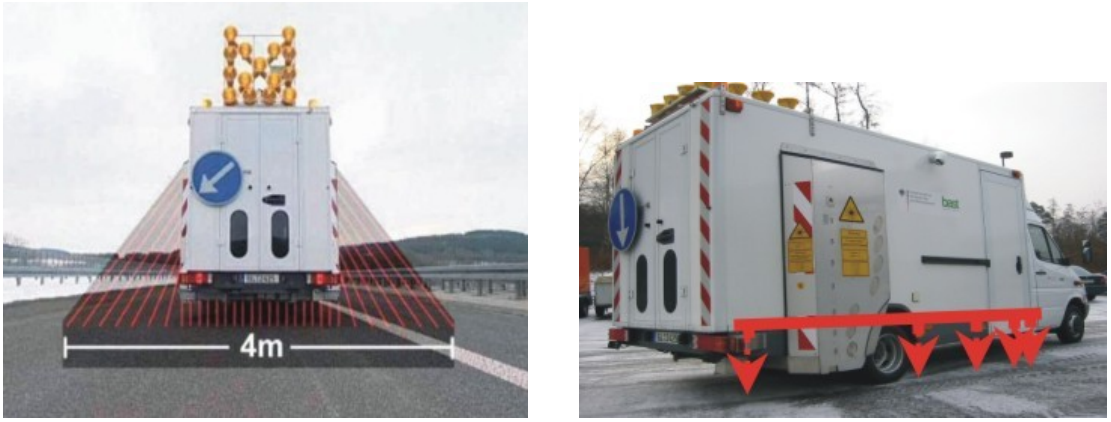


Figure 3: German Measurement Car with laser altimeters; Source: http://www.bast.de/

The second type of maintenance vehicle is equipped with video camera devices that take pictures in the right angle from above the road. To light the pictures right and remain operational even at

darker daytimes, the cameras cooperate with stroboscopes. These pictures are used to find all kinds of cracks on the road. Currently they are analyzed and categorized manually.

Figure 4: German measurement car with video devices and examples; Source: http://www.bast.de/

The last type of measurement car is dealing with the roads adhesion (grip). An additional wheel, which is twisted against the cars moving direction by a little, is pressed onto the surface. By cooling this wheel with water and measuring the forces developed by this system, the transportation engineers the roads adhesion.

Figure 5: Measurement car with extra wheel and detail view; Source: http://www.bast.de/

While this information is only taking the streets surface into account, the engineers have to decide, if an arbitrary pavement failure is originated in its groundwork. To verify the given data, employees take core samples to identify the failure completely.

In addition to that, there are few mounted sensing units on special road segments like bridges or stop lights. While the focus of these devices is to optimize the traffic flow, it's hard use them for failure detection what leads to the fact, that German pavement failure detection is de facto completely based on mobile units.

The data which is collected by those methods must first be normalized and then transformed from data to information to plan constructional measures. This is done by an accumulation of different types of raw data into two main key indicators:

- Substantial road condition

- Serviceability (Driving comfort)

These parameters are input for the asset management of the road network.

In Switzerland, the Swiss Federal Roads Authority (FEDRO) is in charge for the maintenance of the road network. On the most common level, every object (roads, tunnels, bridges and safety equipment) is inspected every 5 years (some objects every 2 years) by private companies. The main motivations are safety, the evaluation of the condition of structures, the optimization of maintenance and the evaluation and elimination of natural hazards. In addition, FEDRO is obliged by law to ensure the safety of national roads but details can be defined by it. During the 5 years inspection the following parameters concerning the condition of structures are assessed: Damage detection and localization, corrosion of steel elements, broken wires (every 10 years), sealing integrity, crack detection, delamination, ageing of materials, joint movements. If required, the following parameters concerning the condition of structures are assessed in addition to the ones listed above: Depth of carbonatization, chloride penetration, humidity in concrete, compressive strength of concrete, permeability of concrete, depth of rebar and natural frequencies. As far as meteorological data are concerned, air temperature and the temperature of the inspected object are recorded. Sunshine and precipitation are recorded if required. Traffic data (weight in motion, number of vehicles and vehicle speed) are recorded in separate stations not directly linked to the inspected objects. Related to safety, excessive movements, settlements, changes of geometry and tilt are assessed. If required, particularly after events, abnormal behaviour of structures, man made impact (accidents, plane crash, and collision of ships with piles), fire or accidents are also evaluated. Several objects are under advanced monitoring or inspection. Rosenberg tunnel is inspected with a vehicle for data acquisition equipped with cameras for automated crack detection every 2 years. This is an experimental approach. The main reasons for doing this is the assessment of the condition of the object and of possible changes, ideally information on the reason for the cracks, scientific research and an optimization of future rehabilitation. FEDRO considers this approach as to expensive with suboptimal value for money.

The Italian Civil Protection Department (Dipartimento di Protezione Civile, DPC) is currently inspecting 20 bridges and 2 dams by visual inspection. This is done whenever there has been a strong earthquake. The main motivation for this approach is the assessment of possible damages and to ensure public safety. Main points of interest are the detection and the localization of damages in particular cracks, changes of geometry, tilt and abnormal behaviour of structures. This approach is considered too expensive, not state-of-the-art and the intervals between inspections are considered too long. In about 50 building wired sensor networks using accelerometers are installed. The main motivations for this approach are safety, disaster warning, an estimation of the damage scenario and scientific research (building behaviour). The parameters of interest are damage detection and localization in particular cracks, natural frequencies, abnormal behaviour and accelerations due to earthquakes.

Planning and scheduling of the maintenance

The planning by the PMS works in 8 steps:

1. Definition of homogeneous road sections
2. Selection of sections to be maintained
3. Analysis of failures and damages
4. Prognosis of future conditions
5. Identification of possible corrective activities
6. Evaluation and prioritising of activities
7. Optimising activities under budget constraints
8. Proposal of short and medium term maintenance program

The results are presented in tables, charts, and diagrams. The criteria for the proposed priority of maintenance tasks are the degree of failure, the traffic density, and the type of traffic the road section. In the Netherlands, the planning horizon is 5-7 years. The scheduling tool RUPS creates a list of maintenance activities for the next 3-4 years. Road works that may cause nuisance to the traffic in the coming year are registered in MELDWERK considering location, date, time, number of lanes closed etc.

The PMS program makes suggestions on how to spend the maintenance budget. In Germany, the situation in neighboured states is not taken into account at this stage. So, the final plan remains to be an extensive discussed and considered task. Unfortunately, due to the federal structure and the given complexity of a street network with a size of approximately 395.000 km, compared to a rail network of approximately 35.000 km, there is not yet an integrative use of a software tool across Germany. As pointed out by Transverket from Sweden, congestion may be caused by many road works at the same time that could be avoided by distributing works in time. It is necessary to have a very good cooperation between different authorities like state roads/municipality road. Also, different types of maintenance works are combined in order to minimize the total stoppage time. This may affect the planning process and selection of methods, material etc. Therefore, synchronised durability of different assets is needed in order to get synchronized maintenance.

For roads, no traffic free period exists. The work at the construction sites themselves is mainly carried out during daylight. This is caused by considerations of safety, quality and costs. In Germany, works during nighttimes and holidays are restricted by authorities. The avoidance of traffic jams is secondary to those constraints. In areas with high traffic in Sweden, road works are carried out by night if possible. It is the aim to minimise or avoid traffic disturbances. The climate in Sweden affects the planning process. A hard winter may result in high costs for winter maintenance that will affect the budget for preventive maintenance. This means that the budget varies from one year to another and that there is necessary to have a high level of flexibility in the planning. In the Netherlands, there is a timeframe available for each part of the network which describes the time of the day/evening/night one (or more) of the lanes or hard shoulder may be closed for maintenance.

According to Transverket, the traffic obstructions caused by maintenance relate to:

- Condition based maintenance: 25%
- Predetermined maintenance: 25%
- Corrective maintenance: 10% (dependant on the traffic volume, on roads with high traffic and high demands on workers protection)
- Inspections: 0%
- Complete renewal: 40% - depends very much on the access to detours

Conclusion

Concluding the asset management strategies, policies and performance, different business models in the rail and the road domain lead to specific company goals. The business relation between railway infrastructure and transportation companies affect stricter constraints considering planning and scheduling. Lines are sold to transportation companies which gives them the right to use it. Thus traffic disturbances directly influence the infrastructures income, considering lines which could not be sold or compensation which had to be paid. Railway infrastructure companies have more emphasis on revenue compared to road domain. The goals of railway infrastructure companies are therefore similar to road-PPP consortiums.

Due to significantly larger road network, road infrastructure managers rely very much on PMS[6]. The measurement of the road condition takes place in larger time scales, i.e. at least each year for rail and every 1-4 years for roads. To predict the road quality is therefore inevitable for decision making between measurements. Nevertheless, full automation of decision making is not suitable for the road domain. Software solutions deliver suggestions for upcoming maintenance tasks and the spending of limited resources. The final decision is based on expertise and engineering knowledge. Diagnosis and prognosis in the road domain can be seen as the benchmark for condition based maintenance.

Maintenance and inspection processes are pushed towards condition-based, preventive maintenance in both domains. In-service inspection without traffic disturbance is state of the art for highway engineering and benchmark for the railway domain. On the other hand, continuous monitoring of road assets takes place only for some tunnels or bridges. The project goal of AUTOMAIN to continuously monitor the condition of the whole rail network therefore can be seen as the benchmark.

For the planning and scheduling of the maintenance, the reduction of traffic disturbances is a main goal for railway infrastructure managers. For road maintenance, this optimisation criterion is less important. The scheduling of maintenance is far more complex for rail due to timetables and reduced opportunities for detours. The coordination between administrations on different levels and in different areas is a huge challenge for highway engineering due to a larger network.

[6] PMS: Pavement Management System, which is a highway asset management system.

Combining maintenance tasks takes place in both domains for efficiency reasons. There are hints that a very strong compression of tasks seems to bear safety issues for road.

Summing up, the benchmarks are condition based preventive maintenance; continuous condition monitoring; prediction of asset condition for decision making; planning and scheduling with aim to minimize traffic disturbance due to maintenance tasks. Thus, the benchmarks are matching the goals of AUTOMAIN.

Appendix D: AUTOMAIN questionnaire to road infrastructure managers

final version.

Introduction.
The challenge of the AUTOMAIN project is to do more effective inspection and maintenance in less time for high density rail freight lines. Therefore the project focus is to optimise and automate maintenance & inspection where possible, also to introduce new planning & scheduling tools and methodology. The AUTOMAIN project has been built up according to the system engineering principles. This includes the comparison of overall results and objectives with other transport modes, i.e. road traffic.

One of the aspects in the first phase is to search for potential good practices and ideas that can be used later on in the project. For that reason an overview of existing benchmarks will be made, as well as some further investigation. This questionnaire is meant to provide the basic information for the further investigations.

Set-up of the questionnaire.
In general we are looking for two kinds of information: qualitative information regarding processes, practices and strategies. And more quantitative information (usually referred to as data) to be used in further analyses.
This form only asks for the qualitative information. It is built around three themes:

1. Asset management strategies, policies and performance
2. Maintenance and inspection processes
3. Scheduling of the maintenance.

General remark
The IM may be responsible for the maintenance of the whole infrastructure. This includes also maintenance of ground constructions, civil engineering constructions (bridge, tunnels), traffic control... In consideration of the time available for the task we propose to concentrate the questionnaire on the heavy maintenance activities.

Answers from The Netherlands.

Asset management strategies, policies and performance

	Question	*Additional information*	*Answer*
1.1	What are the strategic company/ authority goals of the Infra Manager (IM)?	• Describe the background of each strategic goal • Mention and explain the Key Performance Indicators (KPI) that are related to each strategic goal	Strategic goals: • Accessibility (traffic circulation): preventing or limiting time lost on a journey • Traffic safety: reducing the number of victims of traffic accidents • Quality of life: limiting or compensating for the effect of the road on its environment. This concerns not only air, soil and water pollution but also nuisance caused by noise, vibrations, light and stench. KPI's: • Availability: during rush hours and total amount of loss of vehicle hours • Safety: number of death and hospitalization
1.2	How strict do you use the separation between the Asset Owner, Asset Manager and Service Provider?	• Describe who has the role of Asset Owner, Asset Manager and Service Provider • What are your major stakeholders • Explain the advantages and disadvantages of this role model related to the allocation of train free periods	Asset Owner: secretary-general of the department of Infrastructure and Environment Asset Manager: Rijkswaterstaat Service Provider: contractors Stakeholders: (organized) interest groups such as ANWB
1.3	One of the goals of Automain is flexible maintenance with a minimal effect for the traffic. This will influence the relation with the Service Providers. 1. Explain how the Service Provider gets the time frame for doing the work in the current situation.	What are your experiences for: • the amount of outsourced work • the type of outsourced work • the type of contracts (think of balancing financial aspects, incentives and processes) • costs per activity	There is a timeframe available for each part of the network which describes the time of the day/evening/night one (or more) of the lanes or hard shoulder may be closed for maintenance. Almost all the work on the network is outsourced; the workforce of the IM is going down.

	Question	*Additional information*	*Answer*
	2. What does flexible maintenance mean for the relation with the Service Providers and for the process of getting the time frame for the construction on the right moment?	• workforce of the IM • workforce of the Service Provider	
1.4	What KPI do you use related to planned and unplanned maintenance activities regarding traffic flow?	Give for each KPI the following information: • Algorithm, how is it calculated • On which level of detail is it used (object, region, country, road etc.) • What are the mechanisms to control the level of each KPI? • Do you use any incentives, bonuses or penalties regarding to the level of the KPI's?	KPI = 'minder hinder' (less nuisance) = (traffic-jam by maintenance) / (total amount of traffic-jam) < 0,1 In other words: 10% of the traffic-jam may be caused by maintenance. Level of detail: the whole network; there are no concrete incentives, bonuses or penalties (in the relation between Rijkswaterstaat and the department).
1.5	What good practices / benchmarks do you know about how individual infrastructure managers in Europe translate their company goals (such as punctuality) to asset management strategies?	Mention the relevant situation and explain briefly why this is a good practice.	

Maintenance and inspection processes

	Question	*Additional information*	*Answer*
2.1	Explain the processes, involved parties, decision moments and criteria that are relevant to decide whether or not a maintenance activity will be planned.	• What determines when a possession is carried out? i. MGT – scheduled into campaigns (e.g. tamping campaign for a whole route) or	A distinction is made between routine and variable maintenance: 1. Routine maintenance concerns all activities that are necessary to allow the main infrastructure to function from day to day. The routine maintenance is managed by contracts on the basis of service level agreements.

	Question	*Additional information*	*Answer*
		individual sites. ii. Inspection data iii. Availability of plant iv. Public holidays/low traffic v. Availability of budget vi. Pre defined maintenance intervals preventive/prognostic) maintenance vii. Other things …. • Who is in charge of the decision? • Who is the owner of the processes?	2. Variable maintenance concerns major maintenance projects (replacements, renovations and reconstructions). Variable maintenance is planned on the bases of inspections (by central offices): 3. Pavements: measuring vehicles (80 km/h), database, PMS etc. leads to an advise 4. Engineering structures: comparable to pavements 5. Dynamic Traffic Management Systems: in development (for now: life span) Central offices are owner of the process; decision is made in consultation between regional offices and central offices.
2.2	What are the relevant time-scales / planning horizons for maintenance activities?		Planning horizon 5 – 7 years
2.3	Do you use any incentives, bonuses or penalties regarding to the use, overrunning or under running construction time?	Describe the incentives that are in use. In what way are they part of the contract? Do they stimulate the right culture and results or do they occasionally turn out to be counter-productive?	In special occasions: bonus for early opening. Penalties for crossing the timeframe (see 1.3)
2.4	Does the involved equipment affect the decision making?	• Types of worker protection applied – e.g. signal protection, barriers etc • Type of maintenance machine used • Shift length	Not relevant for roads
2.5	To what extent is the IM involved in the improvement of the maintenance	1. Definition of regulations and standards 2. Experiences of IM	Improvement is part of the work (e.g.: higher penalties to prevent crossing the timeframe)

	Question	*Additional information*	*Answer*
	process?	3. Is there a central database for experience/knowledge about maintenance?	
2.6	To what extent does external regulation (safety rules, law) affect the organisation of maintenance activities?	4. Regulations and standards 5. Does this depend upon line speed and road category?	(Variable) Maintenance activities have a strong relation with safety rules. The standards are related to speed / road categories. Rijkswaterstaat is IM for – more or less – one category of roads and applies only one standard.
2.8	What good practices / benchmarks do you know for maintenance and inspection processes?	Mention the relevant situation and explain briefly why this is a good practice.	

Scheduling of the maintenance

	Question	*Additional information*	*Answer*
3.1	Do you use planning/scheduling software for maintenance activities, e.g. a pavement management system?	Describe the systems / databases that you use for: 6. Maintenance activities to be planned 7. Resources availability 8. Process standards	We use planning software; see 2.1 For the planning of maintenance we use scheduling software (RUPS). Input: from planning software (variable maintenance) and experience with routine maintenance. Output: list of maintenance activities for the next 3 – 4 years Road works that may cause nuisance to the traffic are registered in MELDWERK: location, date, time, number of lanes closed etc.
3.2	Do you think automated planning and scheduling tooling would be useful?	How is your current process of planning and scheduling automated? Describe the main benefits of an automated planning and scheduling tool compared to your current situation.	Yes, see 2.1
3.3	Where do you think that automatic planning can contribute most: 9. Scheduling over one day in the future of the elementary	Describe in what time window/interval you will expect most value of automatic	MELDWERK: coming year (the first 2 categories of the *Question*) RUPS: coming 1 – 4 years (third category)

	Question	*Additional information*	*Answer*
	maintenance tasks 10. Planning 1-3 months in the future of the operations 11. Planning over 1-3 years in the future of the operations	planning tooling.	
3.4	Make a rough estimation of the percentage of obstruction of traffic related to: 12. Condition based maintenance 13. Predetermined maintenance 14. Corrective maintenance 15. Inspections 16. Complete renewal (done at the end of the lifetime of object)	Focus on heavy maintenance activities 17. Condition based maintenance 18. Predetermined maintenance 19. Corrective maintenance 20. Inspections 21. Complete renewal (Total of the 5 factors is 100%) How will the future situation differ from the current situation? Is there a differentiation of planning horizon for those maintenance activities?	60 % (variable maintenance) 40 % (routine maintenance) 0 % 0 % (small: 1 - 2% of the budget for maintenance) 0 % (separate budget) 100 %
3.5	Are tasks combined in order to reduce construction time?	Describe whether activities are combined in one construction site in order to reduce possession time	Combination of maintenance to lower the nuisance for the traffic (depends on the amount of traffic)
3.6	Are combined tasks successful in any case or most cases?	Describe whether combined activities are successful or new problems raises due to: 22. availability of maintenance machines 23. reliability of maintenance machines 24. performance of maintenance machines 25. higher complexity of planning and maintenance processes 26. …	Not relevant for roads
3.7	How do each of these factors influence task durations and	Describe the influence of the characteristics on task duration	The approach of maintenance is to prevent as far as possible nuisance to the traffic; task duration is under normal circumstances no issue

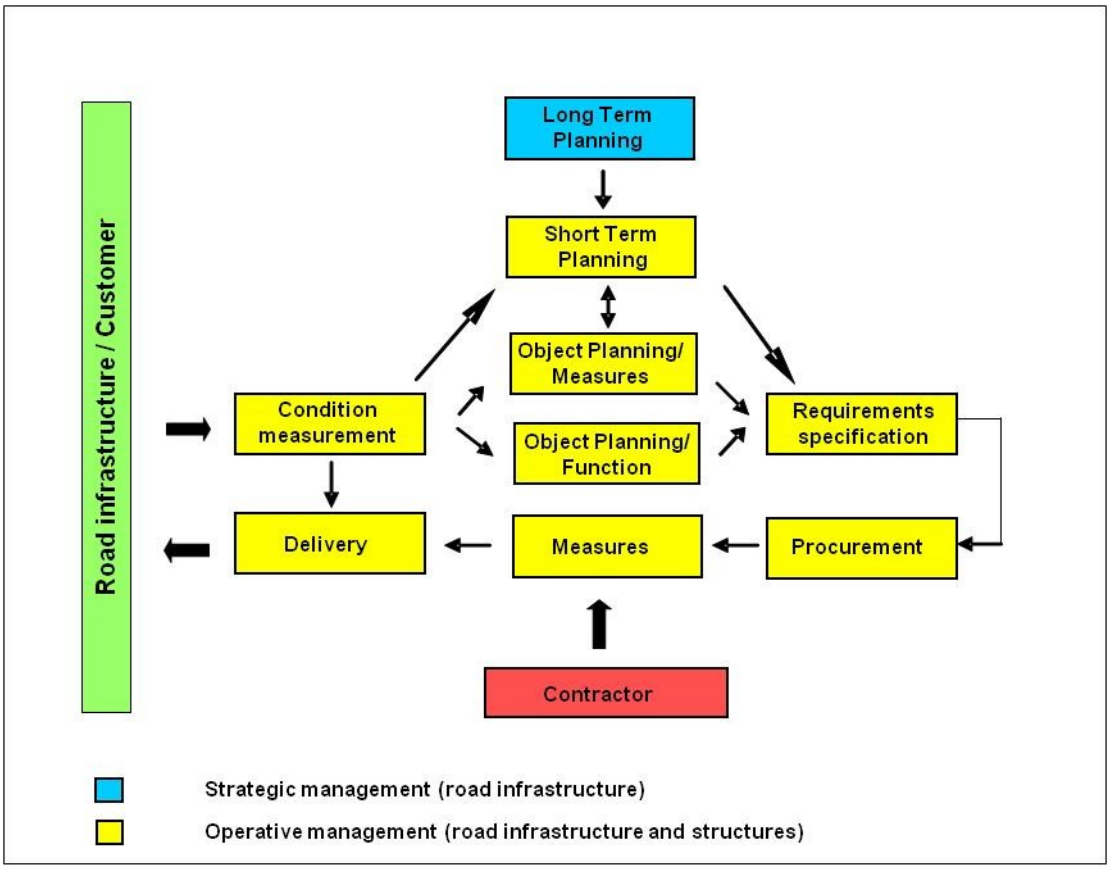
	Question	*Additional information*	*Answer*
	effectiveness? 27. Seasons 28. Night/day 29. Traffic density 30. Availability of alternative routing 31. Region 32. Share of freight traffic 33. Number of lanes	(i.e. will a season influence task duration and to what extend?)	
3.8	What good practices / benchmarks do you know for the integration of maintenance in the traffic flow?	Mention the relevant situation and explain briefly why this is a good practice.	

Answers to the chapters 2-4 with respect to the bridge infrastructure from Sweden.

2. Maintenance and inspection processes

2.1

The bridge management process



Inspection (condition measurement)

Major inspections are carried out with maximum time interval of 6 years and are principally visual, including some non-destructive testing. (Physical focus).

The inspections shall reveal the physical and functional condition of the structures and shall provide the basis for the planning and implementation of measures required to comply with the specified requirements in both the short and long term.

Physical condition is described using the measurement variable defined for each method of measurement. Functional condition for the elements has a condition rating (0 - 3)

Maintenance

See below.

2.2

The maintenance production activities are carried out according to a three year work plan. Once a year this plan is adjusted to available budget.

The decision of the projects in the work plan is taken by the head of the bridge management operations unit (process owner) based on proposals from the bridge managers (Swedish Transport Administration).

Decisive for which projects to carry out is the socio-economic consequences of postponing a project outside the planning period, based on the overall goal to deliver a specified functional standard to the lowest socio-economic cost.

2.3

A system with bonus and penalty when there are divergences from contract time has been used now and then.

A preferable system is incentive procurement where the construction time has a cost (regulated in the tender documents) which is subtracted from (shorter time) or added to (longer time) the bids for the production work.

2.4

(Who´s decision?)

N.b. The Administration buys all construction work from contractors. Of course, the tender documents and external (society) regulations have impact on the contractor´s production planning.

2.5

(Who is the IM?)

The head of the bridge management operations unit is the process owner and thereby also responsible for the development of the management activities.

The management activities are supported by the BaTMan management system (databases, applications etc), http://batman.vv.se).

2.6

Of course, the organization and carrying out of the management activities must follow laws and other external regulations.

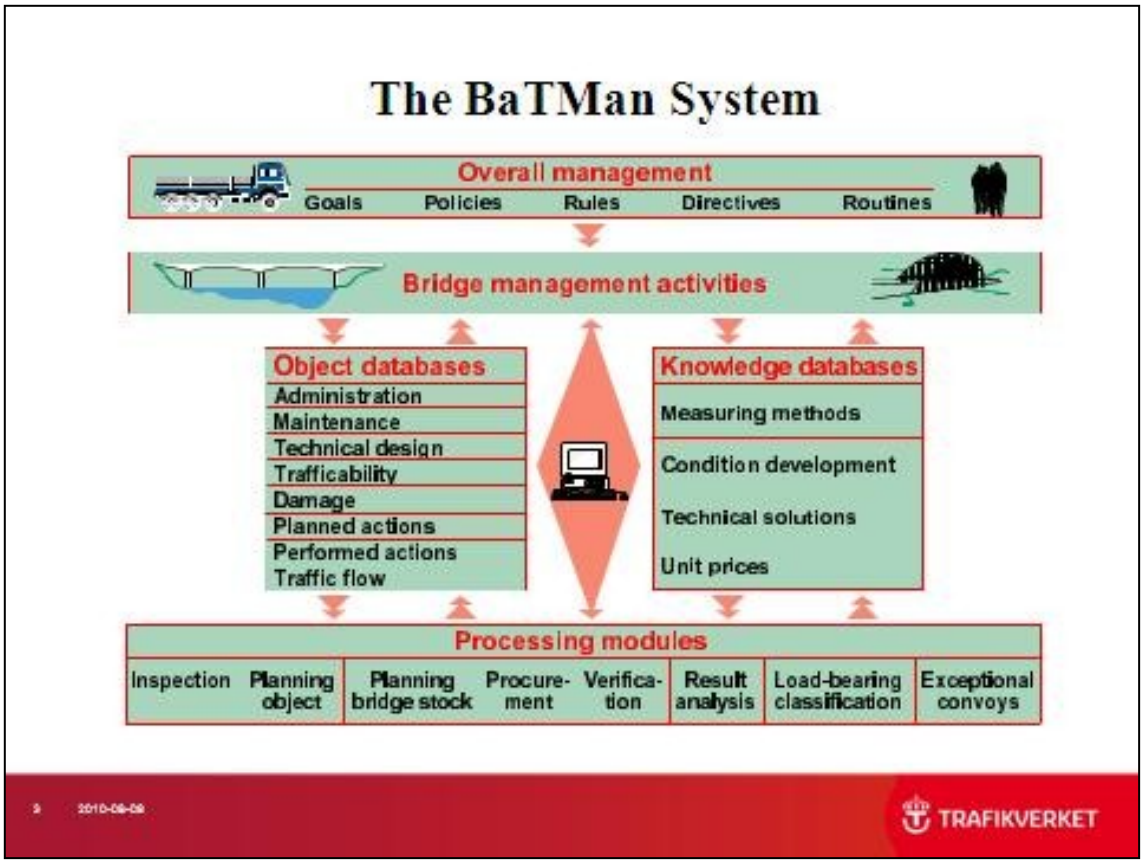
2.8

A developed focus on the functionality of the infrastructure and its components is recommended to facilitate the implementation of important approaches like performance management and performance contracting.

3.1

IT-system support

The Swedish Transport Administration has a bridge and tunnel management system, BaTMan, supporting the carrying out of the management activities. The system is used by all major road and railroad managers in Sweden and furthermore ca 70 local authorities, private road managers and also for the management of the quays in the port of Gothenburg.



The system is also open for the public regarding information, reports, guidelines, handbooks, etc. but not applications. For this an agreement with the owner, the Administration, is necessary.

Object level planning.

In conjunction with the inspections a socio-economic optimum intervention strategy is chosen for a structure. The strategy, considering both maintenance and improvements, is based on the proposed

remedial activities for the elements. In some cases also a second best strategy is described, applicable if the optimum strategy cannot be funded.

The planning horizon for a strategy is the (remaining) functional life span of the road connection (LCC) to which the structure belongs.

3.2

We have no intention to develop the planning process against fully automation. The engineering judgement (input) is absolutely necessary for effective outputs (needs, predictions, options, costs etc.) for example. But partial "automation" is used. For example, the BaTMan system has a completely computerized prioritization module for the short term (three year) planning where all object level planned structures are ranked according to their socio-economic benefit at the same time considering budget restrictions.

3.4

Type of action	**Percentage of total funding**
Operations and time-scheduled maintenance	15
Condition initiated maintenance	67
Reconstruction (the whole structure or major parts of it) for durability reasons.	15
Inspections (condition measurement)	3

3.5

All operation and time-scheduled maintenance and ca 50 % of the condition initiated maintenance are procured in package contracts for 4-5 years. In these contracts the contractor by himself chooses the time for execution of projects within certain limits.

Among the other 50 % of the condition initiated maintenance quite a lot of the projects are combined in packages where the execution time is specified (the contractor cannot by himself choose time for execution).

Answers to the questionnaire from Sweden.

Asset management strategies, policies and performance

	Question	Additional information
1.1	What are the strategic company/ authority goals of the Infra Manager (IM)?	• Describe the background of each strategic goal • Mention and explain the Key Performance Indicators (KPI) that are related to each strategic goal
	Main goal: The overall goal is to safeguard the provision of socio-economically efficient and sustainable transport for citizens and the business community throughout the country. Sub goals: The functional objective concerns accessibility for journeys and transports: The transport system's design, function and use is to contribute to offer everyone basic accessibility with good quality and usability as well as to contribute as a positive force for development in the entire country. The transport system should be gender equal, i.e. equally meet the transport needs of women and men. The impact objective concerns health, safety and the environment: The design and use of the transport system must be adapted to ensure that no one is killed or seriously injured and to contribute to the achievement of environmental quality goals and improved health. The design and use of the transport system must be adapted to ensure that no one is killed or seriously injured and to contribute to the achievement of environmental quality goals and improved health. Functional goals - detailed Road accessibility Accessibility mainly concerns time for a journey or transport and how it meets expectations. KPI: Stoppages and disruptions reduce accessibility. Total stoppages refer to a stoppage in both directions on a two-lane road or at least one direction on multi-lane roads. KPI: The number of state roads with reduced bearing capacity resulting from the spring thaw Railway accessibility The most important aspect of railway accessibility is that trains run on time. This is measured using arrival punctuality at the end station and the number of cancelled trains. KPI: Arrival punctuality for trains is measured as the proportion of trains that arrive at their destination within five minutes compared to the timetable. KPI: Punctuality for freight traffic. Punctuality is based on the train's arrival time at the rail yard. This key figure says nothing about punctuality for freight deliveries by the operator to the end customer. Punctuality in this respect could be achieved even if arrival punctuality to the rail yard has not been achieved. A more accurate measurement of punctuality for freight traffic is under development. KPI: Number of cancelled trains. There are many reasons why trains are cancelled, everything from an accident, to snow storms or a lack of drivers. Trains can also be	

	cancelled when demand for transports drops. KPI: Other key factors for accessibility are the availability of train journeys for travellers. Rest areas and transfer points Efficient rest areas are important to facilitate travel for everyone. Roads where the Swedish Transport Administration should have rest areas have been highlighted. These rest areas offer important basic functions that can also be used by people with disabilities. We have begun to create an inventory of future needs for rest areas and basic places for short breaks. We are also working to provide better information about rest areas. KPI: Road user satisfaction Traffic information Traffic information comprises information to travellers, transport users, transport purchasers and transport providers about normal functioning, disruptions, forecasts and alternative suggestions for journeys. KPI: User satisfaction. Accessibility for car traffic within and between regions Accessibility is reported here as the travel time residents in rural areas have by car to their main town and travel time between regions and the wider world. These analyses are based on travel time when journeys are made at the stipulated speed limits. KPI: Accessibility between rural areas and main town is reported as the number of people who have travel time of more than 30 minutes to their nearest main town, and who have experienced a change in travel time of more than 30 seconds during the year Accessibility for rail traffic within and between regions KPI: Accessibility for public transport is primarily illustrated in terms of travel time and traffic availability Accessibility between Sweden and other countries by road and rail Most international passenger transport between Sweden and other countries by road and rail are via the Öresund Link. KPI: AADT (passenger cars and trucks) KPI: Number of train passages (passenger trains, freight trains, number of passengers) A gender-equal society The transport needs of both men and women must be fulfilled in the planning, design and administration of the transport system KPI: Jämix is a summary index that uses nine key figures to create indicators of central aspects of equality in the organisation. In 2010, 195 organisations took part in the measurement. An organisation can achieve a maximum 180 points. The median value for state authorities in 2010 was 129 points and the Swedish Transport Administration obtained 138 Usability for people with

physical disabilities
The transport system is to be designed to be accessible to people with physical disabilities.
The prioritised public transport network comprises today some 150 railway stations and about 550 bus stops in state infrastructure. Initially, the goal has been by 2010 to have adapted 40 railway stations and all highlighted bus stops.
KPI: Number of facilities adapted for people with physical disabilities
Children and young people
The transport system is to be designed so that children are offered greater opportunities to use it safely and to spend time in traffic environment.
KPI: Percentage of safe school route
Public transport,
walking and cycling
The preconditions to choose public transport, walking and cycling are to improve.

Impact goals - detailed

Climate
Greenhouse gas emissions
The transport sector is responsible for 26 per cent of human carbon dioxide emissions worldwide. It is one of the sectors where carbon dioxide emissions are growing fastest. Carbon dioxide is responsible for the greatest climate impact from the transport sector (emissions of greenhouse gases).

KPI: Carbon dioxide emissions per vehicle type, million tonnes

Official statistics for railway emissions include only diesel traffic. Emissions from the production of electricity used to operate electric trains and electricity distribution losses are not included.

Energy use
Greater energy efficiency is mainly a result of a higher degree of energy efficiency in passenger cars. Rail passenger traffic has also become more energy efficient. Energy use by road freight transports has risen more than for passenger traffic. This is because of a larger rise in freight transport volume but also that heavy commercial vehicles have not increased efficiency as much as passenger cars during the period. It is not possible to see a clear trend in energy efficiency for rail freight transports.
KPI: Energy use per railway area
KPI: Energy use for roads (passenger and rail)
KPI: Energy use for rail (passenger and rail)

Health
Materials and chemical products
In conjunction with construction, operation and maintenance of infrastructure, various materials and chemical products are used that can affect the environment.
Contaminated land
The Swedish Transport Administration work to reduce the number of contaminated areas that could harm or entail inconvenience to human health or to the environment.
The Administration estimates that there are some 4,000 point sources caused

	by railway activities. The number of point sources caused by road activities is unknown. Noise Road and rail traffic is the noise source that effects most people in Sweden. This type of disturbance has increased. Around two million people are considered to be exposed to traffic noise that exceeds the guideline of 55 dBA equivalent noise level outdoors at their homes. A trend with rising traffic volume, a rising influx to cities and the construction of housing in areas exposed to noise also contributes to more people being exposed to noise. KPI: Number of people with noise reductions resulting from measures Air quality Air quality in Swedish towns has generally improved in recent decades, but this is not the case for particulate matter at street level. Levels vary between different years, mainly because of meteorological factors. KPI: Population weighted air quality index KPI: Air pollution emissions nitric oxides, hydrocarbons, sulphur (ktonnes) <u>Landscape</u> Biodiversity The road and railway systems have a negative impact on natural and cultural landscapes and their biodiversity. Mammal and bird populations are displaced when roads and railways are built. Knowledge about this issue and measures have to date focused on the barrier effect. Implemented measures in this field have primarily been the creation of fauna passages and clearing migratory obstacles for fish. KPI: Number of obstacles removed on animal migratory paths on existing road network Wildlife accidents continue to grow. In 2010, 47,475 wildlife accidents were reported to the police. An additional 1,802 reindeer were killed by road traffic. At least 40 people were seriously injured and 5 killed in connection with wildlife accidents. The most probable reason for the significant rise in wildlife accidents in recent years is the rapid rise in traffic volume and a growth in the populations of elk, wild boar, fallow-deer and red deer in southern Sweden. KPI: Wildlife accidents reported to police <u>Safe traffic</u> Fatalities and serious injuries in road and rail traffic According to a parliamentary resolution from May 2009, the number of deaths on Swedish roads is to be halved between 2007 and 2020. The goal for rail transport safety is that the number of fatalities and seriously injured should continue to decline. For road traffic, the number of fatalities has declined while for rail traffic there has been a slight increase. Traffic volumes have increased on both roads and railways. KPI: Number of fatalities in road trac accidents KPI: Fatalities and serious injuries on railways	
1.2	How strict do you use the separation between the Asset Owner, Asset Manager and Service Provider?	• Describe who has the role of Asset Owner, Asset Manager and Service Provider • What are your major stakeholders • Explain the advantages and

		disadvantages of this role model related to the allocation of train free periods
	The Swedish Transport Administration is the asset owner and manager of the road and railway system. The role of service provider varies: Railway traffic is provided by different companies Road maintenance and operations are provided by different contractors Traffic information are provided both by the Transport Administration and private companies The major stakeholders are the government, road users, railway users and the society. The contract between the asset manager and service provider stipulates the conditions. If train free periods are stipulated, the service provider has to accept. The advantage is that train free periods will be well defined in advance; the disadvantage is that the service provider will not be able to optimize its service. Removal of train free periods will improve the possibilities to optimize the use of the railway system and to increase capacity but will put more importance to the maintenance methods. Also, close cooperation between service provider for railway traffic and service provider for railway maintenance and operations may be beneficial. For roads, no traffic free period exists. In areas with high traffic, road works are, if possible carried out by night, when the traffic is lower. Still. Maintenance methods that make it possible to avoid traffic disturbances are beneficial.	
1.3	One of the goals of Automain is flexible maintenance with a minimal effect for the traffic. This will influence the relation with the Service Providers. 1. Explain how the Service Provider gets the time frame for doing the work in the current situation. 2. What does flexible maintenance mean for the relation with the Service Providers and for the process of getting the time frame for the construction on the right moment?	What are your experiences for: • the amount of outsourced work • the type of outsourced work • the type of contracts (think of balancing financial aspects, incentives and processes) • costs per activity • workforce of the IM • workforce of the Service Provider
	For roads: All maintenance and operation works are outsourced For operations 5-year contracts are established For maintenance the type of contracts varies: most often project contracts with 5-year gurantee, but the number of performance based contract are increasing and will continue to do so. There is no specified standard in how the service provider gets his time frame. This is stipulated in each contract and depends on the situation at each project site. When a time frame is stipulated, the service provider has to accept. For roads, if the time	

	frame only allows night work; the cost will be higher and depending on type of work, the quality may be affected.	
1.4	What KPI do you use related to planned and unplanned maintenance activities regarding traffic flow?	Give for each KPI the following information: • Algorithm, how is it calculated • On which level of detail is it used (object, region, country, road etc.) • What are the mechanisms to control the level of each KPI? • Do you use any incentives, bonuses or penalties regarding to the level of the KPI's?
	Total stoppages refer to a stoppage in both directions on a two-lane road or at least one direction on multi-lane roads. Expressed in million vehicle hours: Vehicle hours = Number of stopped cars x stop time (hours). Number of stopped cars = traffic flow/hours x stop time (hours). Basically divided by urban/rural roads	
1.5	What good practices / benchmarks do you know about how individual infrastructure managers in Europe translate their company goals (such as punctuality) to asset management strategies?	Mention the relevant situation and explain briefly why this is a good practice.
	Many authorities use total stoppages as a KPI but often in combination with stoppages during a time period. Eg. Many road works at the same time may cause congestion that could be avoided by distributing works in time. A administrative problem in this that it is necessary to have a very good cooperation between different authorities like state roads/municipality road. Also, different types of maintenance are combined in order to minimize the total stoppage time. This may affect the planning process and selection of methods, material etc: Synchronised durability of different assets in order to get synchronized maintenance. Ref: COST343 "Reduction of road closures by improved maintenance" and "Format"	

Maintenance and inspection processes

	Question	Additional information
2.1	Explain the processes, involved parties, decision moments and criteria that are relevant to decide whether or not a maintenance activity will be planned.	• What determines when a possession is carried out? - MGT – scheduled into campaigns (e.g. tamping campaign for a whole route) or individual sites.

		- Inspection data - Availability of plant - Public holidays/low traffic - Availability of budget - Pre defined maintenance intervals preventive/prognostic) maintenance - Other things …. • Who is in charge of the decision? • Who is the owner of the processes?
	Most decisions of maintenance and operations are condition based. Criteria are defined in Standards for operations and in standards for maintenance. There is a degree of freedom in the standards. Some conditions may require emergency maintenance. For others there is a time frame for maintenance that will be affected by available budget, efficiency etc. The condition of the road network are measured on regular basis (every 1-3 year depending on traffic) and visually inspected by local managers. In rural areas the access to a plant (mobile plant) may be limited to a certain time and maintenance may be concentrated to a certain area one year. Traditionally, there has been a worse case first strategy, but there is an intention to move to a higher degree of preventive maintenance and to base decions on LCC In urban areas, road works are sometimes carried out by night. There is always an objective to avoid road works during periods with high traffic. At the same time, the climate in Sweden limits the time when eg. pavement maintenance can be carried out, which also means that there may be disturbances during the summer holidays. The basic plans are established by the local project leader but coordinated on nation level. The local project leader base his decisions on measured condition, local experience and contact with the local road users. The final decisions are made at national level.	
2.2	What are the relevant time-scales / planning horizons for maintenance activities?	
	The climate in Sweden affects the planning process. A hard winter may result in high costs for winter maintenance that will affect the budget for preventive maintenance. This means that the budget varies from one year to another and that there is necessary to have a high level of flexibility in the planning. The planning process for pavements are 1-3 years (or more). Also, planned work may include work during more than I year.	
2.3	Do you use any incentives, bonuses or penalties regarding to the use, overrunning or under running construction time?	Describe the incentives that are in use. In what way are they part of the contract? Do they stimulate the right culture and results or do they occasionally turn out to be counter-productive?
	In some performance based contracts, contractors have to rent the road in order to carry out maintenance. It will be a benefit for them to shorten construction time. In normal contracts, benefits for short construction time exist in some cases, especially on road with high traffic.	

2.4	Does the involved equipment affect the decision making?	• Types of worker protection applied – e.g. signal protection, barriers etc • Type of maintenance machine used • Shift length
	No Worker protection is regulated by law. The cost for worker protection may influence decisions. The type of maintenance machine and shift length does not affect decisions but it should by including cost for road user disturbances in C/B or LCC analysis	
2.5	To what extent is the IM involved in the improvement of the maintenance process?	• Definition of regulations and standards • Experiences of IM • Is there a central database for experience/knowledge about maintenance?
	The IM is involved in setting up goals that are specified in standards and thereby also involved in the fund raising and budget allocation process. All information about road network condition and road works carried out are available in a central database	
2.6	To what extent does external regulation (safety rules, law) affect the organisation of maintenance activities?	• Regulations and standards • Does this depend upon line speed and road category?
	We have to follow the laws: Road law, Railroad law, electronic power law. The Swedish Transport Agency deals with many regulations that affect the Swedish Transport Administration: <u>The Traffic Registry Department</u> administers and develops the road traffic registry, which supplies society with information about vehicles, driving licences and commercial transport. They also operate the congestion tax system. <u>The Road and Rail Department</u> formulates regulations, examines and grants permits, as well as exercising supervision within the field of road and rail transport over e.g. road traffic, railway, vehicles, driving licences and commercial transport. They also conduct analyses of road traffic and supply information about injuries and accidents within the road transport system. Eg. The Transport agency are responsible for regulation on axle loads, that affects the load on the road network. The Swedish Work Environment Authority affects regulation on road workers safety, working time, hazardoeus material etc	

2.8	What good practices / benchmarks do you know for maintenance and inspection processes?	Mention the relevant situation and explain briefly why this is a good practice.
	Usage of measurement equipment that are able to measure at posted speed, especially at high traffic.	

Scheduling of the maintenance

3.1	Do you use planning/scheduling software for maintenance activities, e.g. a pavement management system?	Describe the systems / databases that you use for: • Maintenance activities to be planned • Resources availability • Process standards
	We have several management systems (Pavements, Bridges etc) Eg. PMS are used as support for planning of pavement maintenance activities. Maintenance project candidates are identified (based on tha maintenance standard) but other factors will affect the final decisions	
3.2	Do you think automated planning and scheduling tooling would be useful?	How is your current process of planning and scheduling automated? Describe the main benefits of an automated planning and scheduling tool compared to your current situation.
	We have no intention to automate the planning but the process can be improved: The Swedish state network is app 100000 km. An automated process require a tremendous amount of information about road structures, road condition, traffic flow, information that are only available to some extent. As mentioned, we use the information to identify candidate projects but the final decision is also influenced by other factors. The intention is to collect more detailed information on identified projects. Still, local experience will influence decisions. The identification of candidate projects can, however, be improved by automated planning and scheduling tools.	
3.3	Where do you think that automatic planning can contribute most: • Scheduling over one day in the future of the elementary maintenance tasks • Planning 1-3 months in the future of the operations • Planning over 1-3 years in the future of the operations	Describe in what time window/ interval you will expect most value of automatic planning tooling.
	For maintenance most work are decided well in advance and stipulated during the tendering process (since we do not do any work in-house). This also means that the best contribution of an automatic planning tool is 1-3 years.	
3.4	Make a rough estimation of the percentage of obstruction of traffic related to: • Condition based maintenance	Focus on heavy maintenance activities • Condition based maintenance • Predetermined maintenance

	• Predetermined maintenance • Corrective maintenance • Inspections • Complete renewal (done at the end of the lifetime of object)	• Corrective maintenance • Inspections • Complete renewal (Total of the 5 factors is 100%) How will the future situation differ from the current situation? Is there a differentiation of planning horizon for those maintenance activities?
	The obstruction to traffic is of to types: The type of work The length of the work Since e.g . corrective maintenance goes faster the total obstruction will be smaller but during the work the obstruction per time unit can be the same as for predetermined maintenance. A complete renewel may require a full close down of a road segment. But if detours are available (or constructed) the obstruction may be low. • Condition based maintenance 25% • Predetermined maintenance 25% • Corrective maintenance 10% (dependant on the traffic volume, on roads with high traffic and high demands on workers protection) • Inspections 0% • Complete renewal 40% - depends very much on the access to detours	
3.5	Are tasks combined in order to reduce construction time?	Describe whether activities are combined in one construction site in order to reduce possession time
	At renewel – of course. At condition based and predetermined maintenance – seldom because of different contractors At corrective – maybe in urban areas At corrective- combined in rural areas but not due to road user obstruction, more to efficiency	
3.6	Are combined tasks successful in any case or most cases?	Describe whether combined activities are successful or new problems raises due to: • availability of maintenance machines • reliability of maintenance machines • performance of maintenance machines • higher complexity of planning and maintenance processes • …
	If maintenance work require extensive work protection there is beneficial to combine. If	

	the maintenance work is fast – fast in fast out – it may be better not to combine. It also depends on type of work. If the work requires continuous movement along the road then is it harder to combine.	
3.7	How do each of these factors influence task durations and effectiveness? • Seasons • Night/day • Traffic density • Availability of alternative routing • Region • Share of freight traffic • Number of lanes	Describe the influence of the characteristics on task duration (i.e. will a season influence task duration and to what extend?)
	• Seasons Many maintenance activities are limited to bare road season (no snow and ice) During the summer there is a requirement to shorten the duration to reduce obstructions. At the same time, pavement work requires a certain time to cool before it is opened for traffic, otherwise initial deformations can occur. • Night/day Night work is more common in urban areas, but there is also concerns about reduced quality during night • Traffic density If the traffic density is high it is more likely to do night work. At very high traffic and high demands on workers protection an option may be to close a lane • Availability of alternative routing If detours are available, the option to close a lane, may improve and open up the opportunity to combine different works. • Region Since different regions have different climate, traffic density, there will be an influence • Share of freight traffic • Number of lanes Many lanes gives better opportunity to close one lane for maintenance	
3.8	What good practices / benchmarks do you know for the integration of maintenance in the traffic flow?	Mention the relevant situation and explain briefly why this is a good practice.
	Workers protection, information to road users and standardized traffic regulation is essential	